EFFECTIVENESS OF CONSTRUCTIVIST APPROACH ON STUDENTS' UNDERSTANDING OF CHEMICAL BONDING CONCEPTS

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

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ABSTRACT

EFFECTIVENESS OF CONSTRUCTIVIST APPROACH ON STUDENTS' UNDERSTANDING OF CHEMICAL BONDING CONCEPTS

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The main purpose of this study was to compare the effectiveness of instruction based on constructivist approach over traditionally designed chemistry instruction on ninth grade students' understanding of chemical bonding concepts. In addition, the effect of instruction on students' attitude toward chemistry as a school subject and the effect of gender difference on understanding of chemical bonding concepts were investigated.

Forty-two ninth grade students from two classes of a chemistry course taught by the same teacher in METU Development Foundation Private School 2000-2001 spring semester were enrolled in the study. The classes were randomly assigned as control and experimental groups. Students in the control group were instructed by traditionally designed chemistry instruction whereas students in the experimental group were taught by the instruction based on constructivist approach. Chemical Bonding Concept Test was administered to both groups as a pre-test and post-test in order to assess their understanding of concepts related to chemical bonding. Students were also given Attitude Scale Toward Chemistry as a School Subject at the beginning and end of the study to determine their attitudes and Science Process Skill Test at the beginning of the study to measure their science process skills.

The hypotheses were tested by using analysis of covariance (ANCOVA) and two-way analysis of variance (ANOVA). The results indicated that instruction based on constructivist approach caused a significantly better acquisition of scientific conceptions related to chemical bonding and produced significantly higher positive attitudes toward chemistry as a school subject than the traditionally designed chemistry instruction. In addition, science process skill was a strong predictor in understanding the concepts related to chemical bonding. On the other hand, no significant effect of gender difference on understanding the concepts about chemical bonding and students' attitudes toward chemistry as a school subject was found.

KEYWORDS: Misconception, Constructivist Approach, Traditionally Designed Chemistry Instruction, Chemical Bonding, Attitude Towards Chemistry as a School Subject, Science Process Skill.

ÖZ

YAPILANDIRICI YAKLAŞIMIN ÖĞRENCİLERİN KİMYASAL BAĞLARLA İLGİLİ KAVRAMLARI ANLAMARINA ETKİSİ

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Bu çalışmanın amacı yapılandırıcı yaklaşımın dokuzuncu sınıf öğrencilerinin kimyasal bağlarla ilglili kavramları anlamalarına etkisini geleneksel yöntem ile karşılaştırmaktır. Aynı zamanda, öğretim yönteminin öğrencilerin kimya dersine yönelik tutumlarına etkisi ve cinsiyet farkının öğrencilerin kimyasal bağlarla ilgili kavramları anlamalarına etkisi de araştırılmıştır.

Bu çalışma ODTÜ Geliştirme Vakfı Özel Lisesi'nde 2000-2001 bahar döneminde gerçekleştirilmiştir. Çalışmaya, aynı kimya öğretmeninin iki ayrı dokuzuncu sınıfındaki kırkiki öğrenci katılmıştır. Sınıflar kontrol grubu ve deney grubu olarak rastgele seçilmiştir. Kontrol grubunda geleneksel yöntem kullanılırken deney grubunda yapılandırıcı yaklaşım kullanılmıştır. Öğrecilerin kimyasal bağlarla ilgili kavramları anlama düzeylerini ölçmek için Kimyasal Bağlar Kavram Testi her iki gruba on-test ve son-test olarak uygulanmıştır. Ek olarak, öğrencilerin kimya dersine yönelik tutumlarını belirlemek için Kimya Dersi Tutum Ölçeği ve bilimsel işlem becerilerini belirlemek için Bilimsel İşlem Beceri Testi her iki gruba da uygulanmıştır.

Araştırmanın hipotezleri ortak değişkenli varyans analizi (ANCOVA) ve iki yönlü çok degişkenli varyans analizi (ANOVA) kullanılarak test edilmiştir. Sonuçlar yapılandırıcı yaklaşımın kimyasal bağlarla ilgili kavramların anlaşılmasında daha etkili oldugunu ve kimya dersine yönelik daha olumlu tutuma yol açtığını göstermiştir. Bilimsel işlem becerisinin de öğrencilerin kimyasal bağlarla ilgili kavramlari anlamarına istatiksel olarak anlamlı katkısı olduğu belirlenmiştir. Bununla birlikte, cinsiyet farkının kimyasal bağlar konusunu anlama ve kimya dersine yönelik tutuma bir etkisinin olmadığı saptanmıştır.

ANAHTAR SÖZCÜKLER: Kavram Yanılgısı, Yapılandırıcı Yaklaşım, Geleneksel Yöntem, Kimyasal Bağlar, Kimya Dersi Tutum Ölçeği, Bilimsel İşlem Becerisi.

To my family

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ICA	: Instruction based on Constructivist Approach
TDCI	: Traditionally Designed Chemistry Instruction
CBCT	: Chemical Bonding Concept Test
ASTC	: Attitude Scale Towards Chemistry as a School Subject
SPST	: Science Process SkillTest
df	: Degrees of freedom
SS	: Sum of squares
MS	: Mean square
$\bar{X}$	: Mean of the sample
P	: Significance level
F	: F statistic

CHAPTER I

INTRODUCTION

Learning occurs when a learner is actively involved in the learning process. Learning outcomes do not only depend on teacher's presentations; instead they are interactive results of the learner's existing structure and newly encountered knowledge. Learning is the product of self organization and reorganization of existing ideas. Unfortunately, there is no exact strategy that will result in success with all students. Students are often unable to integrate facts and formulas although they can successfully solve mathematical problems (Yager, 1991). For this reason, one of the main aims of science education is to make a meaningful understanding of science concepts. Constructivist approach seems to be effective in providing meaningful learning. According to this approach, this kind of learning can take place only when the learner relates the new information to his already existing knowledge. Knowledge cannot be transmitted to the learner's mind from a textbook or by the teacher. Instead, students construct their knowledge by making links between their ideas and new concepts through experience they acquire in school or daily life. These types of experiences can result in assimilation in which new knowledge is incorporated into existing cognitive structure or they can lead to disequilibrium in which experiences cannot be reconciled within the existing structure and accommodation, where cognitive structure is reorganized, occurs. Accommodation allows a return to cognitive equilibrium (Bodner, 1986). Thus, from this point of view, learning is a process of conceptual change. For this reason, effective teaching requires the teacher to consider the learners' personal knowledge. In practice, prior knowledge may be missing or may include wrong conceptions or the learner may fail to make the link between new knowledge and his existing structure (Taber, 2001). Therefore, for effective teaching, the cognitive level of the learners and their conceptual development which means the extent of prior knowledge about the topic necessary for learning new knowledge should be considered. Furthermore, the subject that will be taught should not be too complex. However, this simplification should be done carefully since it may cause students to develop wrong conceptions. Briefly, there should be a correlation between the scientific topics and to what extent the students comprehend this knowledge (Taber, 2000).

Generally, students' wrong ideas about a particular topic are called as misconceptions which prevent learning and very resistant to change. In chemistry, students hold several misconceptions in many areas such as mole concept (Staver and Lumpe, 1995), chemical equilibrium (Gussarsky and Gorodetsky, 1988; Camacho and Good, 1989; Pardo and Solaz-Patolez, 1995), solutions (Ebenezer and Ericson, 1996; Abraham et al., 1994) and electrochemistry (Garnett, 1992). Chemical Bonding is another abstract topic where students have great difficulty. Also, understanding chemical bonding requires some physics topics such as energy and force in which students hold wrong conceptions. Thus, they have a lot of misconceptions in chemical bonding concepts. Since this topic is essential in chemistry in order to comprehend the nature of chemical reactions and some physical properties such as boiling point, students should understand chemical bonding concepts comprehensively.

Conceptual change points to the development and transformation of students understanding from their naive conceptions to scientific explanation. Conceptual change model is a learning model implying that nonscientific conception held by a student would be replaced if the four conditions of the conceptual change model were met (Posner, 1982):

1. Dissatisfaction with existing knowledge

2. Intelligibility of the new conception

3. Plausibility

4. Fruitfulness

This model is based on constructivist theory in which knowledge acquisition is viewed as a constructive process that involves active generation and testing of alternative propositions (Cobern, 1996).

Teaching science focuses on providing students with opportunities in which they have cognitive conflict and they develop different structures based on their experience. Conceptual change can be accomplished if students are given opportunity to be aware of their ideas, to encounter ideas other than their own and to realize the deficiency in their reasoning. This can be promoted by group discussions which allow students to construct their own knowledge out of exchanges with their friends and the teacher. In this way, students can control their learning process. Research studies showed that oral discussions develop students' critical thinking ability and understanding of the content (Gall and Gall, 1990; Hogan, K., Nastasi, B. K. and Pressley, M., 2000). In essence, the constructivist approach oriented instruction used in this study was to activate the students' existing schemata (misconception) related to chemical bonding.

In science education, many research studies indicated that the type of instruction affected students' attitudes toward science as a school subject (Chang, 2002; Parker, 2000). Students' attitudes, feelings and perceptions of science are important for science achievement and their selection of career related to science in the future. In this study, the effect of treatment on students' attitudes toward chemistry was also investigated.

This study also dealt with science process skills that are important for understanding scientific concepts. Science process skills involve identifying variables and hypotheses, designing investigations, graphing and exploring data, explaining results and drawing conclusions. In literature, it has been indicated that learning science requires high cognitive skills (Lazarowitz, 2002). In the present study, the contribution of students’ science process skills to their understanding of chemical bonding concepts was examined.

CHAPTER II

REVIEW OF LITERATURE

Researches in science education focus on improving students' understanding of scientific phenomena. In order to solve a given problem, the student must understand the concepts involved. Students must relate concepts to the ideas they already have so that meaningful learning occurs. From this point of view, learning is a restructuring of existing ideas rather than merely adding information to existing structure. It is accepted that students develops some ideas about natural events before coming to the classroom. Often these ideas are different from scientific explanations and interact with scientific knowledge presented in the class. Consequently, unintended learning outcomes come out. Therefore one of the aims of science education is to make students acquire scientific knowledge meaningfully. On this ground, it seems logical to begin the discussion with the learning, i.e. what knowledge and learning are and how learning occurs. Cognitive development will be emphasized in this part. Then, students' existing ideas and misconceptions will be stated. Next, constructivist approach which views students' existing ideas as a stating point in instruction will be explained. Finally, conceptual change approach, which is based on constructivism, will be discussed.

2.1 Knowledge, Cognitive Development and Learning

We stated that one of the aims of science education is to make students acquire scientific knowledge. So what is meant by knowledge? How do students learn? How do students use their cognitive structure? Knowledge includes a broad variety from skills to complex processes. Goodman and Elgin (1988) described knowledge as an effort starting from certain truths and searching to discover other truths through observation and experiment and so arriving at accurate and comprehensive description of the real world. However, understanding is a cognitive effort starting from what happens to be currently adopted and proceeds to integrate, organize, not to arrive at truth but to construct something that works cognitively and implements further inquiry and invention. Then, meaning is seen as an end product of cognitive ability. People transform meanings to conform to their own versions of knowledge. Meanings are enhanced, extended or deleted as the individual interacts with more complex situations. So knowledge is continuously developing in complexity. Piaget (1950) believed that acquisition of knowledge is a process of self construction. A learner discovers knowledge and as the learner develops and interacts with the environment, he continues to invent knowledge. Learning occurs when the learners is involved in construction of meaning actively.

As an individual's intellectual capacity develops, the importance of the metaphysical aspects of conceptual change will increase. As a result, the age of an individual must be relevant to a conceptual change process.

Piaget also considered three processes important in cognitive development: assimilation, accommodation and equilibration. If a child uses existing concepts to deal with new phenomena, this is called assimilation. When the students' current concepts are inadequate to allow him to grasp new phenomenon, then he replaces or reorganizes his central concepts. This is called accommodation. Equilibrium, determines the child's transition from one stage of development to the next. At each stage, at the beginning, the child uses his logical structure that work well but toward the end of the stage, he becomes dissatisfied with his structure, organizes it and attains a new equilibrium. According to Piaget, equilibrium encompasses both assimilation and accommodation.

On the other hand, Vygotsky (as cited in Steffe and Gale, 1995) dealt with mechanism of development to the exclusion of distinguishable developmental stages. He rejected that single principle, such as Piaget's equilibration, couldn't explain development. He claimed that development is more complex. Vygotsky focused on process rather than product, his interest was not how well the children perform, but what they did under varying task conditions. Cultural and social factors affect the development of intelligence.

Unlike Piaget, Vygotsky focused on social activity. Development is transformation social relations to mental operations.

Vygotsky claimed that learning and development are separate. Each school subject has its own relation to the child development and it varies as the child goes one stage from another. As well as prerequisite skills and knowledge within a discipline, solving problems that enable them to improve their skills is important. Learning is more than acquisition of thinking ability; it is acquisition of many specialized abilities for thinking and occurs through social interactions. Partners work together and co-construct the solution to a problem.

Spivey (as cited in Steffe and Gale, 1995) claims that learning occurs when learners change their cognitive structures as they interact with the environment that allows them to recognize their structure. It is a lifelong activity.

Ausubel(1968) also supported a cognitive approach to learning. However, his ideas differed from Piaget's ideas in that Ausubel focused on conceptual rather than operative forms of knowledge. Ausubel claimed that meaning occurs when learners actively interpreted their experiences using certain cognitive operations that cause learning. He proposed a theory of meaningful reception learning. According to this theory, the most important single factor influencing learning is what the learner already knows. Cognitive structure of the learner determines how knowledge will be incorporated and describes how linkages will occur. Ausubel proposed “anchoring ideas” which are specific, relevant ideas in the learners’ cognitive structure and supply entry points for new information. They enable the learner to construct meaning from new information and experiences. In order to acquire meaningful learning, cognitive structure and anchoring ideas in the cognitive structure are important regarding integration of new knowledge. In meaningful learning, the learner makes connection between what he already knows and new potentially meaningful information in a nonarbitrary and substantive way. For meaningful learning to occur, there should be two conditions: new knowledge must have potential meaning, the learner must have relevant concepts to anchor the new ideas and the learner intends to incorporate the new knowledge in a nonarbitrary, nonverbatim way. When one or more of these requirements are not met, rote learning, verbatim memorization, occurs. In rote learning students do not develop hierarchical framework of successively more inclusive concepts instead they accumulate isolated propositions in their cognitive structure. This causes poor retention and retrieval of new knowledge to solve problems. Therefore, meaningful learning is more preferred outcome in school situations. Ausubel also described reception learning and discovery learning. In reception learning, the concepts and prepositions are presented to the learner by the independent agent (a teacher, a computer or a film) in its final form. In discovery learning, the learner rearranges new information, integrate it with existing structure and construct significant prepositions. It is important that reception and discovery learning can be accomplished through either meaningful or rote process. Further, Ausubel proposed three types of meaningful learning in terms of learning outcome: the first is “representational learning”. It refers to learning the meanings of unitary symbols or words. This is the basic form of the learning serving as the foundation for other types of learning. The second is “concept learning”. In concept learning, the learner relates actively new knowledge to his relevant experiences. The last is “prepositional learning”. In this type of learning, new ideas are expressed in verbal propositions such as making inferences or reasoning. Representational, concept and prepositional learning are hierarchically related. For prepositional learning to occur, students must know the meaning of the concept in a verbal proposition. For concept learning to occur, students must represent concept name and the object it refers. All three types of meaningful learning proceed in the same way. Learners relate new knowledge to his existing cognitive structure in a nonarbitrary and substantive way. In Ausubel’s theory, learning is a building process. New information is added to and integrated with existing cognitive structure. According to Ausubel, meaningful learning can be explained through “subsumption” process in which new knowledge composed of more specific, less inclusive concepts, is linked to more general and inclusive concepts in the learners’ cognitive structure (Driscoll, 1994; Mintzes, Wandersee and Novak, 1998).

Ausubel considered instruction in the way that the most general concepts are best taught first. Instruction should facilitate making relationship between the new knowledge to be learned and which is already in cognitive structure. That is, cognitive structure should be activated during teaching process in order for learning to occur. Instruction should increase discriminability of new knowledge from ideas existing in the cognitive structure. Instruction should enhance the stability and clarity of anchoring ideas for later learning and problem solving. For these purposes, he proposed several instructional strategies such as advance organizers, comparative organizers and integrative reconciliation and progressive differentiation.

Many research studies provide evidence that students hold preinstructional conceptions in many fields and that these are different from the scientific concepts. Students learn science concepts and principles only to a limited degree, they resist to change their existing ideas and sometimes hold on two inconsistent approaches. Teachers, generally, are not aware of students' alternative conceptions and therefore there may occur problems in teaching and learning. Investigating students' conceptions not only reveals important insights about students' way of thinking and understanding in science but also can help researchers and teachers revise and develop their own science knowledge. (Treagust, Duit, and Fraser, 1996). Students' existing ideas play an important role during the learning process. They adapt scientific concepts to their existing cognitive structure. Students should realize conflict in their thinking in order to change their ideas. They should recognize the inadequacy of their knowledge or experiences. Then, they would question their thinking and consider the more fruitful and adequate scientific view and conceptual change occurs (Duit, 1991).

2.2 Misconceptions

The word "misconception" implies

1. students' mistaken answers to a particular situation.
2. students' ideas which cause mistaken answers about a particular situation.
3. students' beliefs about how the world works different than that of the scientists (Dykstra, Boyle and Monarch, 1992).

In order to dispel students' misconceptions, it is necessary to identify the sources of these misconceptions. During learning, the student tries to connect new knowledge into his cognitive structure. If he holds misconceptions, these misconceptions interfere with subsequent learning. Therefore, new knowledge cannot be connected to his existing structure and misunderstanding of the concept occurs (Nakhleh, 1992). So, students' existing ideas are important factors affecting the development of misconceptions.

Haidar and Abraham (1991) found that formal reasoning and preexisting knowledge play an important role in the development of students' conceptions.

Their study stated possible sources of misconceptions as:

i) macroscopic reasoning: The students may have difficulty in translation of observable behaviour of matter to the scale of atoms and molecules.

ii) Instruction: the students may misinterpret instructional devices.

They suggested that chemistry curriculum materials need to be written in a way that promotes connections between students' macroscopic experiences and their scientific microscopic explanations. Students need instruction that will help them develop the link between the macroscopic observations in the laboratory and the microscopic models that chemists use to explain them.

Smith and Metz (1996) also reported the same arguments about microscopic representations. They claimed that chemical concepts should be explained by microscopic representations before applying the mathematics. This might increase comprehension and retention by allowing students to picture the chemistry.

Another possible source of students' misconceptions is everyday knowledge. Prieto et al. (1989) suggest that the students' ideas were result of the interaction between their social and school knowledge. Science teaching should address the issue of everyday language directly in the students' lessons. In the chemistry classroom, students' everyday ideas should be considered firstly but in addition, students should be encouraged to see chemists' ways of looking at the same phenomenon as a fruitful alternative in particular context. Better curriculum materials based on students' ways of learning and their prior knowledge to formal instruction should be developed (Longden, Black and Solomon, 1991; Ebenezer and Ericson, 1996).

Teacher themselves also may cause misconceptions. They may misunderstand the context. However, although instruction is accurate, students may misunderstand some concepts due to inadequate prerequisite knowledge (Taber, 1995).

2.3 Misconceptions in Chemical Bonding

Chemical bonding is one of the basic topics in chemistry. Since it is an abstract concept which can not be applied to everyday life directly, many students aren't able to comprehend this concept. They cannot relate microscopic world to macroscopic world. In addition, understanding chemical bonding requires some physics topics such as energy and force in which students have difficulty in understanding. As a result, they hold many misconceptions related to chemical bonding concepts. Understanding chemical bonding concepts is important in chemistry in order to comprehend the nature of the chemical reactions and some physical properties such as boiling points. Thus, students' misconceptions should be identified and new instruction methods focusing on students' misunderstanding should be developed.

Boo (1998) made a study to identify 12th grade students' understanding of chemical bonding and energetic through interviews. According to his findings, students believed that bond making requires input of energy and bond breaking releases energy.

Students have difficulty in understanding why and how bonding occurs. This point was summarized by Nicoll (2001). Nicoll (2001) described undergraduate students' misconceptions related to electronegativity, bonding, geometry and microscopic representations by interviewing with students. Students' difficulties related to bonding can be summarized as follows:

- Confusing atoms and molecules.
- Failing to consider octet rule.
- Not relating polarity with electronegativity.
- Not distinguishing between ionic and covalent bonding.
- Failing to explain why bonding occurs.

Taber (1994) also reported similar findings. Taber (1994) analyzed students' conceptions of ionic bonding and described students' views as a molecular framework. Students believe that the atomic electronic configuration determines the number of ionic bonds formed; bonds are only formed between atoms that donate and accept electrons and ions interact with counter ions around them, but for those not ionically bonded these interactions are just forces.

The most common misconception among students was about the structure of ionic compounds, specifically the structure of NaCl. Butts and Smith (1987) investigated grade 12 students' understanding of structure and properties of molecular and ionic compounds. They stated that most students can not understand the three dimensional nature of ionic bonding in NaCl. Students think that NaCl exist as molecules and these molecules were held together by covalent bonds. Also, others think that Na and Cl atoms were bonded covalently but the ionic bonds between these molecules produced the crystal lattice.

Tan and Treagust (1999) developed a two-tier multiple choice diagnostic instrument to determine 14-16 year-old students' alternative conceptions related to chemical bonding. Items were developed through interviews with students, students' concept maps, questions of past exams and personal teaching experiences. Then, it was administered to 119 chemistry students in a secondary school. They found that most students have many misconceptions in chemical bonding concept. The common misconceptions found are as follows:

- Metals and nonmetals form molecules.
- Atoms of a metal a nonmetal share electrons to form molecules.
- A metal is covalently bonded to a nonmetal to form a molecule.
- Metals and nonmetals form strong covalent bonds.
- Ionic compounds exist as molecules formed by covalent bonding.

- The strength of intermolecular forces is determined by the strength of the covalent bonds present in the molecule.

Peterson, Treagust and Garnett (1989) studied to construct a test instrument to diagnose grade 11 and 12 students' understanding of covalent bonding and structure and described the misconceptions by using this instrument. Conceptual difficulty and students' misconceptions were identified through unstructured interviews, students' concept maps and open ended pencil and paper test items after instruction. Then, diagnostic instrument was developed on the two-tier multiple choice format which consisted of 15 items and each item consisted of two parts. In the first part, students were expected to answer questions by selecting a choice from two, three or four alternatives. In the second part, students explained the reason for their answers by choosing one reason from four possible reasons. The distracters in this test indicated misconceptions. This test was administered to 159 11th grade and 84 12th grade high school students. The following misconceptions that students hold were stated as follows:

- Covalent bonds were broken when a substance changes state.
- Equal sharing of electron pairs occured in all covalent bonds.
- The polarity of a bond was dependent on the number of valance electrons in each atom involved in the bond.
- Ionic charge determined the polarity of the bond.

- Nonpolar molecules formed when the atoms in the molecule had similar electronegativies.
- Intermolecular forces were molecules within a molecule.
- Number of covalent bonds formed by a nonmetal was equal to the number of electrons in the valance shell.
- Bond polarity determined the shape of a molecule.
- The shape of a molecule was due to equal repulsion between the bonds only.
- Only nonbonding electron pairs influenced the shape of a molecule.

Birk and Kurtz (1999) used the diagnostic test developed by Peterson, Treagust and Garnett (1989) to determine the effect of experience on retention and elimination of some misconceptions of high school students, undergradute students and college and university faculty members about molecular structure and chemical bonding. The researchers perceived the teachers' experience as directly related with the years of study at they spend in their field. The results of this study indicated that as the years that teachers spend in their area increase, students acquire better understanding of molecular structure and bonding. However, even in the faculty level, there was a gap between conceptual understanding and recall knowledge. The most common misconception among undergraduate students was that equal sharing of the electron pair occurs in all covalent bonds. Taber (2003) claims that the reason for this misconception is that use of the term “electron sharing” in covalent bonding causes students to interpret it in its social meaning thus they imply that equal sharing occurs and they cannot conceptualize polar bonds. They think that all covalent bonds are nonpolar.

Taber (2003) studied students’ mental models related to metallic bonding. The findings can be summarized as follows:

- Metals do not have any bonds since all atoms are the same.
- There is some interactions in metals but there is not proper bonding. These students do not think the existence of bonds other than covalent or ionic.
- Metals have covalent and/or ionic bonding.
- Metallic bonding occurs only in alloys. These students have the idea that metallic bonding exists between two different metal atoms.

Taber (2003) suggested that while teaching chemical bonding, first metallic bonding should be introduced and then ionic and covalent bonds should be taught. During studying metallic bonds, students use their knowledge of ionic and covalent bonding in explaining metallic bonding. The instruction may not provide students with appropriate prior learning. Therefore, during instruction, first general notion of bonding should be given in detail and electrical interactions should be emphasized. This study strongly emphasized that students’ prior knowledge affects their learning.

Coll and Taylor (2001) examined secondary school, undergraduate and postgraduate students' conceptions about chemical bonding. At the beginning of the study, the researchers analyzed lesson plans, textbooks, lecture notes and other related materials and summarized eight mental models for chemical bonding as the electron sea model, band theory for metals, a model based on electron transfer, model involving the calculation of electrostatic charges for ionic substances, the octet rule, the molecular orbital theory, the valance bond approach and ligand field theory for covalent substances. Then, interviews were made with students. Students' mental models were compared with the models in the curriculum materials. Some misconceptions were found as follows:

- Metallic and ionic bondings are weak bondings.
- Intramolecular covalent bonding is weak bonding.
- Continuous metallic or ionic lattices are molecular in nature.
- The bonding in metals and ionic compounds involves intermolecular bonding.
- Ionic bonding occurs by sharing of electrons.
- Metallic lattices contain neutral atoms.

They concluded that even postgraduate students with good academic records had such misconceptions. They claimed that the origin of these conceptions might be due to abstract concepts, careless use of terminology or overloading students whose majors are not chemistry with unnecessary materials. As a further study, Coll and Treagust (2003) examined secondary school students' mental models for chemical bonding. The results of this study showed that students saw ionic bonding as a transfer of electrons simply, they do not consider partial ionic character due to the electronegativity difference. Also, they were not sure about the shape of Na and Cl ions when constructing diagram of sodium chloride. They fail to relate the theory of the model to practical use. In addition, although students' models might be correct and helpful in some contexts, there are limitations of their model that prevent application and students saw their models as correct. Therefore, the researchers recommended that teachers should inform students about the limitations of their model and emphasize the link between macroscopic and microscopic level since the students couldn't easily shift between them. The teachers should be careful when using visual representations such as dotted lines or spheres that cause confusion among students.

Another source of misconceptions might be textbooks (de Posada, 1999). De Posada (1999) analyzed Spanish textbooks for grades 9-12 in terms of metallic bonding, how metallic bond is taught and whether textbooks are enough to cause meaningful learning. The textbooks were analyzed by using a questionnaire developed by the researcher to find out logical psychological structure of textbooks and whether they give opportunity for meaningful learning. The questionnaire consisted of 12 questions. The questions were related to the depth of topics, patterns used by authors for presenting information, the relationship between text and illustrations, usage of illustrations and role of activities in teaching-learning process. The chemistry teachers who have experience in the analysis of textbooks and the researcher examined 29 high school textbooks and completed the questionnaire independently. They had consensus in 89% of the cases. Results showed that students can not understand the relationship between the theoretical model and experimental facts. The analogies used could cause misconceptions in students who can not think in abstract terms. There was no integrative reconciliation among topics which provides meaningful learning. Only a few textbooks' approach is constructivist.

2.4 Constructivism

Learning science is a complex and slow process. Students have difficulty in understanding of the most of the concepts in chemistry, biology and physics and hold misconceptions. Often, they have misconceptions about the natural phenomena before coming to the classroom and these misconceptions prevent meaningful learning. Therefore, instruction should focus on students' ideas. Students should be encouraged to think, ask questions, test ideas and explain phenomena. These can be achieved by constructivist approach. Constructivism combines different perspectives such as Piaget's cognitive and developmental perspectives and Vygotsky's interactional and cultural emphasis. From constructivist point of view, knowledge cannot be transferred into the student, instead students construct their own meanings from the words or visual images they hear or see.

Knowledge is not passively received from the teacher or through the senses. It is actively built up by the learner. Constructivism focuses on the way in which learners construct useful knowledge. It may be through personally constructed or socially mediated. Learners form, elaborate and test new knowledge until they become satisfied. Knowledge develops and continues to change with the activity of the learner. Then, learning occurs by changing and organizing cognitive structure. Students create new meaning for scientific concepts by reflecting their mental activity. Cognitive reorganization takes place as learners try to overcome obstacles or contradictions during the activity they involved (Driscoll, 1994). Based on this perspective, teaching is not providing information and checking whether students have acquired it or not. Teaching is creating situations in which students are actively involved in scientific activities and they make their own construction. Teachers see students' constructions through students' sensorimotor and mental activities and communication. Teaching from constructivist theory aims at applicability of knowledge in situations. Students should build connections between daily life and their scientific conceptions. They should realize that science knowledge is a tentative human construction and not an eternal truth (Niedderer, 1987).

Problem solving, reasoning, critical thinking and active use of knowledge are goals of constructivism. Constructivist approach gives priority not to teach the same concepts to all students but to carefully analyze students' understanding to increase learning. Constructivist teachers consider what students think about concepts and formulate lessons and plan instruction on the basis of students' needs and interests. They structure lessons to develop students' higher order abilities such as critical thinking, mindful consideration and reflection, problem solving and active use of knowledge and skills (Brooks and Brooks, 1999). Constructivist teachers focus on the following strategies:

1. They encourage and accept student autonomy.
2. They use primary sources along with manipulative, interactive and physical materials.
3. They encourage students in experiences where they could use their previous knowledge.
4. They allow students' responses to drive lessons and change instructional strategies.
5. They use cognitive terminology such as "classify", "analyze", "predict" and "create".
6. They inquire about students' conceptions at the beginning.
7. They encourage students' inquiry by asking open-ended questions.
8. They encourage students to engage in dialogue both with the teacher and with the other students.
9. They allow wait-time after posing questions.
10. They provide time for students to construct relationships.
11. They frequently use learning cycle model in order to develop students' curiosity (Brooks and Brooks, 1993).

Constructivist approaches are student centered in that they use subject matter for interactive engagement with students. Classroom climate encourages discussions and negotiation of ideas. This give opportunity to students revise their structure and see other students' ideas.

Constructivist teaching strategies take students' existing ideas as a starting point in instruction. To investigate students' preinstructional conceptions many methods can be used such as observations, interviews, conceptual relationships such as concept mapping, diagnostic test items and computerized diagnosis.

2.4.1 Studies Related to Constructivist Teaching Strategies

Researchers developed a lot of teaching strategies based on constructivist approach such as Driver's constructivist teaching sequence (Driver and Oldham, 1986), learning cycle approach (Stepans, Dyvhe and Beiswenger, 1988), conceptual change model (Posner et al., 1982) and bridging analogies approach (Brown and Clement, 1989). Yager (1991) proposed a constructivist teaching strategies as:

1. **Invitation:** Asking questions, considering responding to questions, noting unexpected phenomena, identifying situations where student perceptions vary.

2. **Exploration:** Brainstorming possible alternatives, looking for information, experimenting with material, discussing solutions with others, engaging in debate, analyzing data.
3. **Proposing explanations and solutions:** Constructing and explaining a model, reviewing and critiquing solutions, integrating a solution with existing knowledge and experiences.
4. **Taking action:** Making decisions, applying knowledge and skills, sharing information, and asking new questions.

According to the model for constructivist teaching sequence developed by Driver and Oldham (1986), there are five phases: Orientation, elicitation, restructuring, application and review. Orientation phase introduces students the subject they will learn. Elicitation phase helps students make their ideas explicit and thus they become aware of their thinking. Group discussions, designing posters or writings are useful activities for this purpose. In restructuring phase, students' ideas are clarified and exchanged through discussion and students can develop scientific knowledge. Students are given opportunity to test their ideas and are experienced with cognitive conflict. They engage in problem solving. In application phase, students use their ideas developed in the previous phase in new situations. In the final phase, review phase, students view how their thinking has changed from the beginning of the study to the end. This phase help students construct metacognitive strategies.

In studies where constructivist approach was used, it has been showed that constructivist teaching strategies were effective in enhancing students understanding and achievement. For example, Niaz (1995) studied on dialectic constructivist framework based on cognitive conflict for freshman chemistry students. He reported that students exposed to cognitive conflict method were more successful than students studied traditionally. Also, Caprio (1994) examined the effectiveness of the constructivist approach compared with the traditional lecture-lab method. It was concluded that students taught by constructivist methodology had significantly better exam grades. Moreover, these students seemed more confident of their learning. Akkuş et al. (2003) investigated the effectiveness of the instruction based on the constructivist approach by focusing on the in-class teacher-student and student-student interaction within small groups over traditional method. The results indicated that the students who were instructed by constructivist approach acquired chemical equilibrium concepts better than the students taught by traditional method. This study also concluded that students' previous knowledge and science process skills had an influence on their understanding of the concepts related to chemical equilibrium.

Research studies revealed that constructivist teaching strategies are useful not only improving achievement but also they help students construct their views about science and develop thinking ability. Carey et al. (1989) concluded that prior to the constructivist methodology that included scientific inquiry, most students viewed science as a way of understanding facts about the world. After the constructivist methodology, most of the students saw scientific inquiry as a process guided by questions and ideas.

Tynjala (1998) found similar results, too. She compared learning outcomes of educational psychology students studied traditionally with examinations and studied constructivist learning tasks without examination. Constructivist group students were given assignments that require transforming knowledge, activating previous knowledge, comparing and criticizing different theories. Students discussed their assignments in groups and wrote an essay. To provide research material they were administered a control group's exam but they were not graded. Traditional group students were instructed by traditional methods. They attended classes, studied the textbook on their own and had an examination. Results showed that students in the constructivist group acquired an ability to apply knowledge and developed their thinking and communication skills.

As well as better students' understanding and improvement in thinking skills, students' perception of these types of strategies is an important factor for their achievement. Hand et al. (1997) examined junior secondary school students perceptions of implementation of constructivist approach to the teaching of science. An open-ended questionnaire followed by semistructured interviews was used. It was concluded that most students liked the constructivist teaching learning approaches because of being more actively involved, having more discussion, practical work, less note-taking, having more fun and greater understanding of concepts. By examining interviews, it was seen that students were more active in the learning process. They could state their ideas whether they are wrong or right. They had opportunity to see and control their thinking. They constructed correct knowledge more confidently and became more confident in their understanding of science.

Teichert and Stacy (2002) investigated the effect of students' prior knowledge, integration of ideas with their existing structure and their explanations affected their conceptual understanding of the principles of thermodynamics and chemical bonding. Experimental group students participated in the intervention discussion sections whereas students in the control group were instructed traditionally. Using a curriculum that encouraged students' explanations of their conceptions made students gain a better understanding of bond energy and spontaneity.

2.4.2 Small Group Discussion

Small group discussion is one of the strategies used in constructivist approach. Group study enables the teacher to identify and understand students' thinking processes while they work together in order to develop understanding of scientific phenomena. Student-student interaction involves sharing ideas and motivation through working together on common learning tasks. According to

Piaget, other individuals play an important role in one's cognitive development. By means of group work, an individual can encounter with a cognitive conflict and through negotiations, he develops more complex cognitive structures. Similarly, Vygotsky claimed that higher mental thinking skills develop as a result of social interactions. He proposed that construction of knowledge occurs by working with other students. Vygotsky described two sources of knowledge: One comes from interaction with environment (everyday knowledge) and the other source is formal instruction that occurs in classrooms. Everyday knowledge is affected by peer interactions, language and experience. Learners use both everyday knowledge and school knowledge to construct meaning. Peers can assist each other to learn new concepts more effectively than adults because they have similar developmental levels.

Hudgins and Edelman (1988) investigated the effect of instruction including small group discussions on 4th and 5th grade students' critical thinking ability. Students were grouped as experimental and control. Experimental group students involved small groups consisted of four children. Students had 8 discussion sessions. The teacher behaved as a group mediator. The teacher gave roles to each student in the groups as task definer, strategist, monitor and challenger. There was rotation in the roles in each discussion session. Students read the roles that they play at that session and explained it so that the researchers had idea about students' understanding of their roles. Before and after the discussions, each student was interviewed individually. At this interviews, students were asked a similar question related to content and the researchers had the students read the problem aloud. And then, the students were asked to explain what they understood from the question without looking at it. After that, some time was given to the students to think about. Students were wanted to think aloud. The researcher tried to find the reasoning of students' responses. The results of the study showed that when students encountered with a similar problem, experimental group students could easily apply thinking skills to it, use information and give higher quality answer. So participation in group discussion enhanced students' critical thinking ability.

Meyer and Woodruff (1997) investigated the process of consensus and the learning when seventh grade students work in groups each of which consisted of three or four students. At the beginning, students' existing knowledge was determined by pre-test and concept mapping puzzles. Then, demonstration was conducted and students discussed in groups and write their ideas. After students in groups established consensus, class discussions were conducted. Finally an expert participated in the study for question/answer discussion. Then students were administered the same test concept map puzzle as at the beginning. As a conclusion, they found that students use mutual knowledge, convergence and coherency in the consensus building process. They use analogies to clarify their ideas (mutual knowledge). In case it didn't work, they use what if questions (convergence). Finally, they focus on knowledge building (coherency). During this process, it was observed that students progressed from a simple concept to a higher concept. In addition, collaborative study helped students acquire scientific knowledge.

2.5 Conceptual Change Model

Constructivist approach stresses on students' prior knowledge. It emphasizes giving students opportunities in which they can reflect their knowledge and construct meaning by interacting with objects, events and people. In this way, the teacher may realize students' misconceptions and focus on activities to change them with the scientifically correct explanations. Changing one's conceptions by capturing new conceptions, restructuring or exchanging existing conceptions for new conceptions is referred as "conceptual change". Learning can be seen as a conceptual change. Different researchers use different terms for conceptual change but there is common ground between the various perspectives of conceptual change: Creating links is an important feature of conceptual change theory, otherwise, there is no difference between conceptual change and simple rote learning.

Posner et al. (1982) define conceptual change in terms of assimilation and accommodation. If a student use existing concepts to deal with new phenomena, this is called assimilation. When the students' current concepts are inadequate to allow him to grasp new phenomenon, then he replaces or reorganizes his central concepts. This is called accommodation. There are four conditions of accommodation:

1. There must be *dissatisfaction* with existing conceptions. The individual must first encounter difficulties with an existing conception to consider a new one seriously. The major source of dissatisfaction is the anomaly. An anomaly exist when one is unable to assimilate something. Anomalies provide cognitive conflict that prepares the student's conceptual ecology for an accommodation. The more students consider the anomaly to be serious, the more dissatisfied they will be with current concepts and the more likely they may be ready to accommodate new ones

2. A new conception must be *intelligible*. Finding a theory intelligible requires more than just knowing what the words and symbols mean. Intelligibility also requires constructing or identifying a coherent representation of a passage or theory. This representation may function passively; in paragraph comprehension tasks, anomalous sentences are confusing because they cannot be fit into the reader's memory. Representation may also function actively as a plan for directing ones attention and conducting purposeful searching. When the student can psychologically construct a meaningful representation of a theory it become a tool of thought. Only an intelligible theory can be a candidate for a new conception in a conceptual change.

3. A new conception must be *plausible*. A new conception must have capacity to solve the problems generated by its predecessors. Otherwise it will not appear a plausible choice. In addition, the new conception must be consistent with other theories or knowledge with one's current metaphysical beliefs and epistemological commitments. Therefore it is important to find out students' epistemological commitments in order to understand what students find plausible or more generally, their processes of conceptual change.

4. A new concept must be *fruitful*. It must have potential to open up new areas of inquiry. It leads to new insights and discoveries. Students map their new conceptions onto the world, i.e. they attempt to interpret experience with it.

Teaching science involves providing a rational basis for a conceptual change. Conceptual change involves changes in one's assumptions about the world, about knowledge and about knowing. For these changes, these four conditions are necessary. So teachers should develop strategies to create cognitive conflict in students, organize instruction to diagnose errors in students' thinking, help students translate from one mode of representation to another. Dykstra et al. (1992) also claim that conceptual change depends on disequilibration. The fact that certain conceptions are not changed in the traditional instruction may be due to the failure of that instruction to disequilibrate students with respect to concepts they hold.

Hewson (1982) suggest that competing conceptions must both fulfill the conditions of intelligibility and plausibility before dissatisfaction can be established. For Hewson, dissatisfaction is the key to the change in status of a conception.

Although Posner et al. (1982) implies that nonscientific conceptions would be replaced if four conditions of the conceptual change model were met, many researchers (Bliss and Ogborn, 1994, Garnett, Garnett and Hackling, 1995) say that conceptual change may occur without replacing or extinguishing prior knowledge. Many students hold multiple explanations; they explain concepts by using both scientific and everyday explanation. It is difficult to remove misconceptions; they are highly resistant to change (Tyson et al., 1997).

Chi, Slotta and de Leeuw (1994) developed a theory related to conceptual change. This theory explains why some misconceptions cannot be replaced with scientific conceptions easily. According to this theory, scientific concepts belong to three different ontological categories as matter, processes and mental states. Concepts in the matter are more concrete than those in the processes or mental states. The ontological category of a concept determines the difficulty of learning. If ontological category of a student's concept and scientific concept are the same, then conceptual change occurs easily. However, if two conceptions are ontologically different, learning is difficult. When students are in cognitive conflict, they are confused in terms of assigning attributes to ontological categories. Misconceptions occur when there is a mismatch between students' categorical representation and true ontological category of a concept. Conceptual change occurs when a concept changes its category.

Conceptual change is metacognitive. Metacognition means knowledge of one's own cognitive processes and products (Flavell, 1976). It refers to the knowledge and control of factors affecting learning activity such as knowledge of oneself as a learner and the strategies used in teaching process (Palincsar and Ransom, 1988).

For conceptual change different views of students should be considered and teaching should be metacognitive. Teachers should behave as a manager in order to facilitate students learning by appropriate classroom activities and problems that have relevance and meaning to the students. Moreover, teachers should explore the underlying factors of different ideas without any threat to students who hold them, help students become dissatisfied with their own conceptions and introduce task in which students apply newly learned ideas. Also, teachers should enhance classroom interaction. Beeth (1998) claims that in order to engage students in conceptual change learning, teacher should lead to group discussions where students learn to discuss ideas in a variety of ways. In the classroom, students should express ideas and the reasons for them and discuss about consistency of ideas. In this way, they control their learning. In short, the teachers who teach for conceptual change should have the following characteristics:

1. a respect for and knowledge of learners and their ideas
2. a deep knowledge about appropriate teaching strategies and supporting materials.

Furthermore, students should be aware of their learning process and the goal of learning. They should accept responsibility for their own thinking and learning. They should realize different views of other students and respect them. Students should interact with each other, see different ideas and negotiate common meanings. In this way, students become ready to change their views by comparing their views with another that seems fruitful and plausible.

Driver (1985) described a teaching sequence for promoting conceptual change from a constructivist point of view as:

1. to give students opportunity to make their own conceptions about a particular topic
2. to present empirical counter examples
3. to introduce alternative conceptions
4. to give opportunities to use scientific conceptions

Sungur, Tekkaya and Geban (2001) investigated the contribution of conceptual change oriented instruction to students' understanding of the human circulatory system. They used conceptual change texts accompanying by concept mapping in order to teach the concepts. The results of this study revealed that conceptual change texts accompanied by concept mapping instruction produced a positive effect on students' understanding of the concepts. In addition, students' previous knowledge in biology and their science process skills had a significant contribution to the variation in understanding of the human circulatory system .

In the light of related literature, it can be said that students' misconceptions influence their understanding. Although different teaching strategies have been used, students continue to hold their wrong conceptions. Especially, chemical bonding is one of the most difficult concepts for students. Therefore, further research is needed for improving learning activities in science education and removing students' misconceptions. Conceptual change should be favored in order to obtain greater student understanding in chemistry. For this reason, in the present study, we aimed to determine the effect of constructivist approach on students' understanding of chemical bonding concepts and their attitudes toward chemistry as a school subject when their science process skill was taken as a covariate.

CHAPTER III

PROBLEMS AND HYPOTHESES

3.1 The Main Problem and Subproblems

3.1.1 The Main Problem

The purpose of this study is to compare the effectiveness of instruction based on constructivist approach over traditionally designed chemistry instruction on 9th grade students' understanding of chemical bonding concepts and attitudes toward chemistry as a school subject.

3.1.2 The Subproblems

1. Is there a significant mean difference between the effects of instruction based on constructivist approach and traditionally designed chemistry instruction on students' understanding of chemical bonding concepts when science process skill is controlled as a covariate?

2. Is there a significant difference between males and females in their understanding of chemical bonding concepts?

3. Is there a significant effect of interaction between gender difference and treatment with respect to students' understanding of chemical bonding concepts?

4. What is the contribution of students' science process skills to their understanding of chemical bonding concepts?

5. Is there a significant mean difference between students taught through instruction based on constructivist approach and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject?

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

3.2 Hypotheses

$H_0 1$: There is no significant difference between post-test mean scores of the students taught with instruction based on constructivist approach and students taught with traditionally designed chemistry instruction in terms of chemical bonding concepts when science process skill is controlled as a covariate.

$H_0 2$: There is no significant difference between the posttest mean scores of males and females on their understanding of chemical bonding concepts.

$H_0 3$: There is no significant effect of interaction between gender difference and treatment on students' understanding of chemical bonding concepts.

$H_0$4: There is no significant contribution of students' science process skills to understanding of chemical bonding concepts.

$H_0$5: There is no significant mean difference between students taught with instruction based on constructivist approach and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject.

$H_0$6: There is no significant difference between post-attitude mean scores of males and females.

CHAPTER IV

DESIGN OF THE STUDY

4.1 The Experimental Design

In this study, the quasi experimental design was used (Gay,1987).

Table 4.1 Research design of the study

Groups	Pre-test	Treatment	Post-test
Experimental Group	CBCT ASTC SPST	ICA	CBCT ASTC
Control Group	CBCT ASTC SPST	TDCI	CBCT ASTC

Here, CBCT represents Chemical Bonding Concept Test. ICA is Instruction based on Constructivist Approach and TDCI is Traditionally

Designed Chemistry Instruction. SPST refers to Science Process Skill Test. ASTC represents Attitude Scale Toward Chemistry.

4.2 Subjects of the Study

This study consisted of 42 9^{th} grade students (18 male and 24 female) from two classes of a Chemistry Course from METU Development Foundation Private School taught by the same teacher in the 2000-2001 spring semester. Two instruction methods used in the study were randomly assigned to groups. The data analyzed for this research were taken from 22 students participating instruction based on constructivist approach and 20 students participating in the traditionally designed chemistry instruction.

4.3 Variables

4.3.1 Independent Variables:

The independent variables were two different types of treatment; instruction based on constructivist approach and traditionally designed chemistry instruction, gender and science process skill.

4.3.2 Dependent Variables:

The dependent variables were students' understanding of chemical bonding concepts and their attitudes toward chemistry as a school subject.

4.4 Instruments

4.4.1 Chemical Bonding Concept Test (CBCT):

This test developed by the researcher. The content was determined by examining textbooks, instructional objectives for the chemical bonding unit and related literature. During the developmental stage of the test, the instructional objectives of chemical bonding unit were determined (see Appendix A) to find out whether the students achieved the behavioral objectives of the course and present study. The questions in the test were developed from the literature related to students' alternative conceptions or misconceptions with respect to chemical bonding (Butts and Smith, 1987; Tan and Tragust, 1999; Birk and Kurtz, 1999; Coll and Taylor, 2001; Nicoll, 2001) and the set of pilot interviews with some classroom teachers. Students' misconceptions were summarized in Table 4.2.

Table 4.2 Students' Misconceptions in Chemical Bonding

Bond Formation:
1. Bonds are material connections rather than forces.
2. The atomic electronic configuration determines the number of ionic bonds formed.
3. Bonds are only formed between atoms that donate \ accept electrons.
4. Metals and nonmetals form molecules.
5. Atoms of a metal and a nonmetal share electrons to form molecules.
6. A metal is covalently bonded to a nonmetal to form a molecule.
7. Metals and nonmetals form strong covalent bonds.
8. Ions interact with the counter-ions around them but for those not ionically bonded these interactions are just forces.
9. Ionic compounds exist as molecules formed by covalent bonding.
10. Number of covalent bonds formed by a nonmetal equals the number of electrons in the valance shell.
11. Bonding must be either ionic or covalent.

Table 4.2 Continued

Polarity:
12. Equal sharing of the electron pair occurs in all covalent bonds.
13. The polarity of a bond is dependent on the number of valance electrons in each atom involved in the bond.
14. Ionic charge determines the polarity of the bond.
15. Presence of nonbonding electrons determines the resultant polarity of a molecule.
16. Nonpolar molecules form when the atoms in the molecule have similar electronegativities.
Intermolecular Forces:
17. Intermolecular forces are covalent bonds.
18. The strength of intermolecular forces is determined by the strength of the covalent bonds present in the molecule.
19. Covalent bonds are broken when a substance changes state.
20. Intermolecular forces are forces within a molecule.
Structure of NaCl:
21. NaCl exists as molecules and these molecules are held together by covalent bonds.
22. Na and Cl atoms are bonded covalently but the ionic bonds between these molecules produced the crystal lattice.
23. Students cannot understand the three dimensional structure of ionic bonding in solid NaCl.
24. Solid NaCl does not conduct electricity because it is in separate molecules.

Based upon these misconceptions, a taxonomy was constructed (see Table 4.3).

Table 4.3 Taxonomy of Students' Misconceptions in Chemical Bonding

MISCONCEPTION	**ITEM**
Bond formation	1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 14,15,16
Polarity	3, 6, 8
Intermolecular forces	10, 17,18
Structure of NaCl	1, 7

The test included two parts. First part consisted of two-tier questions and examine students' knowledge of chemical bonding. Each question had two parts: *a response section* in which students were asked to mark only one of two possible answers and *a reason section* in which students were asked to select the reason which explains the answer in the previous part of the question. Second part consisted of multiple choice questions. Each question in this part had one correct answer and four distracters. The distracters of an item reflected students' alternative conceptions or misconceptions found from related literature and pilot interviews with chemistry teachers. The items were related to chemical bonding concepts. There were 18 items totally in the test. The English version was prepared because the language of instruction in Chemistry Course which include chemical bonding subject was in English at METU Development foundation Private School. The conceptual questions required students to think a qualitative conceptual prediction about a situation in which there is a possibility to be directed towards a wrong answer caused by the misconceptions of students. For content validity, the test was examined by a group of experts in science education, chemistry and by the course teacher for the appropriateness of the items as the extent to which the test measures a representative sample of the domain of tasks with respect to the chemical bonding unit of chemistry course.

The reliability of the test was found to be 0.72. This test was given to students in both groups as a pre-test to control students' understanding of chemical bonding concepts at the beginning of the instruction. It was also given to both groups as a post-test to compare the effects of two instructions

(ICA & TDCI) on understanding of chemical bonding concepts. (see Appendix B)

4.4.2 Attitude Scale Toward Chemistry (ASTC)

The previously developed scale (Geban et al., 1994) was used to measure students attitudes toward chemistry as a school subject. This scale consisted of 15 items in 5 point likert type scale (fully agree, agree, undecided, partially agree, fully disagree). The reliability was found to be 0.83. This test was given to students in both groups before and after the treatment (see Appendix C).

4.4.3 Science Process Skill Test (SPST)

The test was originally developed by Okey, Wise and Burns (1982). It was translated and adapted into Turkish by Geban, Aşkar and Özkan (1992). This test contained 36 four-alternative multiple-choice questions. It was given to all students in the study. The reliability of the test was found to be 0.85. This test measured intellectual abilities of students related to identifying variables, identifying and stating the hypotheses, operationally defining, designing investigations and graphing and interpreting data (see Appendix D).

4.5 Treatment

This study was conducted over a four-week period. One of the classes was assigned as the experimental group instructed through the constructivist approach, and the other group was assigned as the control group instructed through traditional instruction. Both groups were instructed by the same teacher on the same content of the chemistry course. The teacher was trained about the implementation of the constructivist strategy before the treatment. The researcher observed classes in the control and experimental groups randomly. During the treatment, the chemical bonding topics were covered as part of the regular classroom curriculum on the chemistry course. The classroom instruction of the groups was three 40-minute sessions per week. The topics covered were the definition of a bond, formation of bonds, types of bonds (intramolecular and intermolecular), polarity and properties of bonds.

At the beginning, both groups were administered CBCT to determine whether there was any difference between the two groups with respect to understanding of chemical bonding prior to instruction. Also, ASTC was distributed to measure students' attitudes toward chemistry as a school subject. SPST was given to all students in the study to assess their science process skills.

In the control group, the teacher directed strategy represented the traditional approach used on the course. The students were instructed with traditionally designed chemistry texts. During the classroom instruction, the teacher used lecture and discussion methods to teach concepts. Also, the students in the control group were provided with worksheets. Each worksheet consisted of one or two pages that included questions to be answered, tables to be completed or space for students to make sketches. The teacher roamed the room, acted as facilitator and answered some questions and made suggestions when needed. Worksheets were corrected and scored and the students investigated their sheets after correction.

The experimental group was instructed by using the constructivist approach. The strategy used was based on Yager's (1991) constructivist teaching strategy. According to this strategy, as a first step (invitation), the teacher asked students some questions at the beginning of the instruction in order to activate prior knowledge of students and promote student-student interaction and agreement before presenting the concept. For example, the teacher began the instruction with a question asking what is meant by a chemical bond. As a second step (step 2: exploration), students were allowed to discuss the question in groups by using their previous knowledge related to atoms. The teacher created groups based on the students' grades in the last semester. Each group contained four or five students. During discussions in groups, they realized both their own and other's thoughts, shared their ideas, defended their answers and reached a consensus about the question. Meanwhile, the teacher didn't interfere with the students. They constructed their tentative answers freely. Each group gave a common answer to the teacher after discussion. In this way, the teacher had an opportunity to view the students' previous ideas. Also, the students had cognitive conflict when their ideas were not adequate to answer the question the teacher asked. This situation supported the first condition of Posner et al.'s (1982) conceptual change model. Dissatisfaction was also promoted by the teacher in the next step. Based on their answers, he explained the concept (step 3: proposing explanations and solutions). While explaining the concept, he emphasized on students' misconceptions and why they were wrong. He presented scientifically correct explanation by using analogies and examples. Since chemical bonding is an abstract topic, he tried to give examples from daily life as much as possible. He used analogies to enhance understanding. For example, while explaining what a chemical bond was, he constructed similarities between magnets and bonds; the fact that that like poles repel each other and unlike poles attract each other is similar to the attraction and repulsion between electric charges. Borrowing books from the library was given as an example for covalent bonding; although the books are given to a person, at the same time they belong to the library. In this step, the teacher tried to accomplish Posner et al.'s (1982) conditions of intelligibility and plausibility by stressing on the students' preconceptions, making relationship between their conceptions and scientific knowledge and giving examples. Moreover, students saw usage of information they obtained in explaining other situations. Therefore, Posner et al.'s (1982) last condition (fruitfulness) was also achieved. Before presenting each new concept, the teacher asked questions which students could answer by using their previous knowledge (step 4: taking action). Some questions were: What is the reason that atoms bond? Why do metals and nonmetals/nonmetals and nonmetals form bond? Why is table salt hard? Why does table salt conduct electricity when dissolved in water? Why is wax low melting substance? Why are metals shiny? All of the questions reflected students' misconceptions found from literature. Yager's (1991) constructivist teaching strategy was used for each question as a circle. Appendix E summarizes two sample lessons based on this strategy.

At the end of the treatment, all students were given CBCT as a post-test. They were also administered ASTC.

4.6 Analysis of Data

ANCOVA was used to determine effectiveness of two different instructional methods related to chemical bonding concepts by controlling the effect of students' science process skills as a covariant. Also this statistical technique revealed the contribution of science process skills to the variation in understanding. To test the effect of treatment on students' attitudes toward chemistry as a school subject and the gender effect on students' understanding, two-way ANOVA was used.

4.7 Assumptions and Limitations

4.7.1 Assumptions:

1. There was no interaction between groups.
2. The teacher was not biased during the treatment.

3. The tests were administered under standard conditions.
4. The subjects answered the questions in the instruments sincerely.

4.7.2 Limitations:

1. This study was limited to the unit of chemical bonding.
2. This study was limited to 9^{th} grade students of a private high school.

CHAPTER V

RESULTS AND CONCLUSIONS

5.1 Results

This chapter presents the results of analyses of hypotheses stated earlier. The hypotheses were tested at a significance level of 0.05. Analysis of covariance (ANCOVA) and analysis of variance (ANOVA) were used to test the hypotheses. In this study, statistical analyses were carried out by using the SPSS/PC (Statistical Package for Social Sciences for Personal Computers) (Noruis, 1991).

The results showed that there was no significant difference at the beginning of the treatment between the ICA group and the TDCI group in terms of students' understanding of chemical bonding concepts ($t = 0.111$, $p>0.05$). With respect to students' attitudes toward chemistry, no significant difference was found between the two groups, either ($t = 0.67$, $p >0.05$).

Hypothesis 1:

To answer the question posed by hypothesis 1 stating that there is no significant difference between the post-test mean scores of the students taught by ICA and those taught by TDCI with respect to understanding chemical bonding concepts when science process skill is controlled as a covariate, analysis of covariance (ANCOVA) was used. The measures obtained are presented in Table 5.1.

Table 5.1 ANCOVA Summary (Understanding)

Source	df	SS	MS	F	P
Covariate (Science Process Skill)	1	245.857	245.857	134.850	0.000
Treatment	1	129.793	129.793	71.190	0.000
Gender	1	3.903	3.903	2.141	0.152
Treatment*Gender	1	1.305	1.305	0.716	0.403
Error	39	72.702	1.864		

The result showed that there was a significant difference between the post-test mean scores of the students taught by ICA and those taught by TDCI with respect to the understanding of chemical bonding concepts. The ICA group scored significantly higher than TDCI group ($\overline{X}$ (ICA) = 12.078, $\overline{X}$ (TDCI) = 8.614).

Figure 5.1 shows the proportions of correct responses to the questions in the post-test for two groups.

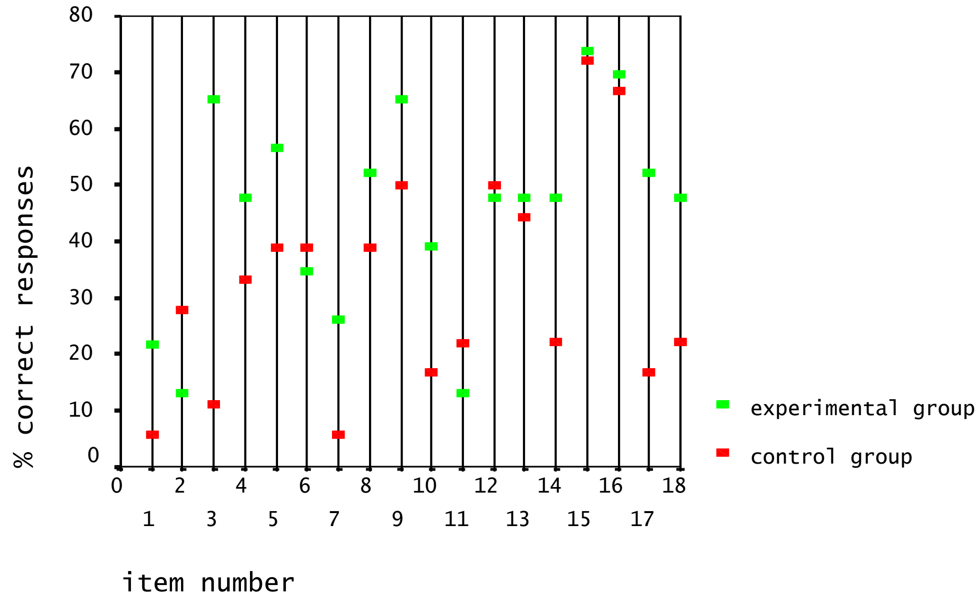

Figure 5.1 Comparison between post-test scores of ICA group and that of TDCI group.

As seen in the figure there was a difference in responses between the two groups to the items in CBCT. Poorer student results were obtained for questions 3, 5, 7, 10, 14 and 17 in the TDCI group. In question 3, students were asked first to select the correct showing representing the electron cloud distribution in the HF molecule and then give the reason. After treatment, in the experimental group, 95.7% of the students answered the first part of the question correctly as closer electron distribution to the fluorine atom. Before treatment, half of the experimental students (50%) responded this part correctly. For the second part of the same question, majority of the experimental group students (65.2%) group answered this question correctly whereas only 16.7% of the students in the control group answered it correctly after treatment. In the experimental group, 65% of the students gave correct answer for the two parts of the question whereas only 11% of the students in the control group responded to the two parts correctly. The alternative conceptions held by the students were that equal sharing of the electron pair occurs in all covalent bonds, and the polarity of a bond is dependent on the number of valance electrons in each atom involved in the bond. It seems that students could not grasp stronger attraction of fluorine for shared electron pair. The misconceptions that this item measured and the percentages of experimental and control group students' selection of alternatives in the posttest are given below:

Table 5.2 Percentages of students' selection of alternatives for item 3

Item 3: The electron cloud distribution in the HF molecule can be best represented by  **because**	**Percentage of students' responses (%)**	
	Experimental Group	**Control Group**
Alternative A Nonbonding electrons influence the positions of the bonding or shared electron pair. (this alternative corresponds to the misconception that presence of nonbonding electrons determines the resultant polarity of a bond)	4.3	11.1
Alternative B As hydrogen and fluorine form a covalent bond the electron pair must be centrally located. (this alternative reflects the misconception that equal sharing of electron occurs in all covalent bonds)	13	38.9
***Alternative C** Fluorine has a stronger attraction for the shared electron pair.	65.2	16.7

Table 5.2 Continued

Alternative D Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair. (this alternative reflects that students relate atomic size and polarity)	14.7	33.3

* Correct alternative

A similar difference between ICA group and TDCI group was also obtained for item 5. Before treatment, 23.5% of the experimental group students and 35% of the control group students responded correctly to this question. After treatment, 58% of the students taught by the ICA, seemed to be comfortable with the right idea that $CaCl_2$ is an ionic compound because there is an electron transfer. On the other hand, 37% of the students taught by TDCI were able to identify whether $CaCl_2$ is an ionic after treatment. The common misconception was that electrons are shared between atoms (28%) and that ability of calcium atom to attract electrons is similar to that of chlorine atom (11%). Based on this item, it can be inferred that students confused the formation of ionic and covalent bonding.

Question 7 was related to the dissolving of NaCl in water. Although both groups showed low achievement for this question, the majority of the TDCI group students thought that NaCl is still molecular in water, which was wrong. Only 5% of the students in the TDCI group gave correct answer to the two parts of this question whereas 28% of the students in the ICA group answered it correctly stating that NaCl existed as a discrete pair of Na^+ and Cl^- after instruction. Among control group students, the common misconceptions were that NaCl exists as molecules (55.6%), and positive charge on sodium ions are neutralized by gaining electrons from chloride ions (22.2%). The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

Table 5.3 Percentages of students' selection of alternatives for item 7

When NaCl dissolves in water, there is still ionic bonds between sodium and chlorine atoms in solution **(1) True** ***(2) False** **because**	**Percentage of students' responses (%)** **Experimental Group**	**Control Group**
***Alternative A** NaCl exists as discrete pairs of Na^+ and Cl^-.	52.2	11.1
Alternative B Ionic bond is broken during the dissolving process.	17.4	11.1
Alternative C Positive charge on sodium ions must be neutralized by gaining of electrons from chloride ions in the solution.	13.0	22.2
Alternative D NaCl is still molecular in water.	17.4	55.6

* Correct alternative

In question 10, students were asked to give a reason to the following question: "Why does not N_2 decompose at high temperatures although its boiling point is very low (-147 ^{0}C)?" Students were supposed to state that the boiling point of N_2 is very low (-147 ^{0}C), on the other hand, at high temperatures, it does not decompose due to intramolecular forces because triple bond is very strong compared to intermolecular (Van der Waals) forces. Before instruction, 31.3% of the experimental groups students gave correct response to the first part of the question and 6.7% responded correctly to the second part of the same question. After instruction 56.5% of the students in this group answered correctly in the first part, and 52.2% of the students gave right answer in the second part. Generally, 40% of the students answered correctly both parts of this question. However, after instruction, only 18% of the students in the TDCI group answered the two parts of this question correctly. Most of the students confused intermolecular and intramolecular forces, they thought that N_2 had strong intermolecular forces, thus it did not decompose at high temperatures (28%). Table 5.4 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

Table 5.4 Percentages of students' selection of alternatives for item 10

The boiling point of N_2 is very low (-147 ^{0}C), on the other hand, at high temperatures, it does not decompose due to **(1)** intermolecular bonds *__(2)__ intramolecular bonds **because**	**Percentage of students' responses (%)** **Experimental Group**	 **Control Group**
Alternative A Intermolecular forces between N_2 molecules are very strong.	8.7	27.8
Alternative B Nitrogen atoms cannot achieve stable octet.	8.7	16.7
Alternative C Intramolecular forces are weaker than intermolecular forces.	30.4	27.8
***Alternative D** Triple bond is very strong compared to intermolecular (Van der Waals) forces.	52.2	27.8

* Correct alternative

For question 17, 55% of the students in the ICA group stated correctly that the boiling point of NH_3 is higher than that of CH_4 because there are hydrogen bonds between NH_3 molecules. However, 17% of the students in the TDCI group answered the same question correctly. Again in this question, students confused intermolecular and intramolecular forces. 33% of the control group students stated that NH_3 contains covalent bonds thus it has higher boiling point. 28% of the students in this group thought that CH_4 had covalent bonds, for this reason, it had lower boiling point. 22% of the students claimed existence of Van der Waals forces in CH_4 molecules as a reason for low boiling point. In Table 5.5, the percentages of experimental and control group students' selection of alternatives in the post-test are presented:

Table 5.5 Percentages of students' selection of alternatives for item 17

What is the reason that boiling point of NH_3 is higher than that of CH_4? (N:7, C:6)	**Percentage of students' responses (%)**	
	Experimental Group	**Control Group**
Alternative A NH_3 contains covalent bonds.	17.4	33.3
Alternative B CH_4 contains covalent bonds.	4.3	27.8
***Alternative C** There are H bonds in NH_3 molecule.	55	16.7
Alternative D There are vander waals forces in CH_4 molecule.	26.1	22.2

* Correct alternative

In question 14, students were supposed to choose the alternative that states true characteristics of chemical bonds. Although 48% of the students in the ICA group gave the correct answer, which was "Bonds are electrostatic forces", 22% of the students in the TDCI group gave the right response. Common misconceptions in the control group were that bonds are either fully ionic or covalent (33.3%) and that bonds are only formed between atoms that donate/accept electrons (38.9%). It is seen that students could not understand the partial ionic character of a bond. The percentages of experimental and control group students' selection of alternatives in the post-test is presented in Table 5.6:

Table 5.6 Percentages of students' selection of alternatives for item 14

Which one of the following represents the true characteristics of chemical bonds?	**Percentage of students' responses (%)**	
	Experimental Group	**Control Group**
Alternative A They are material connections.	8.7	5.6
Alternative B They are only formed between atoms that donate/accept electrons.	17.4	38.9
Alternative C They are either fully ionic or covalent.	26.1	33.3
***Alternative D** They are electrostatic forces.	47.8	22.2

* Correct alternative

For these questions causing striking difference, the difference between the percentages of students' correct responses in the pre-test and the percentages of students' correct responses in the post-test was striking:

Table 5. 7 Percentages of students' correct responses in the pre-test and post-test for selected items

Item	**Experimental Group**		**Control Group**	
	Pre-test (%)	**Post-test (%)**	**Pre-test (%)**	**Post-test (%)**
3	0	65	4.5	11
5	23.5	58	35	37
7	5.9	28	22.7	5
10	5.9	40	13.6	18
14	17.6	48	9.1	22
17	17.6	55	13.6	17

It can be seen that there is an increase in the percentage of correct response in the experimental group. More students in the experimental group removed their misconceptions after instruction than students in the control group. The experimental and control group students' correct response percentages of each question in the CBCT is presented in Appendix F.

Hypothesis 2:

To answer the question posed by hypothesis 2 which states that there is no significant difference between the posttest mean scores of males and females in their understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was run. Table 5.1 also gives the effect of gender difference on the understanding of chemical bonding concepts. The findings revealed that there was no significant mean difference between male and female students in terms of understanding chemical bonding concepts ($F = 2.141$; $p > 0.05$). The mean post-test scores were 10.47 for females and 10.44 for males.

Hypothesis 3:

To test hypothesis 3 which states that there is no significant effect of interaction between gender difference and treatment with respect to students' understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was used. Table 5.1 also gives the interaction effect on understanding of chemical bonding concepts. The findings revealed that there was no significant interaction effect between gender difference and treatment on students' understanding of chemical bonding concepts ($F = 0.716$; $p > 0{,}05$).

Hypothesis 4:

To analyze hypothesis 4 which states that there is no significant contribution of students' science process skills to understanding of chemical bonding concepts, analysis of covariance (ANCOVA) was used. Table 5.1 also represents the contribution of science process skill to the understanding of chemical bonding concepts. F value indicated that there was a significant contribution of science process skills on students' understanding of chemical bonding concepts ($F = 134.850$; $p < 0.05$).

Hypothesis 5:

To answer the question posed by hypothesis 5 which states that there is no significant mean difference between the students taught with instruction based on constructivist approach and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject, two-way analysis of variance (ANOVA) was used. Table 5.8 summarizes the result of this analysis.

Table 5.8 ANOVA Summary (Attitude)

Source	df	SS	MS	F	P
Treatment	1	237.344	237.344	5.731	0.022
Gender	1	134.425	134.425	3.246	0.080
Treatment*Gender	1	18.389	18.389	0.444	0.509
Error	38	1573.600	41.411		

The results showed that there was a significant mean difference between students taught through instruction based on constructivist approach and traditionally designed chemistry instruction with respect to attitudes toward chemistry as a school subject. Students instructed by instruction based on constructivist approach had more positive attitudes ($\overline{X}$=58.000) than students having traditionally designed chemistry instruction ($\overline{X}$=53.150).

Hypothesis 6:

To test hypothesis 6 which claims that there is no significant difference between post-attitude mean scores of males and females, two-way analysis of variance (ANOVA) was run. Table 5.8 also shows the effect of gender difference on students' attitudes. It was found that there was no significant mean difference between male and female students with respect to attitudes toward chemistry as a school subject ($F = 3.246$; $p > 0.05$). Female students' mean score was 53.750 and male students' mean score was 57.400.

5.2 Conclusions

The following conclusions can be deducted from the results:

1. The instruction based on constructivist approach caused a significantly better acquisition of scientific conceptions related to chemical bonding and elimination of misconceptions than traditionally designed chemistry instruction.

2. The instruction based on constructivist approach produced higher positive attitudes towards chemistry as a school subject than traditionally designed chemistry instruction.
3. Science process skill had a contribution to the students' understanding of chemical bonding concepts.
4. There was no significant effect of gender difference on the students' understanding of chemical bonding concepts and their attitudes towards chemistry as a school subject.

CHAPTER VI

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

6.1 Discussion

The main purpose of this study was to compare the effectiveness of the instruction based on the constructivist approach and traditionally designed chemistry instruction on 9th grade students' understanding of chemical bonding concepts.

Based on the statistical analyses results given in Chapter V, it can be concluded that the instruction based on the constructivist approach caused a significantly better acquisition of scientific conceptions related to chemical bonding and elimination of misconceptions than traditionally designed chemistry instruction.

In this research, chemical bonding is studied, which is a very abstract topic. Also, it requires some knowledge from other areas such as forces from physics which students could not fully comprehend. Therefore, students have difficulty in understanding the concepts related to chemical bonding. For example, students couldn't comprehend the nature of bonding. Most students think that bonds are simple connections rather than forces. In addition, they hold another misconception that a bond should be either ionic or covalent. Therefore, when teaching chemical bonding concepts, the teachers should focus on these misconceptions and make the scientific concepts as concrete as possible. It is not enough for students to become aware of their existing ideas, but also they should change their incorrect views by interacting with their teachers and peers. For this purpose, the present study used Yager's (1991) constructivist teaching strategy in the experimental group. In this strategy, as a first step (invitation) the teacher asked questions to the students in order to activate their prior knowledge. As a second step (exploration), the teacher allowed students to discuss the questions in groups. The students were allowed to discuss these questions with their friends. In this way, the teacher created a learning environment where students could use their prior knowledge and become aware of their already existing conceptions. During discussion with their peers, the students tried to make a connection between their existing knowledge and the new concept. For instance, the students' knowledge about the structure of an atom helped them understand why atoms bond to each other. This usage of prior knowledge also favored conceptual change. Students realizing that their current ideas were not effective in explaining the situation took the new knowledge into account seriously. Students in this group were encouraged to apply their experience to new situations. Through discussion with other students, they analyzed and tried to find an answer to the questions. In this way, they took responsibility for their learning. Instead of accepting their teacher's explanations, they discussed the problems and developed critical thinking skills. As a third step (Proposing explanations and solutions), the teacher explained the concept based on students' answers by using some analogies. He focused on students' misconceptions and tried to remove them. As a last step (taking actions), the teacher asked a new question which involves a new concept.

On the other hand, in the control group where traditionally designed chemistry instruction was used, the teacher transmitted the facts to the students who were passive listeners. Generally, he used a lecture method in instruction. He wrote important notes to the board and distributed worksheets to the students to complete without considering students' prior knowledge. The teacher acted as an authority who transfers the facts actively to the students. He presented the "right" way to solve problems. However, students were not given opportunity to use problem-solving skills in other situations.

In the experimental group, social interaction was emphasized for learning. The teacher encouraged the students to work together, to explain what they are doing and thinking during the learning process. They used their current ideas and became ready to change them with the scientifically correct explanations. Moreover, these discussions provided the development of reflective thinking and metacognitive awareness. However, students in the control group were not able to be aware of their conceptions. In this group, there was a slight interaction between the teacher and the students. They listened to their teacher, studied their textbooks and completed the worksheets. The reason why the students in this group were not so successful as the experimental group students might be due to the fact that they were not given the opportunity to think about situations and continued to hold wrong conceptions in their cognitive framework. More meaningful learning occurs if students are asked to think about appropriate questions for a given situation and the explain relationships involved.

Traditionally designed chemistry instruction was based on declarative knowledge, which is factual knowledge. Students were supposed to recall simple facts such as the structure of atoms or a definition of a bond. However, instruction based on the constructivist approach favored procedural knowledge, which means knowledge about knowing how to do certain activities. In the experimental group, through discussions, students applied their knowledge related to atoms to chemical bonding concepts and were able to criticize their thinking. This might cause the difference in the concept tests scores of students in control and experimental groups. Although students in the control group could identify types of bonding, they couldn't explain the reason why or how bonding occurs since they relied on their declarative knowledge. On the other hand, experimental group students used their procedural knowledge by applying their knowledge on how atoms make bonds and acquired meaningful learning.

The present study has similar findings with other research studies using constructivist strategies (Tynjala, 1998; Niaz, 1995 and Carey et al., 1989). Although constructivist teaching strategies seem effective for instruction, it is difficult to implement them in the classroom. Constructivist teaching strategies are time consuming. The teachers should have a good subject-matter knowledge and be flexible in their teaching methods. Otherwise, they tend to use the traditional way of teaching (Smerdon and Burkam, 1999). Jofili and Watts (1995) concluded that primary and secondary science teachers have difficulty in adopting constructivism in the classroom because of their fear of losing control of the class and of using new methodologies. The teachers should be informed in depth about the use of constructivist strategies.

Furthermore, in this study, the science process skill test was administered to all students who participated in the study in order to determine whether there was a significant difference between the two groups in terms of students' science process skills. The results showed that science process skills differed significantly in the two groups. Therefore, this variable was controlled as a covariate. Science process skills reflect one's intellectual ability to identify variables, identify and state the hypotheses, design investigations and graph and interpret data.

Also, this study investigated the effect of treatment (instruction based on constructivist approach vs. traditionally designed chemistry instruction) on students’ attitudes towards chemistry as a school subject. It could be concluded that students instructed through instruction based on the constructivist approach had more positive attitudes toward chemistry than students taught by traditionally designed chemistry instruction. Generally, most students see chemistry as a difficult subject to learn and they do not want to study chemistry. Instruction based on constructivist approach, focused on students’ ideas, encouraged students to think about situations and use their knowledge and share their ideas. Students were actively involved in the learning process. These factors might cause students in the experimental group to have more positive attitudes.

Another purpose of the present study was to investigate whether there was a significant mean difference between male and female students with respect to understanding chemical bonding concepts. The findings indicated that there was no significant mean difference between male and female students. Also, no significant interaction between gender difference and treatment in terms of understanding chemical bonding concepts was found. This meant that, there was no significant difference between male and female students who were instructed by instruction based on the constructivist approach and those who were instructed through traditionally designed chemistry instruction. The reason why no significant difference was found in this study might be due to the fact that since the school where the treatment was conducted was a private school, students had similar backgrounds or experience. This situation might also affect their attitudes toward science; consequently, this study did not find any significant mean difference between males and females in terms of their attitudes toward chemistry, either.

To sum up, this study showed that students had difficulty in understanding chemical bonding concepts and held several misconceptions. By using constructivist teaching strategies, better acquisition of scientific concepts could be observed. Advance questioning activates relevant prior knowledge and promotes meaningful learning. This also causes students to have more positive attitudes towards chemistry as a school subject.

6.2 Implications

In order for meaningful learning to occur, students should relate new information to their current cognitive structure. If they cannot link between new and existing knowledge, they fail to understand new concepts. Therefore, students should have mastered basic ideas first and then should learn more complex ones. They should be given the opportunity to express and share their ideas. The constructivist approach is important in terms of encouraging students to think about the scientific concepts and their conceptions.

Teachers should design their instruction to facilitate conceptual change. They should determine students' prior knowledge and understand how students learn scientific concepts. They should make students realize their conceptions since a change in students' ideas is under their own control. The role of the teacher is to facilitate and support their thinking for conceptual change. The teachers should use effective instructional strategies to identify and eliminate misconceptions. Small group discussions are effective for conceptual change.

Chemistry teaching should favor procedural knowledge. Although declarative knowledge is important and necessary, it is not enough. If students learn how to use their knowledge, they can solve real life problems and develop complex skills.

Curriculum programs should be based on the constructivist perspective and textbooks should be improved so that students' misconceptions can be minimized.

Teacher education should place an emphasis on constructivism.

Teachers should be aware of students' attitudes towards chemistry as a school subject and should seek ways to make students have positive attitudes.

6.3 Recommendations

Based on the results, the researcher recommends the following:

This study can be replicated with a larger sample size.

A study can be carried out for different grade levels and different science courses to investigate the effectiveness of the constructivist approach.

Further study can be conducted in different schools to provide a generalization for Turkey.

Other variables such as students' attitudes towards the constructivist environment can be added to the study.

Other constructivist teaching strategies such as the learning cycle approach can be used.

Collaborative teaching strategies based on the constructivist approach can also be used for negotiation of ideas.

Computers can be used within the constructivist perspective since they provide dynamic displays and visualizations, simulations and models.

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APPENDIX A

INSRTUCTIONAL OBJECTIVES

1. To define chemical bonding.
2. To explain how chemical bonding occurs.
3. To explain Lewis structure
4. To describe types of chemical bonds.
5. To differentiate between intermolecular and intramolecular bonds.
6. To explain ionic and covalent bonds.
7. To distinguish between ionic and covalent bonding.
8. To identify polarity.
9. To discriminate between polar and nonpolar covalent bonds.
10. To explain metallic bonding.
11. To give examples for ionic, covalent and metallic bonding.
12. To express Van der Waals forces, dipole-dipole interactions and hydrogen bonding.
13. To explain structures of ionic and covalent compounds
14. To explain properties of ionic and covalent compounds.

15. To give examples for ionic and covalent compounds.
16. To estimate physical properties of compounds according to the type of bonds they have.
17. To estimate type of bonds that a substance has.

APPENDIX B

CHEMICAL BONDING CONCEPT TEST

PART A

This part consists of the questions that examine your knowledge of chemical bonding. Each question has two parts: <u>a response section</u> in which you are asked to mark only one of two possible answers; <u>a reason section</u> in which you are asked to select the reason which explains the answer in the previous part of the question. On the answer sheet, please circle one answer from both the response and reason sections of each question.

1. At room temperature, sodium chloride, NaCl, exits as a molecule

(1) True **(2)** False

because

A) The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule.

B) After donating its valance electron to the chlorine atom, the sodium ion forms a molecule with the chloride ion.

C) Sodium chloride exists as a lattice consisting of sodium ions and chloride ions.

D) Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms.

2. Water (H_2O) and hydrogen sulphide (H_2S) have similar chemical formulas and structures. At room temperature, water is a liquid and hydrogen sulphide is a gas. This difference in state is due to

(1) forces between molecules **(2)** forces within molecules

because

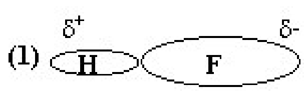
A) The difference in the forces attracting water molecules and those attracting hydrogen sulphide molecules is due to the difference in strength of the O-H and the S-H covalent bonds.

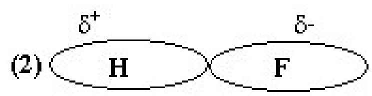
B) The bonds in hydrogen sulphide are easily broken whereas those in water are not.

C) The hydrogen sulphide molecules are closer to each other, leading to greater attraction between molecules.

D) The forces between water molecules are stronger than those between hydrogen sulphide molecules.

3. The electron cloud distribution in the HF molecule can be best represented by





because

A) Nonbonding electrons influence the positions 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.

4. In hydrogen chloride, HCl, the bond between hydrogen and chloride is a/an

(1) covalent **(2)** ionic

because

A) Electrons are shared between atoms.

B) Electrons are transferred.

C) It contains different atoms.

D) It contains Cl atom.

5. Calcium chloride,$CaCl_2$, is a/an

(1) covalent compound **(2)** ionic compound

because

A) Electrons are shared between atoms.

B) Electrons are transferred.

C) Ability of Ca to attract electrons is similar to that of Cl.

D) It exists as molecules.

6. The bonds in H_2O are

(1) polar **(2)** nonpolar

because

A) Shared electrons are attracted equally.

B) Shared electrons concentrate around one atom.

C) Nonbonding electrons affect the position of shared electrons.

D) Valance electrons in each atom determine polarity.

7. When NaCl dissolves in water, there is still ionic bonds between sodium and chlorine atoms in solution

(1) True **(2)** False

because

A) NaCl exists as discrete pairs of Na^+ and Cl^-.

B) Ionic bond is broken during the dissolving process.

C) Positive charge on sodium ions must be neutralized by gaining of electrons from chloride ions in the solution.

D) NaCl is still molecular in water.

8. NaCl in water conducts electricity

(1) True **(2)** False

because

A) It contains ions that carry an electric current.

B) It contains molecules that do not conduct a current.

C) It contains covalent bonds between molecules.

D) Covalent bonds are broken in solution.

9. Solid Cu conducts electricity

(1) True **(2)** False

because

A) It contains metallic bond which provides electron moving.

B) It contains covalent bond.

C) It contains ionic bonds.

D) It exists as a molecule.

10. The boiling point of N_2 is very low (-147 ^{0}C), on the other hand, at high temperatures, it does not decompose due to

(1) intermolecular bonds **(2)** intramolecular bonds

because

A) Intermolecular forces between N_2 molecules are very strong.

B) Nitrogen atoms can not achieve stable octet.

C) Intramolecular forces are weaker than intermolecular forces.

D) Triple bond is very strong compared to intermolecular (Van der Waals) forces.

11. The compound formed between magnesium and oxygen can be used as a heat resistant material to line of furnaces

(1) True **(2)** False

because

A) The covalent bonds between magnesium and oxygen atoms are strong.

B) The intermolecular forces between the magnesium oxide molecules are weak.

C) There are strong ionic forces between magnesium and oxide ions in the lattice.

D) The intramolecular forces within the magnesium oxide molecules are strong.

12. Element X (electronic configuration 2, 8, 18, 8, 2) and element Y (electronic configuration 2,7) react to form an ionic compound, XY_2.

(1) True **(2)** False

because

A) An atom of X will share one pair of electrons with each atom of Y to form a covalent molecule, XY_2.

B) Covalently bonded atoms of X and Y form a network covalent compound.

C) X will transfer two electrons to Y to form an ionic compound XY_2.

D) X will transfer one electron to Y to form an ionic compound XY.

PART B

This part contains multiple choice questions. Please, circle one answer on the answer sheet provided.

13. Which one of the following is correct for potassium bromide, KBr?

A) It does not conduct electricity when it dissolves in water.

B) It contains nonpolar bonds.

C) It contains intramolecular bonds formed as a result of sharing electrons.

D) It contains intramolecular bonds formed as a result of electron transfer.

14. Which one of the following represents the true characteristics of chemical bonds?

A) They are material connections.

B) They are only formed between atoms that donate/accept electrons.

C) They are either fully ionic or covalent.

D) They are electrostatic forces.

15. Which one of the following is correct for ionic bonding?

A) Metals and nonmetals form ionic bond.

B) Compounds containing ionic bond conduct electricity when they are solid.

C) Ionic compounds are gases at room temperature.

D) Ionic compounds exist as molecules formed by covalent bonding.

16. Which one of the following is correct for covalent bonds?

A) Metals and nonmetals form strong covalent bonds.

B) Atoms of a metal and nonmetal share electrons to form molecules.

C) Equal sharing of the electrons occurs in all covalent bonds.

D) Covalent bond occurs due to sharing of electrons.

17. What is the reason that boiling point of NH_3 is higher than that of CH_4? (N:7, C:6)

A) NH_3 contains covalent bonds

B) CH_4 contains covalent bonds

C) There are H bonds in NH_3 molecule.

D) There are vander waals forces in CH_4 molecule.

18. What is the reason that F_2 and Cl_2 are gases at room temperature whereas I_2 is solid at room temperature?

A) The electronegativity of F and Cl is higher than that of I.

B) F_2 and Cl_2 are polar.

C) The wander waals forces are stronger in F_2 and Cl_2 than in I_2.

D) F_2 and Cl_2 are nonpolar.

APPENDIX C

KİMYA DERSİ TUTUM ÖLÇEĞİ

AÇIKLAMA: Bu ölçek, Kimya dersine ilşkin tutum cümleleri ile her cümlenin karşısında Tamamen Katılıyorum, Katılıyorum, Kararsızım, Katılmıyorum ve Hiç Katılmıyorum olmak üzere beş seçenek verilmiştir. Her cümleyi dikkatle okuduktan sonra kendinize uygun seçeneği işaretleyiniz.

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Hiç Katılmıyorum
1. Kimya çok sevdiğim bir alandır…………………..	○	○	○	○	○
2. Kimya ile ilgili kitapları okumaktan hoşlanırım…..	○	○	○	○	○
3.Kimyanın günlük yaşantıda çok önemli yeri yoktur	○	○	○	○	○
4. Kimya ile ilgili ders problemlerini çözmekten hoşlanırım…………………………………………	○	○	○	○	○
5. Kimya konularıyla ile ilgili daha çok şey öğrenmek isterim………………………………….	○	○	○	○	○
6. Kimya dersine girerken sıkıntı duyarım…………..	○	○	○	○	○
7. Kimya derslerine zevkle girerim………………….	○	○	○	○	○
8. Kimya derslerine ayrılan ders saatinin daha fazla olmasını isterim…………………………………...	○	○	○	○	○
9. Kimya dersini çalışırken canım sıkılır…………….	○	○	○	○	○
10. Kimya konularını ilgilendiren günlük olaylar hakkında daha fazla bilgi edinmek isterim…………..	○	○	○	○	○
11. Düşünce sistemimizi geliştirmede Kimya öğrenimi önemlidir…………………………………..	○	○	○	○	○
12. Kimya çevremizdeki doğal olayların daha iyi anlaşılmasında önemlidir…………………………….	○	○	○	○	○
13. Dersler içinde Kimya dersi sevimsiz gelir……….	○	○	○	○	○
14. Kimya konularıyla ilgili tartışmaya katılmak bana cazip gelmez…………………………………	○	○	○	○	○
15.Çalışma zamanımın önemli bir kısmını Kimya dersine ayırmak isterim……………………………...	○	○	○	○	○

APPENDIX D

BİLİMSEL İŞLEM BECERİ TESTİ

AÇIKLAMA: Bu test, özellikle Fen ve Matematik derslerinizde ve ilerde üniversite sınavlarında karşınıza çıkabilecek karmaşık gibi görünen problemleri analiz edebilme kabiliyetinizi ortaya çıkarabilmesi açısından çok faydalıdır. Bu test içinde, problemdeki değişkenleri tanımlayabilme, hipotez kurma ve tanımlama, işlemsel açıklamalar getirebilme, problemin çözümü için gerekli incelemelerin tasarlanması, grafik çizme ve verileri yorumlayabilme kabiliyelerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği yalnızca cevap kağıdına işaretleyiniz.

1. Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettklerini düşünmektedir. Güçlerini etkileyen faktörleri araştırmaya karar verir. Antrenör, oyuncuların gücünü etkileyip etkilemediğini ölçmek için aşağıdaki değişkenlerden hangisini incelemelidir?

a. Her oyuncunun almış olduğu günlük vitamin miktarını.

b. Günlük ağırlık kaldırma çalışmalarının miktarını.

c. Günlük antreman süresini.

d. Yukarıdakilerin hepsini.

2. Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini artıdığı yolundadır. Aynı tip beş arabaya aynı miktarda benzin fakat farklı miktarlarda katkı maddesi konur. Arabalar benzinleri bitinceye kadar aynı yol üzerinde giderler. Daha sonra her arabanın aldığı mesafe kaydedilir. Bu çalışmada arabaların verimliliği nasıl ölçülür?

a. Arabaların benzinleri bitinceye kadar geçen süre ile.

b. Her arabnın gittiği mesafe ile.

c. Kullanılan benzin miktarı ile.

d. Kullanılan katkı maddesinin miktarı ile.

3. Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değşkenleri araştımaktadırlar. Aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?

a. Arabanın ağırlığı.

b. Motorun hacmi.

c. Arabanın rengi

d. a ve b.

4. Ali Bey, evini ısıtmak için komşularından daha çok para ödenmesinin sebeblerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez değildir?

a. Evin çevresindeki ağaç sayısı ne kadar az ise ısınma gideri o kadar fazladır.

b. Evde ne kadar çok pencere ve kapı varsa, ısınma gideri de o kadar fazla olur.

c. Büyük evlerin ısınma giderleri fazladır.

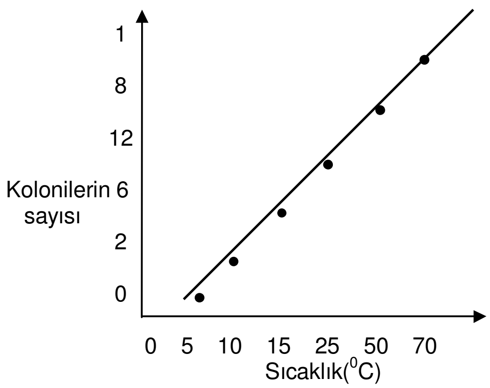
d. Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

5. Fen sınıfından bir öğrenci sıcaklığın bakterilerin gelişmesi üzerindeki etkilerini araştırmaktadır. Yaptığı deney sonucunda, öğrenci aşağıdaki verileri elde etmiştir:

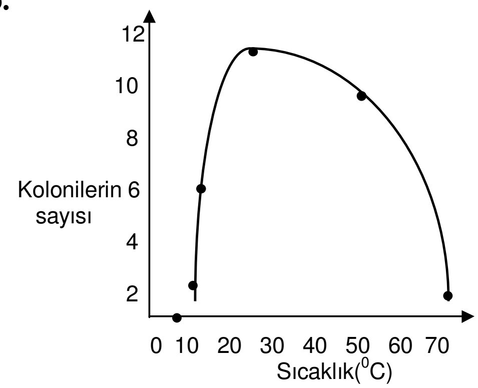
Deney odasının sıcaklığı (^{0}C)	Bakteri kolonilerinin sayısı
5	0
10	2
15	6
25	12
50	8
70	1

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

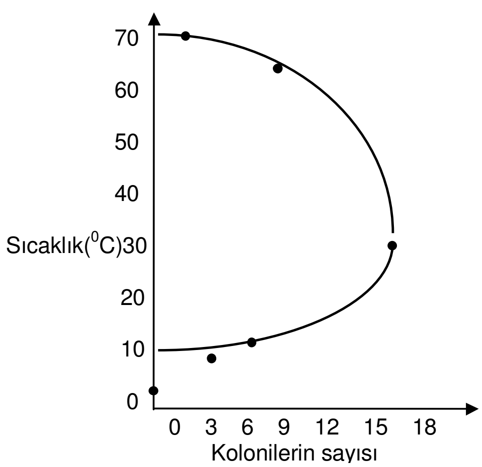
a.



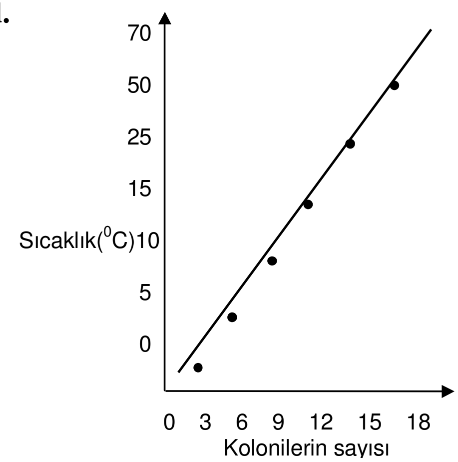
b.



c.



d.



6. Bir polis şefi, arabaların hızının azaltılması ile uğraşmaktadır. Arabaların hızını etkileyebilecek bazı faktörler olduğunu düşünmektedir. Sürücülerin ne kadar hızlı araba kullandıklarını aşağıdaki hipotezlerin hangisiyle sınayabilir?

a. Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.

b. Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.

c. Yollarde ne kadar çok polis ekibi olursa, kaza sayısı o kadar az olur.

d. Arabalar eskidikçe kaza yapma olasılıkları artar.

7. Bir fen sınıfında, tekerlek yüzeyi genişliğinin tekerleğin daha kolay yuvarlanması üzerine etkisi araştırılmaktadır. Br oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğiik düzlem) aşağı bırakılır ve daha sonra düz bir zemin üzerinde gitmesi sağlanır. Deney, aynı arabaya daha dar yüzeyli tekerlekler takılarak tekrarlanır. Hangi tip tekerleğin daha kolay yuvarlandığı nasıl ölçülür?

a. Her deneyde arabanın gittiği toplam mesafe ölçülür.

b. Rampanın (eğik düzlem) eğim açısı ölçülür.

c. Her iki deneyde kullanılan tekerlek tiplerinin yüzey genişlkleri ölçülür.

d. Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

8. Bir çiftçi daha çok mısır üretebilmenin yollarını aramaktadır. Mısırların miktarını etkileyen faktörleri araştırmayı tasarlar. Bu amaçla aşağıdaki hipotezlerden hangisini sınayabilir?

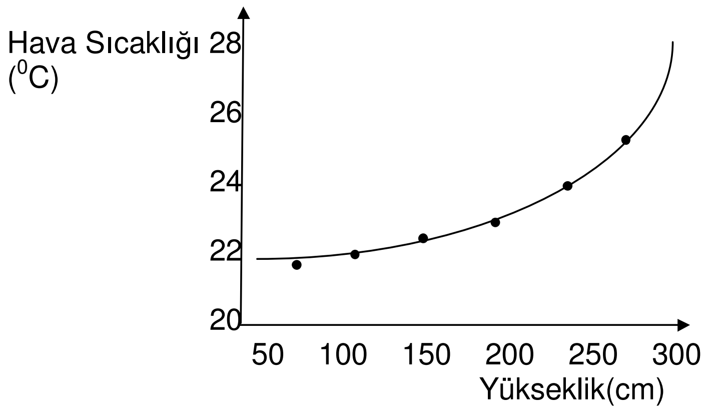
a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.

b. Ne kadar çok mısır elde edilirse, k**a**r o kadar fazla olur.

c. Yağmur ne kadar çok yağarsa , gübrenin etkisi o kadar çok olur.

d. Mısır üretimi arttıkça, üretim maliyeti de artar.

9. Bir odanın tabandan itibaren değişik yüzeylerdeki sıcaklıklarla ilgli bir çalışma yapılmış ve elde edilen veriler aşağıdaki grafikte gösterilmiştir. Değişkenler
arasındaki ilişki nedir?



a. Yükseklik arttıkça sıcaklık azalır.

b. Yükseklik arttıkça sıcaklık artar.

c. Sıcaklık arttıkça yükseklik azalır.

d. Yükseklik ile sıcaklık artışı arasında bir ilşki yoktur.

10. Ahmet, basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçracağını düşünmektedir. Bu hipotezi araştırmak için, birkaç basketbol topu alır ve içlerine farklı miktarda hava pompalar. Ahmet hipotezini nasıl sınamalıdır?

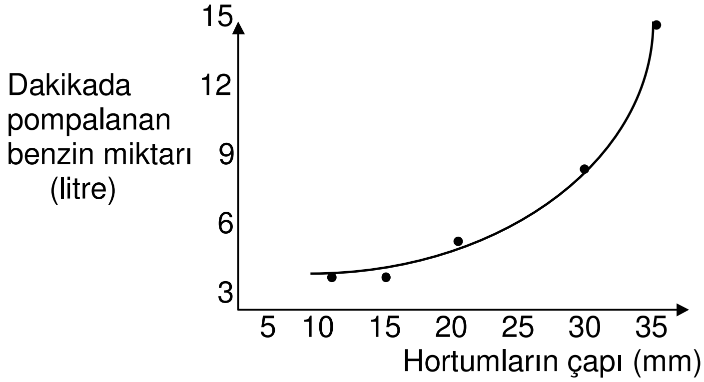
a. Topları aynı yükseklikten fakat değişik hızlarla yere vurur.

b. İçlerinde farlı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.

c. İçlerinde aynı miktarlarda hava olan topları, zeminle farklı açılardan yere vurur.

d. İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

11. Bir tankerden benzin almak için farklı genişlikte 5 hortum kullanılmaktadır. Her hortum için aynı pompa kullanılır. Yapılan çalışma sonunda elde edilen bulgular aşağıdaki grafikte gösterilmiştir.



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

a. Hortumun çapı genişledikçe dakikada pompalanan benzin miktarı da artar.

b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.

c. Hortumun çapı küçüldükçe dakikada pompalanan benzin miktarı da artar.

d. Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

Önce aşağıdaki açıklamayı okuyunuz ve daha sonra 12, 13, 14 ve 15 inci soruları açıklama kısmından sonra verilen paragrafı okuyarak cevaplayınız.

Açıklama: Bir araştırmada, bağımlı değişken birtakım faktörlere bağımlı olarak gelişim gösteren değişkendir. Bağımsız değişkenler ise bağımlı değişkene etki eden faktörlerdir. Örneğin, araştırmanın amacına göre kimya başarısı bağımlı bir değişken olarak alınabilir ve ona etki edebilecek faktör veya faktörler de bağımsız değişkenler olurlar.

Ayşe, güneşin karaları ve denizleri aynı derecede ısıtıp ısıtmadığını merak etmektedir. Bir araştırma yapmaya karar verir ve aynı büyüklükte iki kova alır. Bumlardan birini toprakla, diğerini de su ile doldurur ve aynı miktarda güneş ısısı alacak şekilde bir yere koyar. 8.00 - 18.00 saatleri arasında, her saat başı sıcaklıklarını ölçer.

12. Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?
a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.
b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.
c. Güneş farklı maddelari farklı derecelerde ısıtır.
d. Günün farklı saatlerinde güneşin ısısı da farklı olur.

13. Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?
a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Herbir kovanın güneş altında kalma süresi.

14. Araştırmada bağımlı değişken hangisidir?
a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Herbir kovanın güneş altında kalma süresi.

15. Araştırmada bağımsız değişken hangisidir?
a. Kovadaki suyun cinsi.
b. Toprak ve suyun sıcaklığı.
c. Kovalara koyulan maddenin türü.
d. Herbir kovanın güneş altında kalma süresi.
16. Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinasıyla her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili

hipotezler kurmaya nbaşlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?

a. Hava sıcakken çim biçmek zordur.

b. Bahçeye atılan gürenin miktarı önemlidir.

c. Daha çok sulanan bahçedeki çimenler daha uzun olur.

d. Bahçe ne kadar engebeliyse çimenleri kesmekte o kadar zor olur.

17, 18, 19 ve 20 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın herbirine 50 şer mililitre su koyar. Bardaklardan birisine 0 ^{0}C de, diğerine de sırayla 50 ^{0}C, 75 ^{0}C ve 95 ^{0}C sıcaklıkta su koyar. Daha sonra herbir bardağa çözünebileceği kadar şeker koyar ve karıştırır.

17. Bu araştırmada sınanan hipotez hangisidir?

a. Şeker ne kadar çok suda karıştırılırsa o kadar çok çözünür.

b. Ne kadar çok şeker çözünürse, su o kadar tatlı olur.

c. Sıcaklık ne kadar yüksek olursa, çözünen şekerin miktarı o kadar fazla olur.

d. Kullanolan suyun miktarı arttıkça sıcaklığı da artar.

18. Bu araştırmada kontrol edilebilen değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

19. Araştımanın bağımlı değişkeni hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

20. Araştırmadaki bağımsız değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

21. Bir bahçıvan domates üretimini artırmak istemektedir. Değişik birkaç alana domates tohumu eker. Hipotezi, tohumlar ne kadar çok sulanırsa, o kadar çabuk filizleneceğidir. Bu hipotezi nasıl sınar?

a. Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.

b. Her sulamadan bir gün sonra domates bitkisinin boyunu ölçer.

c. Farklı alnlardaki bitkilere verilen su miktarını ölçer.

d. Her alana ektiği tohum sayısına bakar.

22. Bir bahçıvan tarlasındaki kabaklarda yaprak bitleri görür. Bu bitleri yok etmek gereklidir. Kardeşi "Kling" adlı tozun en iyi böcek ilacı olduğunu söyler. Tarım uzmanları ise "Acar" adlı spreyin daha etkili olduğunu söylemektedir. Bahçıvan altı tane kabak bitkisi seçer. Üç tanesini tozla, üç tanesini de spreyle ilaçlar. Bir hafta sonra her bitkinin üzerinde kalan canlı bitleri sayar. Bu çalışmada böcek ilaçlarının etkinliği nasıl ölçülür?

a. Kullanılan toz ya da spreyin miktarı ölçülür.

b. Toz ya da spreyle ilaçlandıktan sonra bitkilerin durumları tespit edilir.

c. Her fidede oluşan kabağın ağırlığı ölçülür.

d. Bitkilerin üzerinde kalan bitler sayılır.

23. Ebru, bir alevin belli bir zaman süresi içinde meydana getireceği ısı enerjisi miktarını ölçmek ister. Bir kabın içine bir liter soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini nasıl öiçer?

a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kayeder.

b. 10 dakika sonra suyun hacminde meydana gelen değişmeyi ölçer.

c. 10 dakika sonra alevin sıcaklığını ölçer.

d. Bir litre suyun kaynaması için geçen zamanı ölçer.

24. Ahmet, buz parçacıklarının erime süresini etkileyen faktörleri merak etmektedir. Buz parçalarının büyüklüğü, odanın sıcaklığı ve buz parçalarının şekli gibi faktörlerin erime süresini etkileyebileceğini düşünür. Daha sonra şu hipotezi sınamaya karar verir: Buz parçalarının şekli erime süresini etkiler. Ahmet bu hipotezi sınamak için aşağıdaki deney tasarımlarının hangisini uygulamalıdır?

a. Herbiri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

b. Herbiri aynı şekilde fakat farklı ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

c. Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

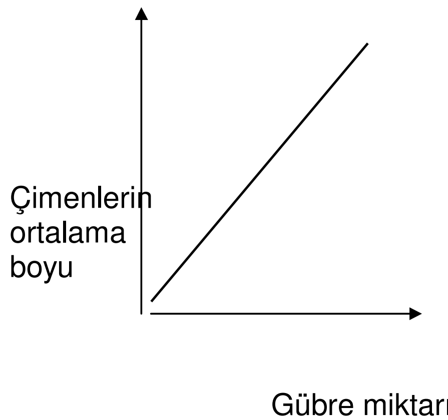
d. Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

25. Bir araştırmacı yeni bir gübreyi denemektedir. Çalışmalarını aynı büyüklükte beş tarlad yapar. Her tarlaya yeni gübresinden değişik miktarlarda karıştırır. Bir ay sonra, her tarlada yetişen çimenin ortalama boyunu ölçer. Ölçüm sonuçları aşağıdaki tabloda verilmiştir.

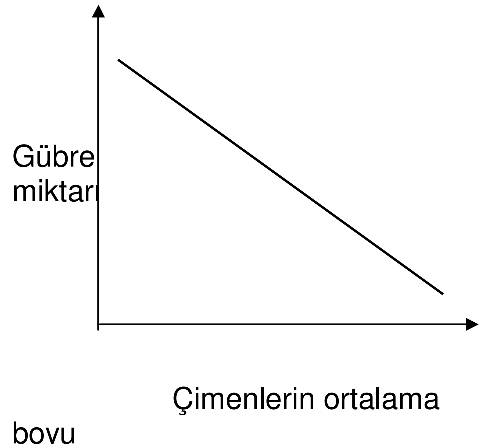
Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

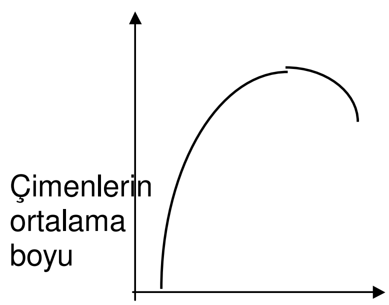
a.



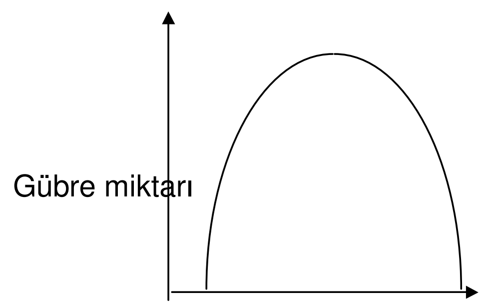
b.



c.



d.



26. Bir biyolog şu hipotezi test etmek ister: Farelere ne kadar çok vitamin verilirse o kadar hızlı büyürler. Biyolog farelerin büyüme hızını nasıl ölçebilir?

a. Farelerin hızını ölçer.

b. Farelerin, günlük uyumadan durabildikleri süreyi ölçer.

c. Hergün fareleri tartar.

d. Hergün farelerin yiyeceği vitaminleri tartar.

27. Öğrenciler, şekerin suda çözünme süresini etkileyebilecek değişkenleri düşünmektedirler. Suyun sıcaklığını, şekerin ve suyun miktarlarını değişken olarak saptarlar. Öğrenciler, şekerin suda çözünme süresini aşağıdaki hipotezlerden hangisiyle sınayabilir?

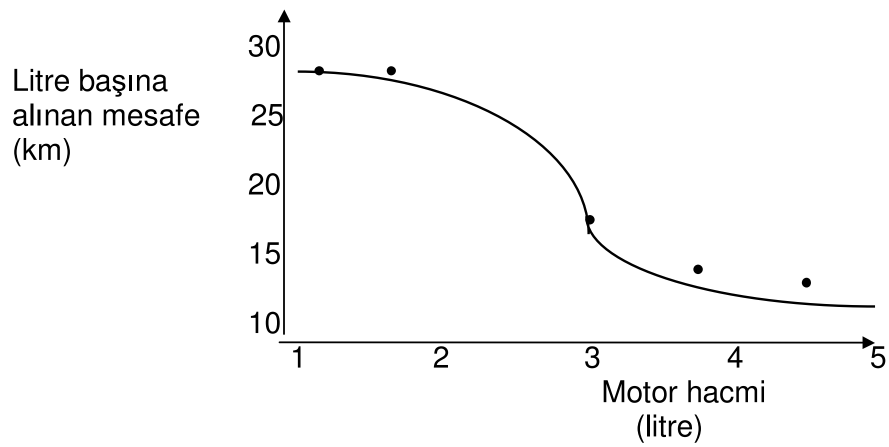
a. Daha fazla şekeri çözmek için daha fazla su gereklidir.

b. Su soğudukça, şekeri çözebilmek için daha fazl akarıştırmak gerekir.

c. Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.

d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştıma grubu, değişik hacimli motorları olan arabalaıın randımanlarını ölçer. Elde edilen sonuçların garfiği aşağıdaki gibidir:



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

a. Motor ne kadar büyükse, bir litre benzinle gidilen mesafe de o kadar uzun olur.

b. Bir litre benzinle gidilen mesafe ne kadar az olursa, arabanın motoru o kadar küçük demektir.

c. Motor küçüldükçe, arabanın bir litre benzinle gidilen mesafe artar.

d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

29, 30, 31 ve 32 nci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Toprağa karıtırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki torağa 15 kg., ikinciye 10 kg., üçüncüye ise 5 kg. çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır.
Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan eled edilen domates tartılmış ve kaydedilmiştir.

29. Bu araştırmada sınanan hipotez hangisidir?
a. Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.
b. Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.
c. Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.
d. Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

30. Bu araştırmada kontrol edilen değişken hangisidir?
a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki torak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

31. Araştırmadaki bağımlı değişken hangisidir?
a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki torak miktarı.
d. Çürümüş yapak karıştırılan saksı sayısı.

32. Araştırmadaki bağımsız değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki torak miktarı.

d. Çürümüş yapak karıştırılan saksı sayısı.

33. Bir öğrenci mınatısların kaldırma yeteneklerini araştırmaktadır. Çeşitli boylarda ve şekillerde birkaç mıknatıs alır ve her mıknatısın çektiği demir tozlarını tartar. Bu çalışmada mıknatısın kaldırma yeteneği nasıl tanımlanır?

a. Kullanılan mıknatısın büyüklüğü üle.

b. Demir tozalrını çeken mıknatısın ağırlığı ile.

c. Kullanılan mıknatısın şekli ile.

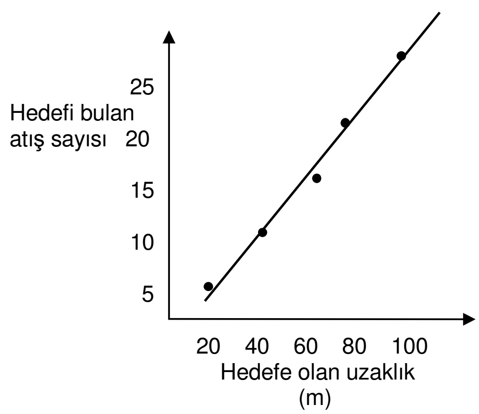
d. Çekilen demir tozlarının ağırlığı ile.

34. Bir hedefe çeşitli mesafelerden 25 er atış yapılır. Her mesafeden yapılan 25 atıştan hedefe isabet edenler aşağıdaki tabloda gösterilmiştir.

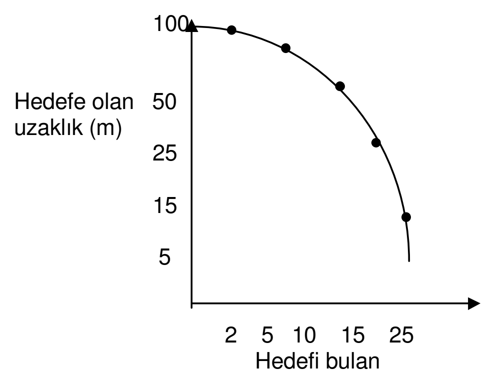
Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

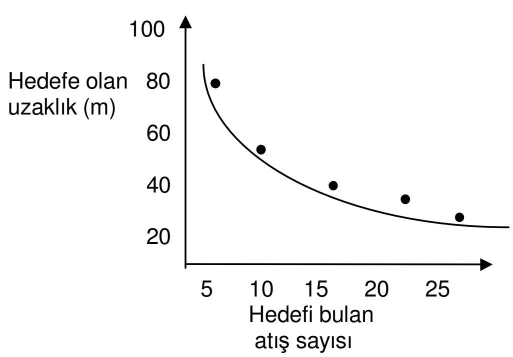
a.



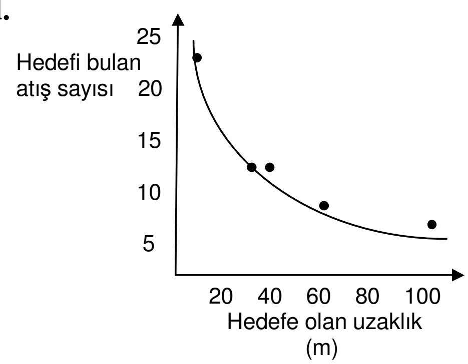
b.



c.



d.



35. Sibel, akvaryumdaki balıkların bazen çok haraketli bazen ise durgun olduklarını gözler. Balıkların hareketliliğini etkileyen faktörleri merak eder.Balıkların hareketliliğini etkileyen faktörleri hangi hipotezle sınayabilir?

a. Balıklara ne kadar çok yem verilirse, o kadar çok yeme ihtiyaçları vardır.

b. Balıklar ne kadar hareketli olursa o kadar çok yeme ihtiyaçları vardır.

c. Su da ne kadar çok oksijen varsa, balıklar o kadar iri olur.

d. Akvaryum ne kadar çok ışık alırsa, balıklar o kadar hareketli olur.

36. Murat Bey'in evinde birçok electrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker. Kullanılan elektrik miktarını etkileyen faktörleri araştırmaya karar verir. Aşağıdaki değişkenlerden hangisi kullanılan elektrik enerjisi miktarını etkileyebilir?

a. TV nin açık kaldığı süre.

b. Elektrik sayacının yeri.

c. Çamaşır makinesinin kullanma sıklığı.

d. a ve c.

APPENDIX E

SAMPLE LESSONS BASED ON YAGER'S CONSTRUCTIVIST TEACHING STRATEGY

SAMPLE 1:

STEP 1 (INVITATION): The teacher asked a question: What do you think what a chemical bond means? The purpose was to activate students' existing ideas and identify their preconceptions.

STEP 2 (EXPLORATION): The teacher created groups based on their grades in the last semester. The groups consisted of four or five students. Each group involved high, medium and low achiever students. The students discussed the question the teacher asked in the previous step in groups. During the discussion, they had opportunity to express their ideas and saw their peers' thoughts. They defended their ideas when there were different ideas in a group. At the end of the discussion, each group was supposed to give a common answer to the teacher. For the previous question, most students thought that bonds were "things" that holds atoms together but they could not explain exactly what the "thing" was.

This step was also important in terms of causing students to have cognitive conflict according to Posner et al.'s (1982) conceptual change model. During discussions, students became aware of their ideas and saw some inconsistencies or gaps in their reasoning and therefore dissatisfaction occurred.

STEP 3 (PROPOSING EXPLANATIONS AND SOLUTIONS):

The teacher got the answers from each group. Based on their answers, he explained the concept. He emphasized on common misconceptions and the topics in which students had difficulty. He used analogies or examples in order to make concepts more concrete. For the question asked in step 1, after the teacher got the students' responses, he wanted students to explain what they meant by saying "thing". However, the groups could not explain it. Then, the teacher introduced bonding concept:

"In nearly all natural substances, atoms and ions exist bound to one another. Most of the substances around us are compounds rather than elements. For example, table salt, NaCl, consists of sodium and chlorine elements:

Na metal Chlorine gas

Table salt

Figure E.1 Reaction between sodium metal and chlorine gas

Similarly, water consists of hydrogen and oxygen elements and has a formula H_2O. At low pressure and high temperature, hydrogen and oxygen gases combine to yield water which has different property from both oxygen and hydrogen: $H_2 + 1/2\ O_2 \longrightarrow H_2O$.

Compounds are formed as a result of reaction between atoms. Since the elements loose their identity during the reaction, compounds can be separated into elements by chemical methods. So, what joins the atoms to each other in a molecule? What is the "glue" that holds the molecule together?

Chemical bonding is responsible for the behaviour of substances around us. Why is table salt a hard, brittle, high melting solid that conducts electricity only when molten or dissolved in water? Why is wax low melting, nonbrittle and nonconducting? Why are metals shiny and bendable substances that conduct whether molten or solid? The answers lie in the type of bonding within the substance. So what is a chemical bond? Most students think wrongly that chemical bonds are material connections simply. However, when we think scientifically, we see that there are *forces* that hold the atoms of elements together in a compound. These forces are called as "chemical bonds". In other words, the "thing" between atoms you mentioned is the electrostatic forces that hold the atoms together. The type and strength of chemical bonds determine the properties of a substance.

You are familiar with the magnets. What will happen if two magnets are put closer to each other? (The teacher showed magnets to the class). We know that like poles repel and unlike poles attract each other. This is similar to the attraction and repulsion between electric charges. There are attractions between particles of two atoms that lead to chemical bonding and hold the structure together."

This step supports conceptual change described by Posner et al. (1982). Since the teacher states clearly what a chemical bond is by using magnets, emphasizing interactions and stressing on students' preconceptions, the concept became intelligible and plausible to the students. In addition, the students realized that they could use this explanation for finding solutions to other questions; in this way, Posner et al.'s last condition (fruitfulness) was achieved.

STEP 4 (TAKING ACTION): The teacher concluded that chemical bonds are electrostatic forces and asked a new question which was: What do you think why chemical bonds form? His purpose was to activate students existing knowledge, which they got in the previous steps.

Then, the students discussed this question in groups and gave a common answer to the teacher as a second step (exploration). The teacher presented the topic as a third step (proposing explanations and solutions) and as a last step (taking action) he asked a new question again.

SAMPLE 2:

STEP 1 (INVITATION): The teacher asked a question which was: What do you think how bonding occur? The purpose was to activate students' existing ideas and identify their preconceptions.

STEP 2 (EXPLORATION): The same groups discussed the question. They used their previous knowledge related to structure of atoms and trends in the periodic table. Most groups believed that metals want to give electron and nonmetals want to take electrons, as a result, chemical bond occurs.

STEP 3 (PROPOSING EXPLANATIONS AND SOLUTIONS):

After getting answers, the teacher realized that students thought that bonding occurs only between atoms that give and accept electrons, which was also stated as a misconception in literature. Then, the teacher asked another question to the groups in order to create cognitive conflict, which was: How does bonding occur between Hydrogen and Fluorine atoms leading HF molecule? The students could not explain this situation. In this way, Posner et al.'s first condition (dissatisfaction) was enhanced.

Then, the teacher explained formation of covalent bonding by emphasizing interactions of particles of atoms: "Let's treat electrons as a point negative charge interacting with the two atoms separated by a distance. The electron will exert an attractive force on the nuclei. If the electron lies between two, the force will tend to pull the nuclei together. If the electron lies outside the region between the nuclei, the force tends to pull the two apart. So, covalent bonding occurs when an electron spends most of its time in the region between nuclei and it is shared between them. At close distances, repulsions between electron-electron and nucleus-nucleus become significant. At this point of minimum energy, bonding occurs. At the points where energy is high, atoms are apart from each other and there is no bonding."

The teacher also used analogy to make the concept more concrete. Borrowing a book from a library was used an example. Although you get the book from the library and you are treated as if it belong to you; yet at the same time, it is counted as being part of the library collection.

The teacher also emphasized interactions since literature showed that students misinterpret the term “electron sharing” used for explaining covalent bonding. They think social meaning of sharing which implies equality and therefore they believed in all covalent bonds, electrons are used equally between atoms, in other words, all covalent bonds are nonpolar. The teacher stressed on this idea, too.

As a result of these explanations, Posner et al.’s conditions of intelligibility, plausibility and fruitfulness were supported.

STEP 4 (TAKING ACTION): The teacher summarized covalent bonding and asked a new question.

APPENDIX F

PERCENTAGES OF STUDENTS' RESPONSES ON CHEMICAL BONDING CONCEPT TEST

		Post-test %	
Item Number	**Response**	**Experimental Group**	**Control Group**
1	True	78.3	77.8
	False*	21.7	22.2
	A	21.7	66.7
	B	34.8	11.1
	C*	39.1	16.7
	D	4.3	5.6
2	1*	60.9	55.6
	2	39.1	44.4
	A	26.1	37.5
	B	30.4	6.3
	C	8.7	-
	D*	34.8	56.3
3	1*	95.7	61.1
	2	4.3	38.9
	A	4.3	11.1
	B	13	38.9
	C*	65.2	16.7
	D	17.4	33.3
4	1*	65.2	33.3
	2	34.8	66.7
	A*	47.8	44.4
	B	43.5	38.9
	C	-	16.7
	D	8.7	-
5	1	30.4	33.3
	2*	69.6	66.7
	A	47.8	27.8
	B*	52.2	61.1

* Correct response

	C	-	11.1
	D	-	-
6	1*	78.3	77.8
	2	21.7	22.2
	A	4.3	22.2
	B*	47.8	44.4
	C	8.7	5.6
	D	39.1	27.8
7	1	43.5	61.1
	2*	56.5	38.9
	A*	52.2	11.1
	B	17.4	11.1
	C	13.0	22.2
	D	17.4	55.6
8	1*	65.2	66.7
	2	34.8	33.3
	A*	52.2	44.4
	B	26.1	33.3
	C	13.0	16.7
	D	8.7	5.6
9	1*	73.9	61.1
	2	26.1	38.9
	A*	69.6	57.8
	B	13.0	12.3
	C	4.3	16.7
	D	13.0	5.6
10	1	43.5	50.0
	2*	56.5	50.0
	A	8.7	27.8
	B	8.7	16.7
	C	30.4	27.8
	D*	52.2	27.8
11	1*	72.7	72.2
	2	27.3	27.8
	A	26.1	33.3
	B	30.4	33.3
	C*	30.4	22.2
	D	13.0	11.1
12	1*	56.5	46.7
	2	43.5	43.3
	A	17.4	16.7
	B	8.7	16.7
	C*	69.6	61.1
	D	4.3	5.6
13	A	39.1	16.7
	B	4.3	11.1
	C	8.7	27.8
	D*	47.8	44.4
14	A	8.7	5.6
	B	17.4	38.9

	C	26.1	33.3
	D*	47.8	22.2
15	A*	73.9	66.7
	B	17.4	-
	C	-	-
	D	8.7	33.3
16	A	4.3	-
	B	8.7	15.6
	C	17.4	27.8
	D*	69.6	56.7
17	A	17.4	33.3
	B	4.3	27.8
	C*	52.2	16.7
	D	26.1	22.2
18	A	17.4	33.3
	B	17.4	38.9
	C*	47.8	16.7
	D	17.4	11.1

VITA

Esen Uzuntiryaki was born in Karabük on August 18, 1974. She received B. Sc. Degree from the Department of Science Education of Middle East Technical University in 1996 and M. S. degree from the same department in 1998. She has been working as a research assistant in the Department of Secondary Science and Mathematics Education of Middle East Technical University since 1996. She has been to the Department of Science Education of University of Georgia as a visiting scholar between September 2002 and May 2003. Her main areas of interest are conceptual change approach, constructivism and chemistry education. She has 10 papers published in scientific journals and conference proceedings, 2 papers and 3 conference proceedings to be published soon.