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The influence of computer-assisted instruction on students' conceptual understanding of chemical bonding and attitude toward chemistry: A case for Turkey

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Abstract

In this study, the effect of computer-assisted instruction on conceptual understanding of chemical bonding and attitude toward chemistry was investigated. The study employed a quasi-experimental design involving 11 grade students; 25 in an experimental and 25 in a control group. The *Chemical Bonding Achievement Test* (CBAT) consisting of 15 two-tier questions and the *Chemistry Attitude Scale* (CAS) consisting of 25 item were the principal data collection tools used. The CBAT and CAS instruments were administered in the form of a pre-test and post-test. Analyses of scores of the two groups in the post-test were compared and a statistically significant difference was found between groups in favor of experimental group. It also seems students from the experimental group were more successful than the control group students in remediation of alternative conceptions. The results of this study suggest that teaching–learning of topics in chemistry related to chemical bonding can be improved by the use of computer-assisted teaching materials.

Keywords: Computer-assisted instruction; Chemical bonding; Attitude; Alternative conception

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1. Introduction

Meaningful learning theory suggests that the learning process consists of an interaction between preexisting knowledge and new knowledge and as a consequence students' own knowledge is central for further learning (Ausubel, 1968; Mintzes, Wandersee, & Novak, 1998). The literature suggests that students often develop ideas that are different from those accepted by scientific community and intended by their teachers (BouJaoude, 1992; Ebenezer & Fraser, 2001; Peterson & Treagust, 1989; Treagust, 1988; Zoller, 1990). Students' ideas that are different to scientific ideas are variously called misconceptions, alternative conceptions, and alternative frameworks (Özmen, 2004); the most being misconceptions and alternative conceptions. Students' alternative conceptions is the term we use here, because it recognizes that to the students' such ideas make sense

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and fit in with their everyday experiences. The conceptions are often highly resistant to change, and according to Niaz (2001a), such ideas should be considered as part of their ‘hard-core’ beliefs.

Many studies all levels of schooling to determine students’ ideas about basic chemistry concepts suggest that students who did not acquire a satisfactory understanding of scientific conceptions occurred as a result of traditional teaching methods such as simple lecturing. Such teaching requires students to sit passively and does not much engage students actively in learning (Morgil, Oskay, Yavuz, & Arda, 2003). In such a traditional teacher-centered classroom, the students thus become listeners, and the teacher gives out the facts and defines important ideas. Students’ participation is often limited to listening to the teacher and perhaps raising their hand to answer questions (Muir-Herzig, 2004). It is reported that traditional teaching methods when used in teaching science means students may understand the subject – but only at a ‘knowledge level’ that involves them memorizing concepts without achieving in-depth understanding. Similarly, highly teacher-centered teaching methods may negatively affect the learners’ beliefs about science, leading them to see science learning as a simple accumulation of facts, and science as uninteresting (Kiboss, 2002; Kiboss, Ndirangu, & Wekesa, 2004). These pedagogical approaches may then influence students’ attitudes, cognitive development and achievement in science education (Çepni, Taş, & Köse, 2006). Because of this, science and chemistry teachers may need to consider alternative teaching approaches – particularly for difficult and abstract science concepts. Some authors suggest this might be achieved by using more learner-centered approaches and particularly those that employ modern information and communication technologies. These technologies can help facilitate knowledge-construction in the classroom and guide student activities, leaving teachers the opportunity to interact with small groups and to diagnose difficulties (Williams, Linn, Ammon, & Gearhart, 2004). Whitworth and Berson (2003) claim that technology-based learning can help develop students’ decision-making and problem-solving skills, data processing skills and communication skills. In student-centered classrooms with the aid of computers, students are able to collaborate, to use critical thinking and to find alternatives solutions to problems (Jaber, 1997). Recently there has been interest expressed in science education reform which emphasizes the need for integrating computer technologies into learning and teaching (Herman, 1996).

The literature notes that computer-assisted instruction (CAI) is one such area recently lauded for its capacity to improve the teaching of difficult and abstract science concepts and to simulate dangerous experiments and to stimulate interest in science learning (Allessi & Trollip, 1991). Computer also may be effective in other areas as a general pedagogical aid that complements regular teaching methods (Kiboss et al., 2004). The term computer-assisted instruction (CAI) is used here to mean an approach where information is delivered by the computer in a manner similar to programmed learning, and that is aimed at student achievement of specific educational goals through step-by-step instruction (Simonson & Thompson, 1994). At this time computer-based technology is (and will likely become more) a component of school and university classrooms. Several capabilities of computers, such as providing individualized instruction, practice, revision, teaching and problem-solving, simulations during the applications and immediate feedback, make computers useful instructional devices for developing desired learning outcomes (Ertepınar, 1995). An additional advantage is that the teacher can use computers at different times and places according to the characteristics of the subject matter, the students, and available software and hardware (Morgil, Yavuz, Oskay, & Arda, 2005). In summary, although authors’ views about contribution of computer based learning environments can make to student achievement vary, the utilization of computers in learning points to positive contributions of computer based learning environments to student learning.

2. Technology and schooling: Turkish scene

Turkey is a candidate for membership of the European Union (EU), and is a developing country with a population of about 70 million. The Turkish Educational System comprises four components: (i) pre-school, which is optional; (ii) basic education, which is 8 years in duration, compulsory, and free in public schools; (iii) secondary education, which is 3 years in duration, is not compulsory and is free in public schools; (iv) higher education including universities, which is generally 4 years, and is not compulsory. Science is a compulsory subject in the Turkish Educational System. Science courses begin at the age of 9–10 (grade 4) and go on until the age of 14–15 (grade 8). In another words, science is a compulsory subject between grades

4 and 8, a total of 5 years. When students come to secondary schools (called lycees), they have to take chemistry, physics and biology as compulsory subjects. The curricula for these subjects include syllabuses based only on textbooks and there are no teacher guides, laboratory manuals or computer programs for simulations, etc. Moreover, the common problems include classroom overcrowding, lack of materials, inadequate laboratories, and poor teacher preparation (Ayas, Özmen, & Genç, 2001).

One of the main objectives of Turkish Science Curriculum is for students to become scientifically literate, which is taken to include: (i) understanding key concepts and principles in science, (ii) having a capacity for scientific ways of thinking, (iii) using scientific knowledge and ways of thinking for individual and social purpose, and (iv) developing of creative and innovative minds. These statements suggest that students' understanding in classrooms is vital for their future, life-long learning, and science teachers need student-centered, alternative instruction methods that enhance students' cognitive understanding, and attitude toward-science. Student-centered teaching is challenging and requires Turkish teachers to change their traditional teaching methods. Today's information and communication technologies can be applied to science education as an alternative teaching way and among these technologies, the use of computer simulations is the most popular and well known (Goldberg, 1997; Gorsky & Finegold, 1992; Grayson, 1996). With the use of computers in the classroom, schools can become more student-centered in approach and more individualized learning may take place (Muir-Herzig, 2004).

Although CAI studies were first developed in the 1960s in countries like the USA, France, and Britain, they started much later in Turkey compared to mathematics and science lessons generally. The first official attempt towards CAI in Turkey began during the 1990–1991 academic years. At this time, the National Ministry of Education bought 12,000 computers for middle and secondary schools, but no preparations were made to understand how to use these computers in an effective way. As a consequence the majority of the schools used computers for reasons other than education – such as keeping records and registration of enrolments (Alyaz & Gürsoy, 2002). Developing the educational use of professional software for CAI started during the 1990s in Turkey when big software production companies brought their programs to Turkey and computerization process accelerated. It is noted in the literature that a technology-based learning environment is complex and demanding for teachers for the following reasons: (i) teachers need to understand the discipline or content well enough to allow students to ask difficult-questions, (ii) they need to be familiar with the use of new representations of science content as a result of computers, such as using graphs, and (iii) understanding of technological and computer-related issues (Fishman, Marx, Best, & Tal, 2003; Ladewski, Krajcik, & Harvey, 1994; Williams et al., 2004). It is a widely held belief that many Turkish school teachers do not have a strong background with regard to using computers in daily-life, and especially in science education. Therefore, it is unlikely that teachers in Turkey use computers in their classrooms in the way desired by Ministry officials (Baki, 2000).

As computers have become more commonplace in schooling, there has been increasing pressure on teachers to incorporate them into their teaching. In order for technology to be successfully integrated into the science curriculum, there are several factors that need to be in place. For example, teacher training is crucial for successful technology integration (Vrasidas & McIsaac, 2001). According to Papanastasiou, Zembylas, and Vrasidas (2003), it is only when teachers have the knowledge, skills, resources, and support available that they will be able to integrate technology in the science curriculum in order to maximize its effects on teaching and learning. The need to prepare teachers to integrate technology into the range of instructional strategies they bring to their teaching is not a new concern, and it has been addressed in the literature (Criswell, 1989). The preparation of teachers to use technology continues to be a basic concern of teachers' educators in Turkey as in other countries (Altun, 1996; Baki, 2000). Baki (2000) reports that when pre-service teachers complete their teacher education programs, they are often faced with the reality that their education did not prepare them to use technology in their teaching. Therefore, learning to teach science with technology is an important concern, and should be integrated into the teacher education curriculum. This means that technology teaching experiences should become an integral part of the pre-service curriculum. With this regard, the Turkish Higher Education Council-World Bank: National Education Development Project (1996–1998) developed a new curriculum including teaching science with computers courses for teacher education programs and this curriculum has been used since 1998.

3. CAI and chemistry teaching

Chemistry is one of the most important subjects in science and contains a number of abstract concepts requiring complex concepts many of which are not obviously applicable outside the classroom (Stieff & Wilensky, 2003; Zoller, 1990). For this reason, students view chemistry as one of the most difficult subjects to study at all levels of schooling. Many researchers have reported on students' conceptions of fundamental, underlying chemistry concepts saying that when fundamental concepts are not constructed adequately, more advanced concepts that build upon the fundamentals are not fully understood (Abraham, Grzybowski, Renner, & Marek, 1992; Nakhleh, 1992).

Chemistry knowledge is represented by scientists at three levels; the macroscopic, the submicroscopic and the symbolic (Johnstone, 1993; Özmen, Ayas, & Coştu, 2002; Raviola, 2001). Because interactions between molecules and atoms occur at a submicroscopic level, chemists refer to the objects and processes which they cannot observe directly at a symbolic level (Stieff & Wilensky, 2003). To understand chemistry at a sophisticated level necessitates students being able to make connection or relations among the levels. However, research suggests that students have difficulties in understanding the submicroscopic and symbolic levels. Concepts such as the particulate nature of matter, physical and chemical change, chemical equilibrium, solutions, acids and bases, chemical bonding, and conservation of mass are topics that students have difficulties in visualizing at submicroscopic level. Over the last two decades a great deal of educational research has been conducted to determine students' alternative conceptions and difficulties in chemistry. Some current research has sought to investigate the underlying causes of difficulties students have when dealing with complex topics, and this research also seeks to develop curricula to help students overcoming these difficulties (Tyson & Treagust, 1999; Voska & Heikkinen, 2000).

Despite much research and curriculum development, it seems students still do not adequately learn many chemistry concepts (Nakhleh, 1992; Tyson & Treagust, 1999). The effectiveness of new and alternative teaching methods of teaching chemistry concepts has been the subject of intensive investigation and ever since educators first began to use computers in the classroom, researchers have tried to evaluate whether the use of educational technology had a significant impact on student achievement (Altschuld, 1995; Kulik & Kulik, 1991; Papanastasiou et al., 2003; Rocheleau, 1995). In the chemistry education literature, there have been numerous studies reporting positive effects of the use of computers on student achievement (e.g., Eylon, Ronen, & Ganiel, 1996; Geban, Aşkar, & Özkan, 1992; Windschitl & Andre, 1998). Such studies suggests that the use of computer simulations is successful in promoting positive of attitudes toward science (Geban et al., 1992; Hounshell & Hill, 1989), and in particular that students' motivation is enhanced by cooperative learning involving student-computer interactions (Hill, Atwater, & Wiggins, 1995; Myers & Fouts, 1992), within a variety of learning environments (Zacharia, 2003). Computer-assisted curricula also provide opportunities for inquiry-based approaches to the teaching of chemistry, and it seems they discourage rote memorization and algorithmic problem-solving while encouraging conceptual understanding and critical thinking (Garnett & Kenneth, 1988). For this reason, many educators now advocate the use of computers in chemistry classrooms (Bodner, 1992), and computer-assisted learning environments attempt to make explicit the information embedded in traditional molecular representations as well as to provide a visual representation of molecular interactions for students. In this way, students can learn chemistry by viewing molecular animations side-by-side with graphical output and chemical formulae. Such an approach is in contrast to traditional chemistry lectures that rely almost entirely on verbal explanation of concepts meaning students have little opportunity to observe molecular interactions (Stieff & Wilensky, 2003).

Research suggest that the use of computer-simulated experiments (CSE) together with a problem-solving approach has a positive affect on students' chemistry achievement, science process skills, and attitude toward chemistry at the high school level (Geban et al., 1992). The results showed that the computer-simulated experiment approach and the problem-solving approach produced significantly greater achievement in chemistry, and that the use of integrated video media (Harwood & McMahon, 1997) also enhances students' achievement and attitude to chemistry. The particular way in which different levels of information are presented by such technologies – microcomputer based laboratory, pH meters, or chemical indicators, influenced secondary students' understanding of acid, base, and pH concepts – also may be influential (Nakhleh & Krajcik, 1994). Recent researches show that computerized molecular modeling improves tenth grade students' spatial ability, understanding of new concepts and achievement about structure and bonding (Barnea & Dori, 1999). Likewise, computer animations together with a conceptual change approach is reported to help students understand that electrons do not travel through aqueous solutions (Burke, Greenbowe, & Windschltl, 1999), when employing computer animations of chemical reactions at the molecular level. Hence, a key feature of such CAI teaching is that it helps students visualize what is happening at the molecular level. This also applies even for more complex systems such as ion formation and solution chemistry (Ebenezer, 2001) where animations in a hypermedia environment enable students to visualize that melting is different from dissolving, how ions are formed, and how hydration takes place.

It is apparently a key feature that student are able to interact with concepts when using CAI. So for example, interactive simulations using modeling and simulation packages for teaching chemical equilibrium helped shift students from memorizing facts to attempting to explain chemical equilibrium and solve chemical equilibrium problems with an overall stronger attempt made at conceptual understanding and logical reasoning (Stieff & Wilensky, 2003). CAI is applicable to a variety of learning tasks including traditionally difficult topics like understanding o chemical formulas and mole related problems (Yalçınalp, Geban, & Özkan, 1995). It seems that using a CAI tutorial program as a supplement to the classroom results in significantly higher achievement at the knowledge, comprehension, and application levels. Likewise, Williamson and Abraham (1995) report computer animations about particulate nature of matter for college students understanding of chemical phenomena such as solutions, ions, phase transitions, precipitation, and dissolving result in higher achievement in evaluation tests.

The studies related to comparison between computer-assisted instruction and traditional instruction shows that technology-based instruction strategies are more effective than the traditional ones. For example, Jackson (1988) conducted a study with secondary school students to find out the effects of the computer on attitudes, motivation and learning, the possible advantages of computer-assisted test programs. Students were distributed into control and experimental groups and the assessment of the experimental group was done by using computers, whereas that of the control group was done through the written test. The statistical evaluations showed a higher achievement rate for the experimental group that received a computer-assisted test. In another study, Ertepınar (1995) tried to determine the effects of the two different teaching methods involving logical thinking skills, computer-assisted instruction and students' portfolios on the achievements of high school chemistry students. The results of the study showed that the application with two methods and the logical thinking skills of the students had a significant contribution to the achievement of the students in chemistry. Levine and Donitsa-Schmidt (1996) compared the traditional learning strategies with computer-assisted activities. The results of the study showed that the experimental group was more successful at answering the questions of the chemistry achievement test than the control group. In another study, Demircioğlu and Geban (1996) compared CAI with the traditional teaching method on sixth grade students in science classes. The results of the study showed that the experimental group that was taught through CAI was found to be more successful. Özmen and Kolomuç (2004) investigated the effect of the computer-assisted instruction on tenth grade students' achievement in solution concept. They found that the experimental group that took computer-assisted instruction had a better understanding than the control group that was given traditional instruction. Recently, Morgil et al. (2005) compared the traditional and computer-assisted learning in teaching acids and bases. At the end of the study, they found that there was a significant difference favoring the experimental group. These results show that CAI together with learner-centered teaching approaches is more effective in terms of student achievement and attitude than traditional learning strategies. In another study, Talib, Matthews, and Secombe (2005) investigated the effect of the computer-animated instruction on students' conceptual change in electrochemistry, qualitatively. The preliminary results of the study showed that targeted conceptions were more intelligible and plausible to the subjects in experimental group in comparison to their counterpart in the control group.

A particular of active area of research for remedying students' alternative conceptions is chemical bonding. Chemical bonding is one of the most important topics in undergraduate chemistry and the topic involves the use of a variety of models varying from simple analogical models to sophisticated abstract models possessing of considerable mathematical complexity (Coll & Taylor, 2002; Coll & Treagust, 2003). It is also a topic that students' commonly find problematic and develop a wide range of alternative conceptions. The concepts of electron, ionization energy, electronegativity, bonding, geometry, molecular structure, and stability are central to much of chemistry, from reactivity in organic chemistry to spectroscopy in analytical chemistry (Nicoll, 2001). It also is important for students to grasp these concepts in understanding why and how chemical bonds occur. In the science education literature, there have been numerous studies to determine students' understanding and misconceptions about chemical bonding (Birk & Kurtz, 1999; Boo, 1998; Coll & Taylor, 2001, 2002; Coll & Treagust, 2001, 2002, 2003; Harrison & Treagust, 2000; Niaz, 2001b; Nicoll, 2001; Robinson, 1998; Taber, 1994, 1999; Tan & Treagust, 1999). These studies have revealed prevalent and consistent misconceptions across a range of ages and cultural settings and the results of these studies show that the students in all levels do not learn chemical bonding with traditional teaching methods as expected. Özmen (2004) has reviewed and collected some of the most important alternative conceptions determined in these studies.

Identification and remediation of alternative conceptions are an important part of the learning process meaning teachers need to be aware of their students' existing ideas that might need to be challenged. The literature suggest that students' preexisting beliefs influence how they learn new scientific knowledge, and play an essential role in subsequent learning (Arnaudin & Mintez, 1985; Tsai, 1996). It is reported that in may cases science learning difficulties occur because students' conceptions are not taken into account, and therefore communication barriers between teachers and learners may not be overcome. The literature also notes that student alternative conceptions are stable and highly resistant to change by traditional teaching methods. This suggests that alternative teaching methods are required to remedy nonscientific beliefs. Although in Turkey for more than a decade, studies have been conducted on teaching chemistry concepts, no systematic studies have been undertaken to explore if CAI has any significant impact on students' learning and achievement about chemical bonding. It is widely reported that computerized training contributes to the development of the visualization skills of the students (Barnea & Dori, 1999). It is possible in a computer simulation program to create animated color graphic images capable of presenting the nature of the chemical bonding through computer simulations that may be difficult to achieve when using traditional chalkboard drawings. Studying in a CAI environment means students have opportunities to internalize concepts related to chemical bonding through active participation in the enriched learning environment. This forms the basis for the present study which was designed to examine: (i) achievement, (ii) attitude changes for secondary chemistry students exposed to the computer-assisted instruction and (iii) the effect of CAI in remediation of the misconceptions was investigated thirdly.

4. Methods

4.1. The study context

As mentioned above, science is a compulsory subject between the grade 4 and 8 in the Turkish Educational System. The elementary school teaching of chemical bonding begins with an introduction, as a part of science at the age of 13–14 (grade 8). At this level, basic concepts such as bonding, ionic and covalent bonds are briefly introduced to students. The formal chemistry lessons start with secondary education (lycee) at the age of 14–15 (grade 9). General chemistry is compulsory and in the lycee chemistry curriculum (grades 9 and 11), chemical bonding concepts are studied in more details. In grade 9, basic concepts about chemical bonding and bond species are introduced, while many concepts about bonding, such as sorts of bonds, intermolecular and intramolecular forces, polarity and apolarity, hydrogen bonds, and hybridization are consolidated and taught more detailed in grade 11. At the university level, students learn bonding in General Chemistry courses in considerable detail.

4.2. Research design

A quasi-experimental design involving non-random assignment into two groups was chosen and this used a non-equivalent pre-test–post-test control group design. One control group (CG) and one experimental group (EG) were selected, and each treatment (CAI and traditional) randomly assigned. In this way, it was intended that teacher differences would be minimized. Schematically, research design is presented as follows:

	Pre-test	Treatment	Post-test
EG	T_1, T_2	X_1	T_1, T_2
CG	T_1, T_2	X_2	T_1, T_2

Here, EG represents experimental group, using the computer-assisted teaching approach (X_1), CG represents control group, using traditional teaching (X_2). T_1 represents Chemical Bonding Achievement Test (CBAT); T_2 represents Chemistry Attitude Scale (CAS).

4.3. Sample

The sample of this study consisted of 50 11th grade students from two chemistry classes with two chemistry teachers in a high school from the city of Trabzon in the North-East Region of Turkey. Additionally, eight experienced chemistry teachers participated into the study and they were involved in in-depth interviews to justify the quality, correctness, usefulness and functions of the teaching materials (see below). Both the experimental and control groups contained 25 students.

4.4. Instruments

Two instruments, the *Chemistry Attitude Scale* (CAS) published previously (Demircioğlu, Ayas, & Demircioğlu, 2005) and the *Chemical Bonding Achievement Test* (CBAT) developed here were used to collect data; these are now described in turn.

4.4.1. Chemistry Attitude Scale (CAS)

The CAS was developed by Demircioğlu et al. (2005) to assess student attitude toward chemistry. The instrument contains 25 attitude statements (11 positive and 14 negative) with each items using a five-point Likert-scale (strongly agree, agree, undecided, partially disagree, and strongly disagree). Ratings ranged from Strongly Agree (5) to Strongly Disagree (1) for the 11 positive statements, the reverse ratings, Strongly Agree (1) to Strongly Disagree (5), were used for the 14 negative statements. As a consequence, potential scores from the CAS ranged from the 25 to 125. The Cronbach's alpha coefficient was calculated 0.84 and independent *t*-test was used to compare the pre-test and post-test scores for the groups. In the analysis, firstly, the total score of the each student on the CAS and then mean score of each group were computed. The mean scores of the groups were compared by using *t*-test for both pre-test and post-test. Some examples of attitude statements which were used in the experiment are given below:

Statement 3. Chemistry lessons are boring for me.
Statement 9. It is important for me to be successful in chemistry lessons.
Statement 11. I will not use the knowledge related chemistry in my daily life.
Statement 16. I enjoy speaking related chemistry.
Statement 20. It is not interesting for me to try solving chemistry problems.

4.4.2. Chemical Bonding Achievement Test (CBAT)

The researcher developed the CBAT to measure students' achievement on chemical for bonding both experimental and control groups before and after the implementation of a CAI intervention (see below). The CBAT consists of 15 two-tier multiple-choice items. The first tier of each item consists of a content question having two, three, or four choices; the second part of each item contains four possible reasons for the answer given in the first tier response. These reasons include one scientifically acceptable answer and three alternative conceptions reported in the literature. This type of question is used to develop an understanding of students' reasoning behind their choices (Odom & Barrow, 1995; Peterson & Treagust, 1989). Based on the teachers' views, students' alternative conceptions identified in the literature (Birk &

Kurtz, 1999; Coll & Taylor, 2001; Peterson, Treagust, & Garnett, 1989), and the researchers own experiences, the researcher developed some questions whilst others were selected from the textbooks and relevant literature (Campbell, 1999; Peterson et al., 1989; Ünal, 2003). In addition to Peterson et al. (1989) work, Ünal (2003) determined several alternative conceptions for chemical bonding from in-depth interviews conducted in Turkey. Three chemistry educators, three chemists, and eight experienced chemistry teachers examined the instrument for content validity done via thorough review of the instrument. The reliability of the CBAT based on Cronbach's alpha was 0.72. An example of an item taken from the literature (Peterson et al., 1989) testing students' understanding of bond polarity is given below (item 7, CBAT):

Which of the following best represents the position of the shared electron pair in the HF molecule?

(1) H :F (2) H : F

The reason for my answer is because:

(A) Non-bonding electrons influence the position of the bonding or shared electron pair.
(B) As hydrogen and fluorine form a covalent bond the electron pair must be centrally located.
(C) Fluorine has a stronger attraction for the shared electron pair.
(D) Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair.

A student's answer to an item was considered correct if the student selected both the correct content choice and the correct reason, as reported in the literature for two-tier multiple-choice items (Peterson et al., 1989).

Scores for test items were placed in one of three categories. Both the correct content choice and the correct reason scored four points; the correct content choice but the incorrect reason or *vice versa* scored two points; and if both the incorrect content choice and the incorrect reason were made, score zero. If a student responded to all CBAT items correctly a maximum of 60 points was possible.

4.5. Development of computer software (CAI material)

Special teaching materials including the use of CAI software package was developed for the study. Using the above instruments the researcher collected data about the effects of this intervention on grade 11 students' attitude, achievement, and the remediation of alternative conceptions for chemical bonding concepts. The steps below were followed during the intervention:

- √ Firstly, research from national and international science education literature about chemical bonding were reviewed to identify potential students' alternative conceptions.
- √ Secondly, in-depth interviews were carried out with participant teachers to determine the difficulties they encountered during the teaching chemical bonding concepts.
- √ Thirdly, several chemistry textbooks, curriculum materials, lesson plans, teachers' notes, and workbook used by the learners were examined, to identify key concepts in chemical bonding, and these analyses were combined with informal interviews with the teachers, and also current chemistry computer software used in Turkey were collected and examined similarly.
- √ Fourthly, after the examination of the above materials, detailed content to be used in the CAI was constructed by taking into account students' learning difficulties, alternative conceptions, and teacher views.

Computer software was prepared by a computer expert in consultation with the researcher using propriety software such as Microsoft PowerPoint, Flash and Adobe Photoshop 6.0. Material thus prepared included figures, graphs, three-dimensional animations, and problem-solving exercises to supplement to theoretical content knowledge. The most important property of this software was the nature of interaction required by the students. For example, students had opportunity to see the effect of factors such as unshared electron pairs, and single or multiple bonds, on molecular geometry. A print-screen view of the effect of unshared electron pairs on molecular geometry for H_2O molecule is given in Fig. 1 as an example.

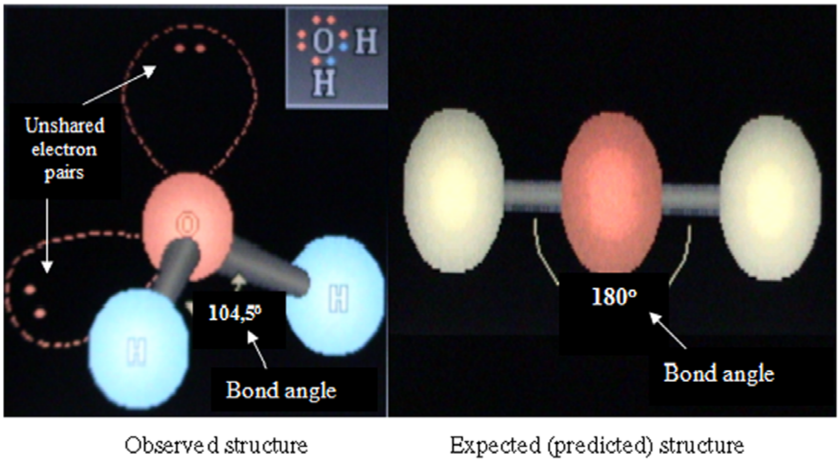

Fig. 1. The effect of unshared electron pairs on molecular geometry for H_2O molecule: observed structure and expected (predicted) structure.

4.6. Procedure

Both CBAT and CAI instruments were piloted with 30 students to check their applicability and to refine items before the administration. The intervention was implemented over a 3 weeks period during the 2004–2005 academic years. After selection of the groups and teachers, the CAI material was introduced to the teacher responsible for teaching the experimental group before the formal treatment. The teachers participated in the study all have similar background and experience, work at same school, and have experience in using computers. The control group students were taught by a traditional teacher-centered approach involving ‘talk-and-chalk’ type lessons – the dominant teaching approach in Turkish schools. The experimental group received the CAI as a supplement to other methods such as PowerPoint presentation and regular classroom instruction. During the intervention, the teacher presented CAI material involving chemical bonding unit to students via a data-show, and students had the opportunity to work on activities using a computer. Because there were 12 personal computers available for the study, each two students worked on one computer. The CBAT and CAS were administered to each group before and after the intervention, as pre-test and post-test. Both experimental and control groups were observed during the implementation of the unit by the researcher. The independent *t*-test was used to compare the pre-test and post-test scores of the groups for each of the instruments.

5. Results and discussion

The results are presented with regard to the effects of traditional and CAI lessons, and their effect on student attitude toward chemistry and understanding of chemical bonding concepts.

5.1. Chemistry Attitude Scale (CAS)

One of the research questions for this study was to determine the effect of CAI on students’ attitude toward chemistry. When the attitudes were assessed and the attitude statements were evaluated according to pre-test

Table 1
The comparison of the pre-test and post-test results of the groups in CAS

	Groups	*N*	Mean	SD	*t*	*p*
Pre-test	Experiment	25	51.56	3.86	0.55	0.585
	Control	25	50.8	5.72		
Post-test	Experiment	25	105.68	7.84	5.696	0.001
	Control	25	95.72	3.86		

results, no statistically significant differences were found between the control and experimental groups ($t = 0.55$, $p = 0.585$) (Table 1), suggesting that groups were similar in respect of attitude. As there were no statistically significant differences between the pre-test scores of the groups, the post-test scores were compared using an independent *t*-test. This showed a statistically significant difference between groups in favor of the experimental group ($t = 5.696$, $p = 0.001$), with regard to their attitude. This result is similar to that reported in the literature, which suggest that CAI-based teaching improves student attitude toward science and chemistry (see Geban et al., 1992; Harwood & McMahon, 1997; Hounshell & Hill, 1989). The comparison of the pre-test and post-test results of the groups was presented in Table 1.

It is worthwhile to note here that in the case of the experimental group, students had the opportunity to work with computers, something not common in Turkish schools, meaning this was a new and interesting experience for them. They gained experience in an enriched learning environment-seeing, doing, interpreting, and interacting with computers individually and it seems they could now see that chemistry may not be as difficult as they thought. Improvement in attitude may of course in some part be due to simply that they enjoyed this type of lesson using CAI.

5.2. Chemical Bonding Achievement Test (CBAT)

The second research question for this study was to determine whether or not the CAI or traditional instruction were effective in improving students' understanding of chemical bonding unit. The CBAT test was administered to both groups as pre-test and post-test. The responses to the CBAT pre-test and post-test are presented in Table 2.

As can be seen from Table 2, although the proportion of students correctly answering the items post-test are higher than 65% overall compared with the pre-test, the experimental group were more successful than the control group. Examination of test scores using the *t*-test, found no statistically significant differenced between the pre-test scores of the experimental and the control groups' students, but statistically significant differences in the case of the post-test scores (Table 3).

As can be seen from Table 3, there were no statistically significant differences between pre-test results ($t = 0.48$, $p = 0.628$), but statistically significant differences between the experimental ($M = 81.28$) and control groups ($M = 72.08$, $t = 7.993$, $p = 0.001$) with respect to chemistry achievement. These results suggest that the students in the experimental group scored higher than the students in control group in the achievement test on chemical bonding, meaning they have developed a better understanding of chemical bonding as a result of the CAI intervention. This is similar to findings reported in the literature which points to positive effects of CAI for student achievement in chemistry (see Barnea & Dori, 1999; Ertepınar, 1995; Levine & Donitsa-Schmidt,

Table 2
Percentages of students correctly answering the first part and both part of CBAT

Item no.	Experimental group (%)				Control group (%)			
	Pre-test		Post-test		Pre-test		Post-test	
	First part	Both part	First part	Both part	First part	Both part	First part	Both part
1	44	28	84	76	40	32	80	68
2	56	40	88	80	48	40	84	76
3	40	36	76	72	48	44	80	76
4	44	36	84	76	52	44	84	76
5	60	56	92	88	56	52	88	80
6	56	48	84	76	60	48	80	72
7	48	40	80	72	40	32	76	68
8	44	36	80	72	48	36	72	64
9	56	52	88	80	52	44	84	80
10	60	52	92	84	56	48	84	80
11	48	40	84	76	52	44	80	72
12	44	40	76	68	40	36	72	64
13	56	44	84	76	56	48	84	72
14	52	44	84	72	52	40	80	68
15	44	36	80	68	48	40	84	72

Table 3
Comparison of the pre-test and the post-test scores of the groups in CBAT

	Groups	*N*	Mean	SD	*t*	*p*
Pre-test	Experiment	25	31.28	4.28	0.488	0.628
	Control	25	30.72	3.82		
Post-test	Experiment	25	81.28	4.65	7.993	0.001
	Control	25	72.08	3.39		

1996; Morgil et al., 2005; Williamson & Abraham, 1995). In these studies, the effectiveness of the computer-assisted instruction was approved by the researchers. Especially, CAI materials used in these studies were more useful than the traditional approaches in teaching complex chemistry concepts. The results of the studies in the related literature are harmonious with the current study with this manner.

The third research question for this study was to determine if CAI or traditional instruction was effective in the remediation of the student alternative conceptions. In Turkey, there are a few studies related to effectiveness of CAI. In these studies, the main aim of the research is generally to determine the effectiveness of the CAI compared with the traditional teaching on students' achievement and attitudes (Ertepınar, 1995; Morgil et al., 2005). Studies related to remediation of students' alternative conceptions using CAI are limited. Because intended to determine the effectiveness of the CAI in remediating of the students' alternative conceptions, this study is new with this manner. And also, the CAI material used in the study was developed based on the literature data related to students' alternative conceptions on chemical bonding. Considering students' alternative conceptions in developing of the computer-assisted materials is also new approach for Turkey.

Since the distracters of the test items developed by the researcher are alternative conceptions reported in the literature, the alternative conceptions revealed in this study are similar to those in the literature. The proportion of students holding alternative conceptions for both groups pre-test and post-test is presented in Table 4.

As can be seen from Table 4, students from both groups hold a number of alternative conceptions–in a similar proportion for the pre-test. However, the experimental group students hold less alternative conceptions post-intervention-an indicator of the effectiveness of the CAI intervention.

One of the alternative conceptions encountered is equal sharing of the electron pair in all covalent bonds. This is also a common alternative conceptions reported in the literature (see Peterson & Treagust, 1989; Peterson et al., 1989). In the CBAT, the students were asked to predict the position of the shared electron pair in the HF molecule and give the reason for their prediction. As seen from Table 2 (item 7), 40% of the students in experimental group and 32% of the students in control group could correctly ascertain the position of the shared electron pair in the H—F bond and give the correct reason for their choice in pre-test. Post-intervention for this item this changed to 72% of experimental group and 68% of control group students. The most common remaining alternative conceptions is that students believe that equal sharing of the electron pair occurs in all covalent bonds, meaning they ignored the influence of electronegativity and resultant unequal sharing of the electron pair. In addition to this, some of the students seem to believe that the polarity of a bond is dependent on the number of valence electrons in the bond and/or that the nonbonding electron pairs determine the polarity of the bond. Similar alternative conceptions are reported in the literature (Peterson et al., 1989). Some students seem to believe that the more valence electrons atom has, the more it attracts the bonding electrons which determine the polarity of the bond. Based on these ideas, the CAI material includes an explanation and exampled of the effect of electronegativity on sharing of electrons in a covalent bond and strives to inform students about how equal and unequal sharing occur in a covalent bond – by stating that bonds become polar when electrons are more strongly attracted to one side of the bond, and that this depends on the electronegativities of atoms involved. As can be seen from Table 4 (items 1 and 2), the experimental group students were more successful than the control group students in remediating this alternative conceptions.

Another alternative conception commonly encountered in the literature is the shape of molecules. The students in both groups seem to think that only repulsion between bonds, bond polarity, and repulsion between nonbonding electron pairs are responsible for the shape of molecules. These alternative conceptions are reported for many secondary school students and undergraduate chemistry students (Campbell, 1999; Peterson et al., 1989). As can be seen in Table 4, 24% of experimental and control group students pre-test believe that

Table 4
The percentages of students' alternative conceptions determined in the pre-tests and post-tests in both groups

Alternative conceptions	Experimental group (%)		Control group (%)	
	Pre-test (%)	Post-test (%)	Pre-test (%)	Post-test (%)
Equal sharing of the electron pair occurs in all covalent bonds	36	12	36	24
The polarity of a bond is dependent on the number of valence electrons in each atom involved in the bond	32	12	36	20
Non-bonding electron pairs influence the position of the shared pair and determine the polarity of the bond	40	16	40	28
Ionic charge determines the polarity of the bond	28	12	24	16
The shape of molecules is due only to equal repulsion between the bonds	24	8	24	16
The shape of molecules is due only to the repulsion between the nonbonding electron pairs	36	8	32	24
Bonds polarity determines the shape of molecule	32	12	28	20
Non-polar molecules form only when the atoms in the molecule have similar electronegativities	36	16	36	24
A molecule is polar because it has polar bonds	28	12	32	20
Strong intermolecular forces exist in a continuous covalent solid	20	8	16	12
The bonding in metals and ionic compounds involves intermolecular bonding	20	12	24	16
Covalent bonds are broken when a substance changes shape	36	20	30	24
van der Waals forces form only between noble gases	28	12	28	20
Ionic bonds form only between alkali metals and halogens	40	16	40	28
Hydrogen bond is an intermolecular bond	36	16	32	20
Students confuse covalent bonds with ionic bonds	32	12	28	12
Students confuse polar bonds with apolar bonds	28	12	28	20
Electrons are lost at bonding time	32	12	36	29

molecular shape is only due to repulsion between bonds. For example, when asked to predict the shape of N_2CI_4 molecule, many students selected a response indicating a belief that the shape of molecule is due to repulsion between bonds only. Such students did not consider the influence of bonding and non-bonding electron pairs on the nitrogen atom. However, post-test, the experimental group scores (8%) were lower than the control group scores (16%, see Table 4). In another example, when asked to predict the shape of the SCI_2 molecule, some students said SCI_2 was a linear molecule and incorrectly and based this on repulsion between the two S—CI bonds. While students with this alternative conception did not consider the nonbonding electrons on the sulfur atom, some said the SCI_2 was V-shaped and explained as a result of repulsion between non-bonding electron pairs. After the CAI classes, the experimental group are more successful than the control group. Bond polarity is another commonly misunderstood factor with regard to the shape of a molecule. For example, some students seemed to believe that the shape of the $COCI_2$ molecule is due to the stronger polarity of the C=O double bond in the molecule, without taking into account other factors such as the nonbonding electron pairs. The CAI intervention was specifically designed to remedy such alternative conceptions. With this regard, the effects of repulsion between bonds, bond polarity and repulsion between non-bonding electron pairs on molecular shape were explained for different molecules using animations. As an example, the effect of unshared electron pairs on the molecular shape of H_2O is given in Fig. 1. In this example, the students have the chance to compare the expected and observed structures for the H_2O molecule. The students are expected to understand the effects of both O—H bond polarity and non-bonding electron pairs when determining the shape of molecule. Because both O—H bond polarity and non-bonding electron pairs on oxygen atom are what causes the V-shape of the molecule, rather than a linear structure – reducing the bond angle from 180° to 104.5°. In fact, the non-bonding electron pairs are primarily responsible for the V-shape in H_2O molecule.

Another alternative conception found here is to do with the polarity of molecules. Some students seemed to believe that a molecule is polar if it has polar bonds, and others consider the polarity to be only dependent on the electronegativity difference between atoms forming the bonds. Similar alternative conceptions are reported in the literature (Peterson & Treagust, 1989). Students exhibiting this alternative conception seemed to believe that non-polar molecules form between atoms of similar electronegativities;

and that polar molecules are formed between atoms of different electronegativities. For example, similar to alternative conceptions identified by Campbell (1999), in this study it was found that some students think CIF_3 is non-polar because there is very little difference between the electronegativities of CI and F, but that CF_4 is polar because of the large electronegativity difference between the C and F atoms. Such students did not seem to consider the effect of molecular shape and bond polarity on the polarity of the molecule. Again the CAI intervention, the effect of each of these factors was separately explained suing different molecules and employing animation.

There also were a number of other alternative conceptions about chemical bonding identified in this study. For example, as reported in the literature (Taber, 1998) some students confuses the definition of covalent and ionic bonding – stating that ionic bonding is sharing of electrons and covalent bond formation involves the transfer of electrons. Some students seem to believe that covalent bonds are broken when a substance changes shape; that van der Waals forces form only between noble gases; that ionic bonds form only between alkali metals and halogens; that the hydrogen bond is an intermolecular bond; and that electrons are lost when bonding occurs. Some of these alternative conceptions are also reported in the literature. Again in the CAI intervention, detailed explanations were employed to directly address these alternative conceptions and concepts in which students had learning difficulties.

Some researchers claim that computer-assisted instruction in comparison to the conventional methods of teaching can enhance transfer learners' alternative conceptions (Jimoyiannis & Komis, 2001) and enhance understanding of scientific conceptions (Ronen & Eliahu, 2000). Most studies in this field have shown the benefits of CAI over the traditional teaching methods (Eylon et al., 1996; Geban et al., 1992; Windschitl & Andre, 1998) and these researches state that CAI enhances students' achievement and attitude toward chemistry. This is also true for this study. The results of this study show that scientific understanding levels and the ratio of remediation of alternative conceptions of experimental group students are higher than the control group ones. In addition, CAI has enhanced the attitudes of experimental group students toward chemistry. The results are similar to the results of the related literature with this manner. On the other hand, the content of this study is specific only to chemical bonding. Although previous studies report positive results with different chemistry concepts and literature have lots of studies related to chemical bonding, especially related with determining students' conceptions, there is no study related to computer-assisted instruction in chemical bonding as far as I investigate. Therefore, the results of this study are different from the others and important and useful for future researches.

6. Conclusions and implications

In this study, the effect of a CAI intervention on student attitude toward chemistry, and their understanding of and remediation of alternative conceptions for chemical bonding were investigated. The CAS and CBAT instruments were administered to experimental and control groups before and after CAI. No statistically significant differences in means was found between the groups with respect to chemistry achievement ($t = 0.48$, $p = 0.628$) or attitude toward chemistry ($t = 0.55$, $p = 0.585$) pre-test, but were post-intervention (CBAT, $t = 7.993$, $p = 0.001$; CAS, $t = 5.696$, $p = 0.001$). These results point to a positive effect of the CAI intervention on student achievement and attitude toward chemistry. The results of this study suggest that teaching and learning of concepts related to chemical bonding can be improved by using CAI. This necessitates development of computer software for different chemistry concepts in order to enhance students' visualization skills and understanding. But, this does not mean that computer usage alone is crucial in influencing students' attitudes, achievement and remedying alternative conceptions. As with most teaching methods, CAI has some limitations. It is an assertion here that CAI needs to be integrated with other teaching methods to be most effective in enhancing student learning of chemistry concepts.

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