THE EFFECTS OF COMPUTER-BASED INTERACTIVE CONCEPTUAL CHANGE TEXTS ON 11TH GRADE STUDENTS' UNDERSTANDING OF ELECTROCHEMISTRY CONCEPTS AND ATTITUDE TOWARD CHEMISTRY

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ABSTRACT

THE EFFECT OF COMPUTER-BASED INTERACTIVE CONCEPTUAL CHANGE TEXTS ON 11TH GRADE STUDENTS' UNDERSTANDING OF ELECTROCHEMISTRY CONCEPTS AND ATTITUDE TOWARD CHEMISTRY

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The purpose of the study was to investigate the effect of conceptual change oriented instruction accompanied by computer-based interactive conceptual change text (CBICCT) on 11th grade students understanding of electrochemistry and attitude toward chemistry. The study was conducted in an anatolian high school in Ankara with two science classes with 66 students in May 2009. A quasi experimental design was used. The classes was assigned to groups; one as control group and the other as experimental group. While control group was given traditional instruction, experimental group was given conceptual change oriented instruction accompanied by CBICCT.

Electrochemistry Concept Test (ECT) was administered before and after treatment and Attitude Toward Chemistry Scale (ATCS) was administered after treatment to collect data about students' concepts about electrochemistry and attitude toward chemistry, respectively. To investigate possible covariates, Science Process Skills Test (SPST) was administered after treatment.

The collected data were analyzed with two way analysis of covariance (ANCOVA) and two way analysis of variance (ANOVA). Gain scores of ECT was analyzed with two way ANCOVA when SPST scores controlled as covariate and the results showed that the experimental group developed significantly better understanding of concepts than control group. The results also showed that no mean difference between males and females, and no interaction effect between instruction method and gender were found. The analysis of ATCS showed that experimental group developed significantly more positive attitude toward chemistry than control group. However, no significant difference between males and females, and no significant interaction between method and gender in terms of attitude toward chemistry were found.

Keywords: Conceptual Change Model, Conceptual Change Text, Computer Assisted Instruction, Attitude Toward Chemistry, Electrochemistry.

ÖZ

BİLGİSAYAR DESTEKLİ ETKİLEŞİMLİ KAVRAMSAL DEĞİŞİM METİNLERİNİN 11. SINIF ÖĞRENCİLERİN ELEKTROKİMYA KAVRAMLARINI ANLAMASINA VE KİMYAYA KARŞI TUTUMLARINA ETKİSİ

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Bu çalışmanın amacı Bilgisayar Destekli Etkileşimli Kavramsal Değişim Metinleri (BDEKDM) ile birlikte verilen kavramsal değişim yaklaşımına dayalı öğretim yönteminin 11. sınıf öğrencilerin elektrokimya kavramlarını anlamasına ve kimyaya karşı tutumlarına etkisini incelemektir. Bu çalışma Mayıs 2009'da Ankara'daki bir anadolu lisesinin iki fen sınıfına kayıtlı olan 66 öğrenci ile yapılmıştır. Yarı deneysel bir araştırma tasarımı kullanılmıştır. Sınıflar grup olarak atanmıştır; bir sınıf kontrol grubu, diğeri ise deney grubu olarak. Kontrol grubunda geleneksel öğretim yöntemi ile ders anlatılırken deney grubuna BDEKDM ile birlikte verilen kavramsal değişim yaklaşımına dayalı öğretim yöntemi ile ders anlatılmıştır.

Öğrencilerin elektrokimya ile ilgili kavramları hakkında bilgi toplamak için Elektrokimya Kavram Testi (EKT) uygulamadan önce ve sonra verilmiş, kimyaya karşı tutum hakkında bilgi toplamak için uygulama sonunda Kimyaya Karşı Tutum

Ölçeği (KKTÖ) kullanılmıştır. Muhtemel ortak değişkenleri belirlemek için uygulamadan sonra Bilimsel Süreç Becerisi Testi (BSBT) kullanılmıştır.

Elde edilen veriler iki yönlü ortak değişkenli varyans analizi (ANCOVA) ve iki yönlü varyans analizi (ANOVA) kullanılarak analiz edilmiştir. BSBT ortak değişken olarak alınarak EKT fark skorları ANCOVA ile analiz edilmiş ve sonuçlar deneysel grubun anlamlı bir şekilde daha iyi bir kavram anlayışı geliştirdiğini göstermiştir. Yine sonuçlar göstermiştir ki, erkekler ve kızlar arasında anlamlı fark ve yöntem ile cinsiyet arasında anlamlı etkileşim bulunamamıştır. KKTÖ'nin analizi, deneysel grubun kimyaya karşı daha olumlu bir tutum geliştirdiğini göstermiştir. Ancak kimyaya karşı tutum bakımından erkek ve kızlar arasında anlamlı bir fark ve yöntem ile cinsiyet arasında anlamlı bir etkileşim bulunamamıştır.

Anahtar Kelimeler: Kavramsal Değişim Modeli, Kavramsal Değişim Metni, Bilgisayar Destekli Eğitim, Kimyaya Karşı Tutum, Elektrokimya.

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LIST OF ABBREVIATIONS

CCCM	: Classical Conceptual Change Model
ECT	: Electrochemistry Concept Test
ATCS	: Attitude Toward Chemistry Scale
SPST	: Scientific Process Skill Test
CBICCT	: Computer-Based Interactive Conceptual Change Texts
ERIC	: Educational Resources Information Center
SSCI	: Social Science Citation Index
ANCOVA	: Analysis of covariance
ANOVA	: Analysis of variance
N/A	: No answer
F	: Fisher’s F distribution
Sig.	: Significance
df.	: Degree of Freedom
t	: Student’s t distribution
M	: Mean
SD	: Standard deviation
N	: Number of subjects

MANOVA : Multivariate analysis of variance

MANCOVA : Multivariate analysis of covariance

CHAPTER 1

INTRODUCTION

1.1 Theoretical Background

What is learning? This question is probably as old as the human history. Philosophy, psychology, and education have investigated learning processes to explain what learning is and how people learn. Systematic studies on learning started at the beginning of the twentieth century. Ivan Pavlov conducted experiments on animal behaviors and these experiments were well accepted by European and especially American psychologists (e.g. Yerkes & Morgulis, 1909). Pavlov's experiments were conducted on human subjects, results were published and a new view of learning was established that learning was a reaction to environmental stimuli (Watson & Rayner, 1920). Watson (1913) named this view as Behaviorism. Behaviorism remained dominant view in educational research more than fifty years. Initially, studies based on Pavlo's work proposed classical conditioning that suggested that with repeated stimuli a new behavior could be obtained (Watson & Rayner, 1920). Later on, Skinner (1964) proposed the idea of "operant conditioning" which suggested that consequences of the behavior determines whether the behavior changes or not.

Second half of the twentieth century witnessed a change in the view of learning. The popularity of behaviorism decreased when Piaget's (1970) work influenced science education community very deeply. Piaget proposed his theory of knowledge and stated that knowledge is the result of interaction between the learner and the objects. This interaction could occur in two ways (processes), assimilation and accommodation – an analogy of the same terms in biology. If new knowledge fits into the learner's mental structure (schema) then the new knowledge is taken into the structure with little change (assimilation). If the new knowledge does not fit the mental structure then some modification is done in mental structure and/or knowledge to fit the new knowledge. Piaget's theory of knowledge gave rise to the idea of constructivism. Constructivism suggest that the knowledge is not transferred, the learner interprets and builds it up (von Glassersfeld, 1982). Constructivism became very popular during second half of the twentieth century and numerous research have been done that supported constructivist view of learning.

In 1980's the focus of science education research has shifted from how students learn to what students already knew. Researches have shown that students have ideas before they come to science classes and these ideas are different from scientific views (Driver & Easley, 1978). Numerous terms were generated to call these ideas such as "misconceptions", "alternative frameworks" (Driver & Easley, 1978), "alternative conceptions", "naive beliefs" (Wandersee, Mintzes, & Novak, 1994). The common feature of these ideas was that they were very resistant to change (Driver & Easley, 1978). Over more than two decades science education researches focused on identification of misconceptions in many fields of science education (Duit, 2009).

Research on misconceptions had many benefits on science education literature. However, most importantly, it contributed development of different theories of conceptual change. Inspired from Piaget's assimilation and accommodation (1970) many theories were proposed to explain conceptual change. These theories could be divided in two categories: (a) theories based on Kuhn's coherence and (b) theories based on Toulmin's fragmentation (diSessa, 2006).

Kuhn (1996) proposed that concepts in science changes with revolutions in history of science. As an analogy, some of the theories of conceptual change proposed that conceptual change in learning proceeds in a similar way that the concepts of sciences changes (Posner, Strike, Hewson, & Gertzog, 1982). If an old concept fails to explain a phenomena than the concept is replaced by a better one. Several conceptual change models based on Kuhn's idea have been proposed. Conceptual change model proposed by Posner et al. (1982), mental frameworks proposed by Vosniadou (1994) and ontological shift proposed by Chi, Slotta and Leeuw (1994) were some of the models studied in science education. More detailed information about these models and about others can be found in Chapter 2.

Toulmin strongly criticized Kuhn's idea of coherence. According to Toulmin, different ideas about same concept can coexist (diSessa, 2006). diSessa proposed his model that he called as "knowledge in pieces". In his model, people have knowledge pieces that are called as p-prims (phenological primitives). These knowledge pieces do not have to be coherent, they can be consistent or inconsistent with scientific ideas. They never disappear. However, when the learner confronts with a new concept the functions of p-prims change to accept the concept into mental framework.

In this study, Conceptual Change Model proposed by Posner et al. (1982) was central idea. Therefore, concise information will be given in this chapter although more detailed information will be provided in Chapter 2. Conceptual Change Model has two major components: (a) the conditions that need to be satisfied for an individual to experience conceptual change, and (b) the individual's conceptual ecology "that provides the context in which the conceptual change occurs and has meaning" (Hewson & Thorley, 1989, p. 541).

There are four conditions that need to be satisfied before conceptual change can take place: (a) a dissatisfaction with the existing conception should occur, (b) the learner must find the new conception to be intelligible; (c) the learner must find the new conception to be plausible, and (d) the learner must find the new conception to be fruitful (Posner et al., 1982).

Hewson and Thorley (1989) describe two possibilities when a learner confronts a new conception. First possibility is that the new conception could be consistent with the existing ideas. If the learner finds the new conception intelligible, plausible and fruitful than the status of the conception rises and it is incorporated into the existing conceptions. However, second possibility is that the new conception could be inconsistent with the existing conceptions. The learner could find the new conception intelligible. In that case, the new conception cannot be plausible because it is in contradiction with the existing conceptions. In order to make it plausible, the status of the blocking element, the contradicting conception, should be lowered. If we let a student become dissatisfied with his/her old conception than he/she could find the new conception plausible and fruitful. Studies on conceptual change and elimination of misconceptions have been particularly interested in the second possibility because it is more difficult to achieve.

The conditions of Conceptual Change Model are very important, as each of them should be met in order a conceptual change occurs. However, the other component of Conceptual Change Model, conceptual ecology, is also very important. Posner et al. (1982) stated that "inquiry and learning occurs against the background of the learner's current concepts" (p. 212). Learner's current concepts or learner's conceptual ecology influences whether learner assimilates or accommodates the new concept. Thus, whether a condition is met or not greatly determined by the learner's conceptual ecology. Some of the important concepts that learner's conceptual ecology are anomalies, analogies, metaphors, epistemological commitments, metaphysical beliefs and concepts, and other knowledge.

1.2 Rationale for the Study

Many strategies have been used to implement Conceptual Change Model in classroom. One of the strategies involves the use of conceptual change text. Conceptual change texts are generated using the components of conditions of Conceptual Change Model (Roth, 1985). Its effectiveness has been tested (e.g. Chambers & Andre, 1997) and found to be effective. Its advantage over other strategies is that it can be implemented in large sized classes. However, since misconceptions could be very resistant to change (Driver & Easley, 1978), its effectiveness needs to be enhanced. Currently, conceptual change texts are used in traditional paper-based format that contain texts and, preferably, static images. However, development of electronic media seems to provide an alternative to this format.

With the recent developments in technology computers have been integrated in our daily life. The sizes of the computers are not as big as they used to be. Notebooks have similar size of a traditional book or pocket sized cell phones that have similar properties of a computer have advantage of mobility to bring knowledge source to anywhere the learner wants. Additionally, conventional and wireless internet is available to reach the needed information. The availability of computer and internet has somewhat changed the habit of knowledge acquisition. Studies (Akinoglu, 2002; Toruk, 2008) have shown that the influence of computers and internet on people's daily life activities including education has greatly increased. For example, e-mail almost completely replaced its paper-based counterpart. Few people use conventional mail nowadays. Same future could be awaiting the paper-based books because the usage of e-books is increasing especially with the increasing number of mobile e-book reading devices.

One of the advantage of using computers and internet over conventional paper-based is its multimedia feature. This feature has drawn attention of education research on computer-based learning. Especially, the idea of multiple presentation has given rise to studies on computer-based instruction. Multiple representations have emerged from the idea that instruction could be designed according to the work mechanism of human mind (Mayer, 2001). Research on learning with representations has shown that learners' performance improves when they interact with appropriate representation and their performance improves more when they interact with more than one representation (Ainsworth, 2006). Three theories were proposed to explain the benefit of multiple representations: (a) Dual Code Theory proposed by Paivio (1986), (b) Cognitive Load Theory proposed by Sweller, van Merrienboer and Paas (1998) and Cognitive Theory of Multimedia Learning proposed by Mayer (2001).

Computer-based instruction can provide better multi-representational learning than any other instructional type for the reasons that (a) computers can do everything that other devices (e.g. television, audio player, charts, etc.) do, (b) they can be programmed to interact with the students, and (c) they can be used for both class discussion and individual learning.

In current study, a different type of conceptual change text has been produced. This conceptual change text is a computer operated file prepared with a computer software. The difference of this computer-based conceptual change text is that it has properties of a paper-based conceptual change text with animations. Thus, both texts and animations are used as verbal and visual representations.

Another feature of the computer-based conceptual change text is its interactive interface. Students can control their learning with the interface. They can choose their idea on the text and see whether their idea is true or false. They can study the reason why their idea is not true as long as time permits. Students can construct their own learning in this way as suggested by constructivist view of learning.

1.3 Research Questions

This study has addressed the general research question: “Is conceptual change oriented instruction accompanied by computer-based interactive conceptual change text (CBICCT) effective on students’ conceptual change and attitude towards chemistry?” Based on this general research questions, following specific research questions were investigated:

1. What is the effect of the conceptual change oriented instruction accompanied by CBICCT and traditional instruction on students’ understanding of electrochemical cell and electrolysis concepts when science process skill is controlled as covariate?

2. What is the effect of gender differences on students' understanding of electrochemical cell and electrolysis concepts when science process skill is controlled as covariate?

3. Is there a significant interaction between method and gender with respect to student's understanding of electrochemical cell and electrolysis concepts when science process skill is controlled as covariate?

4. What is the effect of the conceptual change oriented instruction accompanied by CBICCT and the traditional instruction on students attitude toward chemistry?

5. What is the effect of gender differences on students' attitude toward chemistry?

6. Is there an interaction between method and gender with respect to students' attitude towards chemistry?

1.4 Null Hypothesis

The above-mentioned research questions were tested with the following null hypothesis:

$H_0(1)$: There is no significant mean difference between students taught with conceptual change oriented instruction accompanied by CBICCT and students taught with traditional instruction with respect to their gain scores obtained from Electrochemistry Concept Test when science process skill is controlled as covariate.

$H_0(2)$: There is no significant mean difference between male and female students with respect to their gain scores obtained from Electrochemistry Concept Test when science process skill is controlled as covariate.

$H_0(3)$: There is no significant interaction between instruction method and gender with respect to the gain scores obtained from Electrochemistry Concept Test when science process skill is controlled as covariate.

$H_0(4)$: There is no significant mean difference between students taught with conceptual change oriented instruction accompanied by CBICCT and students taught with traditional instruction with respect to their scores obtained from Attitude Towards Chemistry Scale.

$H_0(5)$: There is no significant mean difference between males and female students with respect to their scores obtained from Attitude Towards Chemistry Scale.

$H_0(6)$: There is no significant interaction between instruction method and gender with respect to the scores obtained from Attitude Towards Chemistry Scale.

1.5 Significance of the Study

Johnstone (1993) claimed that there are three components of chemistry: the macrochemistry (visible part), the submicrochemistry (invisible part such as atoms and molecules) and the representational chemistry (symbols of the elements, chemical equations, stoichiometri). Johnstone illustrated chemistry as a triangle and the three corners of this triangle were made of these three components of chemistry. He stated that without discussing all three components it is not possible to explore all chemistry subjects. Most of the misconceptions in electrochemistry are related to submicrochemistry component such as the movement of cations, anions and electrons, reactions occurring in solutions, and reaction occurring at electrodes. Therefore, strategies targeting the eliminations of misconceptions related to submicrochemistry component are more commonly needed. Two of the effective strategies are considered to be implemented in combination in the classes: (a) conceptual change texts and (b) animations.

Paper-based conceptual change texts were successfully used to eliminate misconceptions in electrochemical cells (e.g. Yuruk & Geban, 2001). However, it could be difficult to let students experience cognitive conflict and to change misconceptions because the movement of cations, anions and electrons, reactions occurring in solutions, and reaction occurring at electrodes are abstract concepts and traditional conceptual change texts could be inadequate to make these concepts intelligible. However, computer-based conceptual change texts used in this study include animations to help the students visualize these invisible processes, making these concepts more intelligible and thus, supporting conceptual change.

There have been studies investigating the effects of animations on students conceptual change (Sanger & Greenbowe, 2000) or the effects of conceptual change texts accompanied with animations (Ozmen, Demircioglu, & Demircioglu, 2009). However, interactive computer-based conceptual change text has not been found so far in literature. Therefore, this study contribute to the science education literature by providing a new type of educational material.

This material has two potential significance: (a) it can be used in classroom by integrating in any teaching method, and (b) it can be implemented on internet for students' usage as this material is also suitable for individual use. Any student who has a computer and an internet connection can reach this computer-based conceptual change texts at home. The number of course materials provided on internet is dramatically increasing and this study could contribute to the collected materials.

1.6 Definitions of the Terms

Traditional Instruction: an educational setting with face to face, sometimes one way, sometimes two way communication. In this setting, the teacher gives the lecture, asks questions (generally algorithmic problems) and answer the questions that students ask.

Conceptual change: The change in status of a concept a learner holds. In this study, conceptual change is the change in status of the concepts related electrochemistry topic measured by Electrochemistry Concept Test.

Conceptual Change Model: There are different conceptual change models. However, in this study, Conceptual Change Model is the one proposed by Posner et al. (1982)

Conceptual Change Text: A text generated using the components of conditions of Conceptual Change Model. The text used in this study is based on the study of Roth (1985).

Computer-based interactive conceptual change text: It is a computer operated file prepared with a computer software. It makes use of both texts and animations to help learners change their concepts.

Conceptual change oriented instruction accompanied by computer-based interactive conceptual change texts: In this instruction method, students learn concepts with the help of computer-based interactive conceptual change texts.

Animation: Dynamic images generated by the computer.

Simulation: An interactive copy of a natural event in which the result of the event is calculated and presented by the computer

Computer-Based Instruction: An instruction using the computer as the primary delivery method. In this study, however, computers are used only to prepare and implement conceptual change text in classroom

Attitude Towards Chemistry: Attitude measured by Attitude Toward Chemistry Scale (Geban, Askar, & Ozkan, 1992).

1.7 Assumptions

The following assumptions have been made in this study:

1. The participants responded honestly and accurately to all measures used in this study.

2. No interaction between treatment and control groups has occurred.

3. Reliability and validity of all measures used in this study are accurate enough to permit accurate assumptions.

1.8 Limitations/Delimitations

The following limitations are relevant to the present study:

1. The sample size in this study is limited by the number of students enrolled in an anatolian high school in Ankara.

2. The generalization could be made for the schools in the city of Ankara similar to the characteristics described in this study.

3. This study is limited to the schools with a computer laboratory.

4. Content of the chemistry topic is limited to electrochemical cells and electrolysis.

CHAPTER 2

REVIEW OF LITERATURE

In this chapter, literature about misconceptions, conceptual change, conceptual change texts, computer assisted instruction and teaching electrochemistry will be discussed. Conceptual change model used in this study mainly based on the model of Postner, et al. (1982) so the literature discussed will be around this model. Next, a review of the studies that have investigated the effects of conceptual change texts and refutational texts will be presented. Thirdly, computer assisted instruction, mainly its application in science education, was discussed. Last part is a literature review about the factors affecting teaching of electrochemistry and methods to overcome these difficulties.

2.1 Misconceptions

Over more than three decades, researches have been focused on students' conceptual understanding in science (Duit, 2009). In his book, Educational Pschology: A cognitive view, David Ausubel called students' ideas as "preconceptions (that are) amazingly tenacious and resistant to extinction" (Driver & Easley, 1978). Most of these studies have evidently showed that students' understandings in many fields of science are substantially different from the scientific views (Driver & Easley, 1978) and the studies admitted that generally these conceptions were very resistant to change (Driver & Easley, 1978; Wandersee et al., 1994). Driver and Easley (1978) and Wandersee et al., (1994) reviewed the terms for students' view and presented an analysis of the subtle distinctions in the usages of these terms. The terms, which stands for students' views of natural phenomena mentioned in Driver and Easley (1978) were "misconceptions", "alternative frameworks", "alternative interpretations", "preconception", "children's interpretations", and in Wandersee et al. (1994) "alternative conceptions", "naive beliefs", "erroneous ideas", "multiple private versions of science", "underlying source of error", "personal models of reality", "spontaneous reasoning" and "persistent pitfalls". In this study, the dominant term "misconceptions" has been adopted to refer students' conceptions that are not consistent with scientific views of natural phenomena.

Smith, diSessa, and Roschelle (1993) analyzed misconception literature and have found seven assertions that the researches have in common:

- *"Students have misconceptions"* (p. 118). Students have explanations to natural phenomena. However, their ideas are different from the scientific views; in other words, they have different concepts other then instructed in schools.

- *"Misconceptions originate in prior learning"* (p. 119). Students' conceptions originated from their interactions with their everyday life.

- *"Misconceptions can be stable and widespread among students. Misconceptions can be strongly held and resistant to change"* (p. 120). Misconceptions are not temporarily held by students. These ideas are very stubborn and stay even after the instructions.

- *"Misconceptions interfere with learning"* (p. 121). A number of researches in science and mathematics show that students' misconceptions interfere with the new concepts and obscure understanding of the content.

- *"Misconceptions must be replaced"* (p. 122). Majority of the studies insist that misconceptions are useless and should be completely dispelled and replaced by scientifically accepted concepts.

- *"Instruction should confront misconceptions"* (p. 122). In order to dispel misconceptions, instruction programs should target misconceptions; it is believed that if misconceptions are exposed to students and the concepts (alternative and scientific) are put in competition then students more likely leave their ideas and replace them with scientific one.

- *"Research should identify misconceptions"* (p. 123). Smith et al. found this assertion indirectly from the character of the researches as they appeared in literature to identify misconceptions in as many domains as possible.

Smith et al. (1993) had some criticism on part of these assertions mentioned above. They believed that some of the assertions contradicted with the constructivism. For example, the notion that misconceptions are resistant to change is trivial. The scientific concepts are believed to be more complex then misconceptions. Constructivism suggests that learners construct their own knowledge from simple to more complex. In that case, since misconceptions are simpler than scientific concepts than learners should have no difficulties to construct scientific concepts over misconceptions.

Another criticism of Smith et al. was about replacement of misconceptions with scientific concepts. They suggested that learning was not a simple process of replacing old idea (misconception) with new idea (scientific concept). This idea also contradicted with constructivist notion that new knowledge was gained with the help of old knowledge. If previous concept was discarded what source could the learners use to construct their knowledge.

Despite those criticisms, the misconceptions movement was very productive for science education. Smith et al. (1993) found out that its most important benefit has been its influence on the growth of research on science and mathematics because while a small amount number of research on science domain was conducted in 1970's, the number has been dramatically increased in 1980's and it has been still growing.

2.2 Conceptual Change

In science education literature the dominant belief is that learning is the change of learners' existent ideas (concepts) to new ideas they confront. Ausubel and Piaget had great impact on studies that investigate students' conceptual change. In the preface to his book Educational Psychology: A Cognitive View, Ausubel said that "If [he] had to reduce all of educational psychology to just one principle, [he] would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (1968, p. vi). The interaction of existing and new concepts was (probably) best described by Piaget (1970). In his development theory, Piaget implies that students will construct interpretations of newly learned material by *assimilating* it into existing schemes. If students cannot interpret new information, then existing concepts must be replaced or reorganized via the process of *accommodation*. Assimilation and accommodation is the core of conceptual change models (Posner, et al. 1982).

With the ample evidence of students' misconceptions in science classes, conceptual change theories have become important in science education (diSessa, 2006; Postner, et al., 1982). In many areas in the science, students have misconceptions and in order to eliminate these misconceptions, students should change their concepts. Currently, there is no consensus on how conceptual change occurs. In science education research, models which explain the mechanism of conceptual change are mainly based on two different views; the concepts are replaced or reorganized. Ozdemir and Clark (2007) have made a well organized overview about conceptual change theories. They grouped conceptual change theories under two perspectives; (a) the knowledge-as-theory and (b) knowledge-as-elements. Actually, these two perspectives are representatives of the ideas of two philosophers; Kuhn and Toulmin. While knowledge-as-theory perspective is based on Kuhn's coherence, knowledge-as-elements perspective is based on Toulmin's fragmentation (diSessa, 2006). These ideas (of Kuhn and Toulmin) were about how concepts changed in science. However, as an analogy, these ideas were applied to conceptual change in learning (diSessa, 2006; Postner, et al., 1982)

2.2.1 Models Based on Kuhn's Coherence

These models are influenced by Kuhn's ideas about how science changes through history of science. Kuhn was very much affected by Gestalt Theory and Piaget' assimilation and accommodation. In his book, The Structure of Scientific Revolutions (1996), he told us his ideas about how science progressed. Kuhn claimed that science progressed with revolutions in history of science. According to Kuhn, some new discoveries cause anomaly in normal science (activities that scientists focused on) because this discovery does not fit to current pattern of normal science. This anomaly causes a crisis in the normal science. Normally, normal science has a tendency to resist against this type of anomalies and most of the time it successfully suppresses these anomalies. However, some discoveries could not be suppressed very long time. At this point, a destruction/construction procedure commences and a new paradigm is established. Kuhn calls this process "Scientific Revolution" or "Paradigm Shift"

Kuhn (1996) advocated strong coherence of ideas. Two ideas could coexist if they are coherent, if not, one of the ideas replace the other one. Accordingly, Kuhn put the idea of "incommensurability" forward. Incommensurability suggests that when a new paradigm is constructed, the old one is completely deserted because of the very nature of normal science, the old paradigm will be suppressed by the new one, so the old and new paradigm cannot exist at the same time.

Inspired by Kuhn's description of conceptual change in science, educators suggested a similar procedure for conceptual change in learning (Carey, 1985; Posner et al., 1982; Strike & Posner, 1992;). Different models were developed based on Kuhn's coherence. Most widely applied model was developed by Posner et al. (1982). In science education literature, researchers refer the model developed by Posner et al. when they use the words "Conceptual Change Model". Different terms were used to distinguish this model such as Standard Model of Conceptual Change (Seyedmonir, 2000), "Cold" Model of Conceptual Change (Kutza, 2000) or Classical Conceptual Change Model (Duit & Treagust, 2008). In this study, the term Classical Conceptual Change Model will be used to refer the conceptual change model of Posner et al. (1982). This model will be explained in the next section.

Another model was proposed by Carey (1985). This model is based on incommensurability of concepts. Carey claimed that adult's and children's concepts are coherent but incommensurable. Change from one to another can be through three types of processes. First, one concept replace another in "replacement" phase. In "differentiation", the concept is divided into subconcepts or more specific concepts. In "coalescence", specific concepts are merged into more general concepts. The problem with this model is that it is domain specific. diSessa (2006) found this model to be suitable for biology learning as Carey's subject area is biology.

The third model is "The Theory Theory" which is advocated by Allison Gopnik. Gopnik (2003) claimed that children have theories about concepts in the same way the scientists do. Children investigate the phenomena around them and establish coherent rules to explain them, i.e. they build their own theories. Children continuously test their theories, like scientists. When their theories are falsified with many observations and testings they build alternative theories. If the alternative theory is more satisfied to them than it replaces the old one. In general, the theory theory is a model for both cognitive development and scientific development. This model explains why misconceptions are so resistant to change; because they are innate theories developed using the same way that scientists do.

Vosniadou (1994) presented another model of conceptual change. She suggested that learner's mind operates on the basis of a few domain-specific constraints (or in Vosniadou's terms, "entranched presuppositions"). These constraints are organized in a theoretical structures, which she called as framework theories. Framework theories are constructed in early childhood and are not available to conscious awareness and hypothesis testing. Framework theories constrain the flow of knowledge just like Kuhn's paradigms. Learners also have specific theories. A specific theory contains interrelated propositions or beliefs that describe dailylife experiences or phenomena. Specific theories are created through observation or social environment of the learner. However, specific theories are constrained by the framework theory. To distinguish these two terms, Vosniadou gave an example related to heat in physics. The belief “hotness can transfer from one object to to another which is less hot by direct contact” (p. 48) is a specific theory. The framework theory which constrains this belief is that “hotness is a transferable property of physical objects” (p. 48). Vosniadou also used the term “mental models” to describe learners’ epistemological beliefs. Mental models are mental representations generated to explain and to predict phenomena in the physical world. Since the mental models are generated from specific and framework theories, they can be used to obtain valuable information regarding these knowledge structures. Vosniadou describe her conceptual change model using these three key constructs (framework theories, specific theories and mental models). In her model, she claimed that learners could go through two types of conceptual change. The simplest one is “enrichment” which is “the simple addition of new information to an existing theoretical framework through the mechanism of accretion” (p. 49). This type of conceptual change is easy because the new information is consistent with the knowledge structures, so a new mental model could be easily created. However if the new information is inconsistent with the specific theories or framework theories than the other type of conceptual change, “revision”, is needed. Vosniadou claimed that revision is easier when the new information is inconsistent with the specific theories only. Since specific theories are relatively smaller knowledge structures they can be changed more easily. However, if a revision of a framework theory is needed than the conceptual change becomes much more difficult because a coherent structure should be changed. In her conceptual change model, Vosniadou described three cases if unsuccessful revision happened. If the information is not added to framework theory than “inconsistency” occurs where learners use same old mental after instruction. If information is added to a separate structure and used only in certain occasions (e.g. school exams) than “inert knowledge” is produced. “Misconceptions” occurs when the inconsistent information is forced to coexist with the old information. Vosniadou calls this model as synthetic mental model. Some examples of syntheticcccc mental models were investigated such as mental models of earth in Vosniadou (1994) and Vosniadou and Brewer (1992), mental models of day/night cycle in Vosniadou (1994) and Vosniadou and Brewer (1994), and mental models of heat in Vosniadou (1994). Vosniadou (1994) argued that unsuccessful revision is caused by lack of metaconceptual awareness. Instructions should be designed to let students know their own knowledge structures and the mechanism of conceptual change.

Another model of conceptual change was developed by Chi, Slotta, and Leeuw (1994). This model has three assumption. First assumptions is that that entities in the world belong to three different ontological categories: matter (or things), processes, and mental states. There are also several subcategories embedded within each major category. Some of the subcategories also have subcategories. So, a hierarchy of subcategories continues. For example, the processes category is divided into "procedure," "event" or "constraint–based interaction" subcategories. Matter category is divided into "natural kind" and "artifacts," and the mental states category is divided into "emotional" and "intentional." Each category differs from the others since they do not have similar ontological attributes. Chi et al. defined ontological attribute as "a property that an entity may potentially possess as a consequence of belonging to that ontological category" (p. 29). For matters, for example, "being containable", "storable", "having volume, "having mass" are some ontological attributes.

Second assumption is that many scientific concepts belong to "constraint-based interaction", which is a subcategory of "process" (Chi et al., 1994). Constraint-based interactions are limited by a known or knowable set constraints or defined by contrasting them with "events", which is another "process" category. Chi et al. pointed out that constraint-based interactions involves components of other ontological categories and this makes this category a bit problematic.

According to Chi et al. (1994), third assumption is when students assign concepts to categories to which they don't belong misconceptions arise. For example, if students put electrical current under the "liquids" subcategory (probably because of the analogies in textbooks) then electrical current can have properties such as "has volume" or "occupies space".

Chi and Roscoe (2002) claimed that, in this model, a ontological shift is needed in which students reassign their concepts into correct ontological categories. To do this, first of all, lack of awareness should perish (like in Vosnidou (1994) i.e. students should be confronted with the incorrect assignments.

2.2.2 Models Based on Toulmin's Fragmentation

While perspectives based on coherence are dominant within science education community, increasing support to perspectives based on fragmentation can be found in science education research (Clark, 2006; diSessa, 2006; Ozdemir & Clark, 2007; diSessa, Gillespie, & Esterly, 2004). These perspectives represent opposite of Kuhn's coherence: Toulmin's fragmentation view in which revolutionary change view is criticized and instead of a whole framework, science has seen as a sum of localized pockets (fragments) (diSesse, 2006). Science changes as these pockets change just like the evolutionary process in biology.

diSessa (2002, 2006) proposed most well known model of this perspectives which he called as "knowledge in pieces". In his model there are different knowledge types ranging from p-prims to coordination classes (nominal facts, narratives and mental models inbetween (diSessa, 1996, 2006)). The simplest knowledge form is p-prims (phenomenological primitives). According to diSessa (2002), p-prims are isolated, individual knowledge elements. In this way, they don't need to be coherent. However, diSessa characterized p-prims as atomic because although they are isolated they are evoked as a whole. P-prims are used to explain phenomena but they cannot be explained. For example, "Force as a Mover" (diSessa, p. 40) explains movement of a subject on which a force applied. However, no one needs a justification for this p-prim because everybody knows that "things go in the direction you push them" (diSessa, p. 40). Sometimes conflicts between p-prims can occur but this conflict cannot be solved. diSessa emphasized that p-prims cannot be extinguished or replaced by scientific concepts, however, many of them change their functions as scientific concepts.

diSessa (2002) discussed also coordination classes, which are more complex knowledge pieces. Unlike p-prims, coordination classes may contain other knowledge types including p-prims. Naive minds could have p-prims, however, they do not necessarily have coordination classes. To relate with more familiar terms, diSessa argued that coordination classes are models for scientific concepts and theories contain coordination classes.

In his model, diSessa (2002) argue that conceptual change occurs when p-prims change their functionality. diSessa also propose that misconceptions could be fixed when, unlike the models proposing replacement of concepts, students establish correct coordination classes with appropriate p-prims and other knowledge elements. Similar to other models, diSessa suggested students' awareness of their knowledge to establish coordination classes.

2.3 Classical Conceptual Change Model

As mentioned before, conceptual model developed by Posner et al. (1982), which is referred as Classical Conceptual Change Model (CCCM), has so much affected research on conceptual change that it has dominated science education literature.

CCCM is affected by three philosopher: Thomas Kuhn, Irme Lacatos and Stephan Toulmin (Postner et al., 1982). Postner et al. argued that conceptual change in science and conceptual change in learning are resembled therefore conceptual change could be explained using an analogy to conceptual change in science. Posner et al. pointed out two phases of conceptual change in science. First one is the work against the central commitments which organize scientific research. These commitments usually deal with the problems; they act like a buffer that blocks instant changes. Thomas Kuhn called these commitments paradigm or normal science and Irme Lacatos called them as research programs. Similarly, Posner et al. indicated that students use their existing ideas to deal with new phenomena which they called as assimilation. The second phase of the conceptual change in science which Posner et al. inspired by involves the situations in which the commitments could not deal with the new phenomena and therefore needed modification. Kuhn called this phase as scientific revolution or paradigm shift and Lacatos called as change of research programs. Posner et al. argued that students also could confront situations in which their concepts were inadequate to deal with new phenomena. In that case, they must replace or reorganize their concepts. Posner et al. called this phase as accommodation.

In CCCM the main focus is how accommodation takes place (Posner et al., 1982). The model consists of two major components: (a) the conditions that need to be satisfied so that the person successfully completes the conceptual change process, (b) individual's conceptual ecology (or existing concepts) that provides suitable context in which conceptual change occurs (Hewson & Thorley, 1989).

2.3.1 Conditions of Conceptual Change

There may be many conditions to be satisfied. However, CCCM focused on four important conditions: (a) there must be dissatisfaction with current conceptions, (b) a new conception must be intelligible, (c) a new conception must be plausible, and (d) a new conception should be fruitful. (Posner et al., 1982)

In order to consider the new conception as alternative conception it must be intelligible to the learner. If the new conception has little meaning to the learner no other conditions can be fulfilled. Hewson and Thorley (1989) point out the importance of intelligibility like this:"Without intelligibility, a conception has no status to a person and cannot become either plausible or fruitful" (p.542). The learner must understand the meaning of the terms. However, understanding what the terms or symbols mean is not enough. The learner should build coherent representation of the conception "in the form of propositions, images or networks of interrelated propositions and/or images" (Posner et al., 1982, p. 216).

The conception must be initially plausible, i.e. the learner should see the new conception logical and true. The conception should fit into the learners' existing knowledge structure (or conceptual ecology) (Posner et al., 1982). If the new conception is inconsistent with the existent knowledge structure, it cannot be a good candidate to replace the old idea because the learner cannot integrate it into his/her system.

Once the new conception is intelligible and plausible, the learner checks its usefulness in his/her knowledge system. Does new conception solve the anomalies? Does it lead to new insights and discoveries? If the answers of these questions are "yes" then the new conception will be fruitful and the accommodation becomes easier (Posner et al., 1982).

Fourth condition, dissatisfaction, is the elimination mechanism. Hewson and Thorley (1989) termed the first three conditions as status of a person's conception. They stated that once these three conditions are fulfilled the status of the new conception will be raised, i.e. the conception is changing. However, if the new and old concepts are not coherent (as it is very likely in accommodation) two conceptions cannot coexist according to Kuhn's incommensurability (1996), one of them should be abandoned. At this point dissatisfaction decides which one will be. The conception with lower status (Hewson & Thorley, 1989) or the one, which encounters difficulties to solve problems (Posner et al., 1982), will most likely be abandoned. Therefore, it can be claimed that dissatisfaction unplugs the old conception from the learners knowledge system.

2.3.2 Conceptual Ecology

Second component of conceptual change is conceptual ecology. Posner et al. (1982) stated that they took this term from Toulmin (although Toulmin criticized Kuhn's strong coherence which is the central idea of CCCM) to "refer to those concepts which govern a conceptual change as a conceptual ecology" (p. 213). Hewson and Thorley (1989) defined conceptual ecology as major component that "provides the context in which conceptual change occurs and has meaning" (p. 541). Posner et al. (1982) found out that some concepts are important factors to determine the course of the accommodation. These are: (a) anomalies, (b) analogies and metaphors, (c) epistemological commitments, (d) metaphysical beliefs and concepts and (e) other knowledge such as knowledge in other fields and competing concepts.

Conceptual ecology has a very important role in conceptual change. The four conditions, which need to be fulfilled, are closely related with learner's conceptual ecology. All conditions happen within the boundaries of conceptual ecology. For example, a concept cannot be intelligible if learner's conceptual ecology is not suitable, or Posner et al. (1982) claimed that a concept is plausible if it fits into the learner's conceptual ecology.

2.3.3 Revision of Initial Model

After Posner et al. (1982) proposed their initial model, strong criticism leveled at CCCM. First, some researchers (e.g. Smith et al., 1993) have criticized the idea that student knowledge is coherent and theory-like. Smith et al., advocate the idea that the knowledge is fragmented and each fragments are used in the development of new concepts. They thought it unlikely occurs that an old concept is replaced by the new concepts because they are incoherent. Based on constructivist view of learning they proposed that the old idea should be the knowledge on which the new knowledge will be constructed.

Another critics has been made by Pintrich, Marks, and Boyle (1993). They called CCCM as "Cold" Conceptual Change Model because they thought that instructional studies in the conceptual change literature ignored motivation component that are part of conceptual change. They argued that CCCM is too rational; the model overemphasized cognitive process and neglected the affective variables that are part of learning, e.g. motivational beliefs.

As a response to critics, Strike and Posner (1992) proposed a revision of initial CCCM. They presented a critique to initial model. In their revision, (a) they shifted their emphasis from misconceptions to conceptual ecology and disagreed their previous symbolic representation of misconceptions. (b) they proposed that scientific conceptions and misconceptions are part of the conceptual ecology; they cannot be thought as separate cognitive objects which are affected by conceptual ecology and conceptual ecology should be seen as a dynamic and developing patterns of the components, and (c) they also accepted the role of motivational beliefs in conceptual change and suggested a larger idea of conceptual ecology to include social components such as motives and goals.

2.4 Conceptual Change Texts

CCCM was initially developed as an epistemological framework and Posner et al. (1982) recommended teachers to develop teaching strategies that (a) create cognitive confilicts among students, (b) help the teachers to investigate the characteristics of students' ideas about concepts, (c) help the teachers to deal with students' misconceptions, (d) help students understand science conctent by giving contents in multiple modes, and (e) help teachers to monitor conceptual change. Posner et al. emphasized in their study that they did not answered the questions of whether their recommendations could be implemented and whether the implementation would be effective. However, large body of literature about implementation of CCCM showed that strategies based on CCCM could be implemented in science classrooms and these strategies were effective. One of the proposed instructional strategies used in science education research is conceptual change texts. Conceptual change texts are designed to supplement teachers (and their methods) in classroom. Other conceptual change strategies are very appropriate for small-sized classrooms. (Chambers & Andre, 1997). However, conceptual change using these strategies is more difficult accomplished in large-sized classes because identifying misconceptions, engaging students into conditions of conceptual change and monitoring whether the conditions of conceptual change have been met are very difficult processes.

Using conceptual change text in class may have two benefits. The first one stated by Chambers and Andre (1997) is that in large-class situations, changing features of the texts and adding components of conditions of CCCM to help promote conceptual change may facilitate student construction of scientific conceptions. Even in small-class situations, where other conceptual change methods are used (or not used), conceptual change texts could supplement in-class instruction and may help teachers teach in a way that promotes conceptual change.

Second benefit could be creating better science textbooks that enable students to replace misconceptions with scientific conceptions (Tasdelen & Koseoglu, 2008). Tasdelen and Koseoglu reviewed the literature for alternative texts and found that studies have been made about conceptual change texts, refutational texts, learning cycle texts, analogy texts, and inquiry texts. Among them, conceptual change texts and refutational texts were more widely used in classrooms. Research on conceptual change texts (Roth, 1985; Chambers & Andre, 1997) and on refutational texts (Guzetti, Williams, Skeels, & Wu, 1997; Palmer, 2003) showed that these texts were effective in changing student's misconceptions. Conceptual change texts and refutational texts are very similar; they are both based on CCCM. The only difference is that that in conceptual text, before giving the information that shows the inconsistency, students are asked to make predictions about the situation (Chambers & Andre, 1997).

Early attempts to create conceptual change text was traced to Roth (1985). What Roth did different from textbook writers were (a) collecting knowledge of middle grade students misconceptions about photosynthesis and food for plants and (b) obtained documentation of difficulties encountered by students. Roth integrated experiments included in Science Curriculum Improvement Study to the text. The text was manipulated so that the conditions of conceptual change was intended with the text's features. The text first asked question like, "How do you think plants get their food?" or " How would you define food?" to surface the hidden misconceptions of the students. Then, the text showed in a narrative way that the misconceptions they had are wrong (dissatisfaction) and than presented them the scientific explanation with concrete examples and/or evidences so that it made the explanation intelligible and plausible. For example, in Roth, the text provided an explanation of scientific concept of photosynthesis. Finally, the text provided example of key concepts and asked numerous application question to help students apply new concepts to different situations which contradicted with old concepts (fruitfulness). Roth prepared this text and compare it with two commercially available text with the same content. He analyzed the results of the study and found that students made sense of the disciplinary concepts in a meaningful way when they read the text with conceptual change strategy. Other two commercial texts were not effective in terms of conceptual change.

In another study, Chambers and Andre (1997) studied the relationship between gender, interest and experience in electricity, and conceptual change text manipulations on a simple current concept. Chambers and Andre created a conceptual change text about a physics topic and compared with traditional text. The conceptual change text was prepared in a similar way Roth (1985) did in his study. In their study, Chambers and Andre (1997) found that conceptual change text they prepared was effective in conceptual change. Moreover, Chambers and Andre found that conceptual change text worked both female and male students effectively.

Mikkilä-Erdman (2002) compared the effects of different text designs in her study. She created a conceptual change text about photosynthesis and compared it with a traditional text taken from a science textbook. However, in her conceptual change text design, no refutation part was used. Instead, the differences between misconceptions and scientific explanations were systematically emphasized in seven parts which she called as metaconceptual text units. Both texts were implemented to 200 students, 10-11 years of ages, as reading and understanding session. Analyzing the data, Mikkilä-Erdman found that conceptual change text helped students construct more relevant mental model and improved students' concepts about photosynthesis.

In a very recent study, Alkhawaldeh and Olimat (2010) investigated the effect of conceptual change texts accompanied by concept mapping instruction on eleventh grade students' understanding of cellular respiration concepts. They prepared a conceptual change text covering the concepts of anaerobic respiration, glycolysis, and aerobic respiration. Each text started with asking questions, giving possible answers, which were students' ideas contradicting with scientific ideas, and mentioning that these answers were wrong, then they gave scientific explanations in a plausible, intelligible way. They also introduced examples and figures to increase the fruitfulness of the ideas. After implementing conceptual change texts in the classroom, students were asked to draw their own concept maps. At the end of the study, results showed that students taught with conceptual change texts were significantly better in terms of their delayed posttest scores.

In last decade, a number of studies about conceptual change texts have been conducted in Turkey, too (e.g. Balci, 2006; Cakir, Geban, & Yuruk, 2002; Geban & Bayir, 2000; Gunay, 2005; Kose, Ayas, & Usak, 2006; Özmen, Demircioğlu, & Demircioğlu, 2009; Pabuçcu, 2004; Sungur, Tekkaya, & Geban, 2001; Yuruk & Geban, 2001). The current increasing number of studies about conceptual change texts shows that researchers in Turkey continously contributing to literature about conceptual change texts. While studies about conceptual change texts in world literature generally focused on topics of physics and biology, examples of studies investigating the effectiveness of conceptual change texts on concepts about chemistry as well as physics and biology can be found among the research conducted in Turkey. For example, Yuruk and Geban (2001) compared conceptual change oriented instruction with traditional instruction. They prepared a conceptual change text about electrochemical cell concepts and used as text material in a conceptual change oriented instruction in experimental group. In control group, traditionally designed instruction was used. Yuruk and Geban stated that after statistical analysis, students who took conceptual change text oriented instruction developed better understanding of concepts that were consistent with scientific concepts.

Özmen et al. (2009) investigated the effects of conceptual change texts on another chemistry topic – chemical bonding. They prepared conceptual change text related misconceptions about chemical bonding and implmeneted it in experimental group with the help of computer animations. They found that while no significant difference with respect to concept test scores was found between groups before implementation, students in experimental group performed significantly better than control group with respect to posttest and delayed posttest scores.

Studies on topics of biology and physics, though relatively less than the number of the studies about chemistry topics, were also conducted in Turkey. For example, Sungur et al. (2001) used conceptual change texts about human circulatory system with concept maps to increase effectiveness. Students in experimental group were taught with conceptual change texts accompanied by concept mapping instruction and students in control group were taught with traditional instruction. They found that students instructed with conceptual change text accompanied by concept mapping instruction were more successful in overcoming misconceptions. Another example is about a concept of physics. Şahin and Çepni (2011) investigated the effects of conceptual change texts on eighth grade students' understanding of gas pressure concept. They prepared conceptual change text related gas pressure concept and supported the text with concept cartoons, animations, and Diagnostic Branched Tree. They described how they prepared the conceptual change texts and implemented to a group of eighth graders. No result was given in the study, however.

In conclusion, research on both conceptual change and refutational change texts showed that these texts types were more effective than traditional texts. For example, a meta analysis study conducted by Guzzetti, Snyder, Glass, and Gamas (1993) statistically examined 25 studies about refutational texts and indicated that refutational texts are more effective than traditional texts in producing conceptual change.

2.5 Computer Assisted Instruction

The influence of technology on our daily life is unstoppably increasing. We are surrounded by cell phones, computers, mp3 players, LCD televisions and other electronic appliances. Great majority of the people accept the indispensability of technological devices.

There is a common myth among people that technology and the science are the same (McComas, 2002). Moreover, two extreme views also exist (Benenson, 2001). One view is that technology is an application of science. On the other hand, other view states that science is nothing without the use of technology. However, both are incorrect. The science and technology are so closely related that people make mistakes. Both science and technology mutually benefit each other. Many scientific developments made use of technology and many technological developments required scientific knowledge.

The technology is perceived in different ways in education. According to Benenson (2001), the definitions of technology, for some people, is teaching students the use of computers, for others, technology is a branch of vocational studies. Benenson argued that there is a bias that technology mainly consist of computers. However, computers are not different from notebooks, papers, or pencils; they are all tools. Benenson included hardware as well as software in the definition of technology. Benenson’s broad definition consisted of (a) everyday stuff as well as high technology, (b) cooperation rather than competition, (c) analysis and design, (d) the multiple (and often conflicting) criteria needed to evaluate nearly all of technology, (e) problems of importance to children, and (f) software as well as hardware.

In education, especially in science education, educational goals are motivated by people’s technological needs and experiences. Olson (1992) stated that most people like to know more about their environments and to have some influence on them because the technology designs their environments they live in for their benefit but generally without their contribution. As people's awareness increases, the need for technology literacy also increases.

The curriculums also recognized the importance of technology in education. For example, The Project 2061 Benchmarks states that:

> Young children are veteran technology users by the time they enter school. They ride in automobiles, use household utilities, operate wagons and bikes, use garden tools, help with the cooking, operate the television set, and so on. Children are also natural explorers and inventors, and they like to make things. School should give students many opportunities to examine the properties of materials, to use tools, and to design and build things. Activities should focus on problems and needs in and around the school that interest the children and that can be addressed feasibly and safely. (American Association for the Advancement of Science, 1993).

A recent curriculum reform in Turkey also increased the emphasis on technology. In 2004, elementary science curriculum was changed. The new curriculum (Talim ve Terbiye Kurulu Başkanlığı, 2005) changed the name of elementary science course as "Science and Technology". Another major change is that a new strand has been added. This new strand, "Science, Technology and Society" has aimed to emphasize the interaction among science, technology and society.

2.5.1 Multiple Representations

The use of technological developments in education has been more popular with the increasing number of research on multiple representations (e.g. Ainsworth, 1999, 2006). Mayer (2001) used multimedia learning instead of multiple representations and defined multi-representational learning as "learning from words and pictures" (p.3). The words can be printed or spoken and the pictures can be static or dynamic (Mayer & Moreno, 2003). Mayer (2001) stated that multiple representations emerge from the idea that instruction could be designed according to the work mechanism of human mind. Research on learning with representations has shown that learner's performance improves when they interact with appropriate representation (Ainsworth, 2006). Currents researches on multiple representations assume that increasing the number of representation also increase performance. Ainsworth, (1999) claimed that one of the benefit of using multiple representation is that using more than one representation it is more likely to capture students' interest. Once students' interest captured, teachers could have a good opportunity to promote conditions of effective learning. Ainsworth (1999, 2006) argued three functions of the use of multiple representations – complement, constrain, and construct. The complementary role is that any weakness of one representation could be supported by others. Together they more likely establish a flawless process. The second one, constrain function is that any misinterpretation of one of the representations could be constrained by another representation, which is more familiar to the learner. Third function is that multiple representations help students generate a deep understanding of a situation.

Three popular theories are to explain learning with multiple representations. These are Dual Code Theory proposed by Paivio (1986), Cognitive Load Theory proposed by Sweller, van Merrienboer, and Paas (1998) and Cognitive Theory of Multimedia Learning proposed by Mayer (2001).

2.5.1.1 Dual Coding Theory

Paivio's dual coding theory explains how verbal and symbolic knowledge is integrated into students' mental framework. Paivio (1986) proposed human cognition could deal simultaneously with verbal and symbolic knowledge. Each knowledge (verbal and symbolic) is processed by separate subsystems, one is for processing verbal knowledge and the other one is for processing for symbolic knowledge. These subsystems are structurally and functionally distinct. They can be active without the other one. However, these subsystems are also interconnected. If one is active, the other can be activated, too. The quality of processing is different when one is activated with other then when activated without other. It means that a student can have better understanding of a concept when experienced both verbal and visual (symbolic) instruction than when experienced only verbal or visual instruction.

2.5.1.2 Cognitive Load Theory

Sweller, van Marrienboer, and Paas (1994) maintained that learners have a limited working (short-term) memory and a long-term memory with great capacity. The working memory load is lower when the elements are uninteracted or isolated. Learning isolated elements allows serial learning rather than simultaneous one. For example, learning symbols of periodic table needs less workload, the knowledge is transferred to long-term memory with little processing. When highly interacted elements are entered in working memory, the elements need to be processed which cause heavy workload to working memory. For example, learning the grammar of a foreign language causes high working load to working memory. This activity is categorized as Intrinsic Cognitive Load (Paas, Renkl, & Sweller, 2003). It is called intrinsic "because demands on working memory capacity imposed by element interactivity are intrinsic to the material being learned" (p. 1). According to Mayer and Moreno (1998), presenting the content through both verbal and visual representations reduces the load in each working memory.

2.5.1.3 Cognitive Theory of Multimedia Learning

Cognitive Theory of Multimedia Learning has used some features of Dual Coding Theory and Meaningful Learning (Mayer, 1997). Mayer's theory has three underlying assumptions: dual channels, limited-capacity and active processing. The verbal and nonverbal objects are received through either eyes or ears in the information processing system. Similar to dual-coding view, pictures and words are selected and registered into memory separately. There are two separate memory systems for verbal knowledge and visual knowledge, each has limited capacity. The selected words or images are then organized in a coherent way. All selected words are associated each other to build a verbal model and all selected images are associated each other to build a visual model. After that, there can be transformations between verbal and visual memory systems. At the end, the learner construct a mental model based on received verbal and visual information.

2.5.2 Multiple Representations in Chemistry

Research on multiple representations has been of particular interest in the area of chemistry (Ardac & Akaygun, 2004, 2005; Kozma, 2003; Sanger, 2000; Sanger & Greenbowe, 2000; Wu, Krajcik, & Soloway, 2001). According to Johnstone (1993), there are three components of chemistry: the macrochemistry (visible part); the submicrochemistry (invisible part such as atoms and molecules) and the representational chemistry (symbols of the elements, chemical equations, stoichiometri). Johnstone illustrated chemistry as a triangle and the three corners of this triangle were made of three components of chemistry. While learning chemistry, students should concentrate on three components to explore inside the chemistry triangle. Johnstone criticized that old chemistry generally ignored the submicrochemistry and concerned only with other two components. As a result, students did not explored most of the inside of chemistry triangle although chemistry could learn best in the area near the submicrochemistry corner.

Many studies on different chemistry topics have shown that representations of microscopic phenomena corresponding to observable phenomena improve conceptual understanding of the domain. For example, in a study by Ardac and Akaygun (2004), a group of students received multimedia-based chemical change instruction that emphasized concept representations at the molecular level and another group received regular instruction. At the end of the instruction, the group who received multimedia instruction outperformed the other group receiving regular instruction in terms of their posttest scores. Ardac and Akaygun (2005), in another study, investigated the effects of static and dynamic visuals on students understanding. Three instructional conditions were compared; dynamic visuals on individual-based instruction, dynamic visuals on whole-class instruction and static visuals on whole-class instruction. Third study showed that students who used dynamic visuals performed better than the students who used static visuals. Moreover, students who used dynamic visuals individually developed more coherent concepts than the students who used dynamic visuals in whole class lecture. Finally, Sanger (2000) conducted a study involving students’ conceptions of pure substances and mixtures. He showed that students who received molecular instruction performed better in answering conceptual questions at the molecular level

2.5.3 The Role of Computers in Education

Teaching with multiple representations is actually not a new idea. It can be traced back to the programmed instruction (Skinner, 1958). In his work, Skinner said:

> There are more people in the world than ever before, and a far greater part of them want an education. The demand cannot be met simply by building more schools and training more teachers. Education must become more efficient. To this end curricula must be revised and simplified, and textbooks and classroom techniques improved. In any other field a demand for increased production would have led at once to the invention of labor-saving capital equipment. Education has reached this stage very late, possibly through a misconception of its task. Thanks to the advent of television, however, the so-called audio-visual aids are being reexamined. Film projectors, television sets, phonographs, and tape recorders are finding their way into American schools and colleges. (p. 969)

Skinner was a behaviorist psychologist. He intended to design a technology based on setting up specific forms of behavior by arranging appropriate "contingencies of reinforcement," to control specific classes of stimuli. He called this technology as "teaching machines". At that time, student centered instruction had been popular and Skinner was one of the proponents of this view. In his attempt, teaching machines were intended to take the role of teachers. Skinner claimed that this machine was a mediator which brought the student into contact with the person who produced the material. With this machine, more students could be thought at the same time like mass production. Skinner also noted that his aim was not completely replace teachers with machines; he aimed to decrease the load or burden of teachers so that teachers could teach more students with more efficiency.

The audio-visual aids were limited to television sets, video players, and audiotape players till the end of 1980's. However, these devices provided linear knowledge, i.e. knowledge was given without interaction. Teachers controlled the information flow and students had no role in this instruction. In 1980's personal computers appeared for educational and household uses. However, these early personal computers were expensive and had limited capacity. They were operated on text-based interface and they could show only text base materials and still images. They had games too but with very decent graphics. During 1990's, with the technological development, computers became more affordable and usable. More powerful hardware enabled the development of operating systems with audio-visual interface in computers. Computers became alternatives for video players, TV sets and audiotape players and served as a device that could show texts, still images, films, games, and audio. Not only it gathered the specifications of other devices but also it provided the opportunity to have students interact with these audio-visual aids; students could choose the knowledge they wanted. This property made computers a wonderful candidate for constructivist view of learning that proposes that learners should construct their own knowledge.

Today, computers can do virtually anything other tools (electronic or non-electronic) do. Thus, there is no surprise that computer applications are primary materials for multiple representations. Majority of computer programs used for multiple representations consist of either animations, simulations or both of them. Since educational computer programs contain either or both of them, these terms and their usage in education need to be explained.

2.5.4 Animations

Recent advances in technologies give rise to the usage of highly illustrated materials like animations for instruction rather than traditional text-based materials (Lowe, 2003). Animations present the learners a copy of natural phenomena. Burke, Greenbow, and Windshildt (1998) define animations as "a series of visual images displayed in rapid succession on a computer screen, providing the illusion of motion" (p. 1658). These dynamic images can show the learner events that can be seen with the human eye. Why are the animations needed if we can observe the real one? The answer is simple. Many phenomena cannot be observed in classroom. Some of them are too dangerous for students to observe such as chemical reactions. Some of the phenomena need very long time to occur such as growing of a plant. Some of the phenomena need expensive equipments or materials. Animations can provide virtual observation of phenomena free of danger, much cheaper and as fast or as slow as the learners want.

Animations can show also phenomena which cannot be observed such as reactions at molecular level. Many misconceptions in chemistry are about phenomena at microscopic level (e.g. Horton, 2007). Therefore, most of the studies have investigated the effect of animations on students' conceptions about chemical phenomena at microscopic level. In many studies, animations have been found to improve student's understanding of chemical phenomena at microscopic level when compared to regular instruction with static images. (Sanger, Brecheisen, & Hynek, 2001; Sanger & Greenbowe, 2000; Yang, Andre, & Greenbowe, 2003). Sanger et al. (2001), for example, found that most of the students who watched two animations before conducting laboratory experiments less likely selected responses suggesting that particle motion stops after equilibrium is reached. Yang et al., (2003) observed that students who watched animations about chemical reactions performed better on content tests compared with students viewing static diagrams

With the development of internet, it is very easy to find commercial or free animations. However, it is not always easy to find animations that are suitable for the goals of the instructions. Furthermore and worse than this, if the commercial or free animations contain conceptual errors, they can have students developed more misconceptions just as images in textbooks did. For these reasons or possibly for other reasons the instructors need to develop their own animations. Burke et al. (1998) pointed this issue in their study and established a guideline to develop and use computer animations. They suggested that, first of all, a single concept should be identified and the second step should be construction of an outline. Burke et al. advised to develop animations which (a) are short (20-60 seconds per concept), (b) have an accurate subject content, (c) preferably contain accompanying text and/or narration, (d) have nonlinear navigation with detailed, clear, navigation buttons,

(e) address misconceptions reported in literature, (f) are interactive, based on students engagement, (g) have assessment and give feedback, (h) are suitable to publish on internet or local area network, (i) are pretested on faculty, students and classrooms, (j) provides an opportunity to construct knowledge, (k) could be used on different computer platforms (PC or Macintosh), and (l) does not violate copyright

2.5.5 Simulations

Computer simulations are software that "represent the dynamic responses of one system by the behavior of another system modeled after it" (Encyclopedia Britannica Online, 2010). In science, simulations are used to study visible or invisible natural phenomena. For example, an acid base simulation enables the learner perform acid-base reactions without taking the risk of working with real acids and bases (Clarke, 2001).

Although simulations and animations are different softwares, people confuse these terms most of the time. Animations are just image sequences which present a natural process. On the other hand, simulations can use texts, still images or animations to present a natural process. Learners can manipulate the conditions in simulations and can observe same event as it happens in real world. Simulations are based on scientific models and mathematical equations; they are virtual experiments to observe virtual events representing real events.

Clarke (2001) indicated two significant benefits over other learning methods. First one is motivation. He claimed that learners find simulations very motivating because they are environment that challenge students. Second benefit is simulations are very effective in transferring learning because students confront same context that they live in.

A number of studies showed that computer simulations are effective in students' learning and skills (Geban et al. 1992; Akpan & Andre, 2000; Trundle & Bell, 2010; Trey & Khan, 2008). Geban et al. (1992) showed that computer simulated experiments enabled students gain variety of scientific skills and enhance their achievement in chemistry. Trundle and Bell (2010) used a simulation software that showed the moon phases. The result showed that students who used the simulation program were better in sequencing moon phases compared to natural observers. However, simulation had no effect on students' conception about moon phases or their abilities to draw moon phases.

Despite these outcomes, Olson (1992) reported different results. He suggested that although simulations enhanced students' conceptions they must be used with traditional methods. The main reason that cause him come to this conclusion was that students were suspicious to the results of the simulations. Some of the students were not able to rely on the results of the simulations. They relied on real experiments instead.

2.5.6 Criticism about Computer Assisted Instruction

Although there are numerous studies indicating positive effects of computer assisted instruction on students' achievement there are strong criticism against it. Clark (1983) investigated studies and some meta-analysis about the effects of multimedia. He argued that the studies and meta-analysis, which showed influence on learning, actually did not find any influence at all. He claimed that the results were affected by confounding variables, methodological mistakes or bias. His view of multimedia learning was that multimedia is a tool, just as paper, pencil, textbooks are. He stated:

> The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition. Basically, the choice of vehicle might influence the cost or extent of distributing instruction, but only the content of the vehicle can influence achievement (p. 445).

Clark's first claim was that researchers misinterpreted results they obtained. For example, when they found no difference they concluded that multimedia was equally effective as traditional instruction. Clark displayed some evidences, which he found in meta-analysis, to support his arguments. For example, he showed that the differences between multimedia instruction and conventional instruction vanished when same instructor produced both treatments. The time for treatments was apparently not equal. More time was given for the multimedia group so they invested more effort. A serious claim that Clark submitted in his study was that not all treatments were computer assisted instruction. Some of the treatments were just presentations of some texts or tests via computer screen. Clark also attributed some of the effects of multimedia to novelty effect which was not controlled in some studies.

Some inconsistent results also supported criticism to computer-assisted instruction. On one hand, animations did not improved student's understanding (Narayanan and Hegarty (2002), on the other hand, a meta-analysis of 26 studies comparing dynamic and static visualizations conducted by Höffler and Leutner (2007) found a medium-sized effect size favoring dynamic over static visualizations. These inconsistencies could be a result of the issues that Clark (1983) pointed out. However, this could be because of the characteristics of the animations instead. Tversky, Morrison, and Betrancourt (2002) indicated that when animations are too complex, irrelevant or fast cognitive load was increased which caused decrease of effectiveness of the animations. Tversky et al. suggested that animations should have addressed the targeted concept and should have been well perceived and understood by the learners (e.g. Sanger et al. (2001) showed their drawing three times or more to make sure that students understand drawings).

2.6 Electrochemistry

2.6.1 Concepts of Electrochemistry

Electrochemistry is the study of matter-electricity relationships, the factors effecting cell potentials, and the mechanism and the usage of the electrochemical cells (Talim Terbiye Kurulu Başkanlığı, 2008). It is one of the topics that many science education researchers were interested in (Sanger & Greenbow, 1997a, 1997b, 1999; Sanger & Greenbowe, 2000; Niaz & Chacon, 2003; Lin, Yang, Chiu, & Chou, 2002; Ozkaya, 2002; Yuruk & Geban, 2001). The reason for this interest was that studies indicated that students found this topic difficult (Johnstone, 1980). Ozkaya (2002) found out that in many countries such as United Kingdom, North America, Australia, and The Netherlands, students stated that electrochemistry was one of the most difficult topics in chemistry.

Despite the fact that students found electrochemistry very difficult, concepts of electrochemistry is familiar. Even in early childhood, children confront some concepts like batteries. Most of the toys are battery-operated. A very young child can recognize that the battery-operated toy does not function when batteries are removed. Maybe, he/she cannot be aware of electricity but he/she can infer that batteries operate the toy. When batteries are dead, the child can suggest buying new batteries.

In Turkey, the foundation of electrochemistry in schools is established in fourth grade science classes at elementary school (Talim Terbiye Kurulu Başkanlığı, 2005). For example, one of the specific objectives is "student is able to recognize that batteries have two poles as (+) and (-)" (p. 143). In elementary school, chemical aspects of batteries are not emphasized.

Students confront electrochemistry as a topic in 11th grade chemistry classes at secondary school (Talim Terbiye Kurulu Başkanlığı, 2008). A total 27 periods are allocated to this topic to be taught in classroom. The topic is divided in three units (suggested by Secondary School Chemistry Curriculum (Talim Terbiye Kurulu Başkanlığı, 2008)): Matter-Electricity Relationships, Standard Electrode Potentials and Electrochemical Cells. The concepts, which are emphasized in this topic, are Faraday's laws, redox reactions, oxidation, reduction, oxidation-reduction potential, standard electrode potential, electrode, half-cell, galvanic cells, electrolytic cells, electrolysis.

In 2010, there was only one question in Lisans Yerleştirme Sınavı-2 (University Entrance Exam-2) regarding to electrochemistry (Figure 2.1) (Öğrenci Seçme ve Yerleştirme Merkezi, 2010). However, there were questions, which assessed inorganic chemistry knowledge, needed the knowledge of oxidation and reduction as prerequisite.

2.6.2 Misconceptions in Electrochemistry

Several studies reported misconceptions about electrochemistry (Garnett & Treagust, 1992a, 1992b; Oguda & Bradley, 1994; Sanger & Greenbow, 1997a, 1997b). Ogude and Bradley (1994) noted that chemistry exam questions were often quantitative questions and students could solve these. However, when qualitative questions that needed deeper conceptual knowledge were asked, few students were able to answer these questions. In their study, they investigated South African pre-colege and college students regarding microscopic aspects of electrochemical cells. They found that some of the students believed that electrons could flow through salt bridge and/or through solution and ions stick to the electrodes. They identified two possible sources of this misconception. First, students learn current of electricity before they learn electrochemistry. They learn the phrase of “continuity of the circuit” and this phrase possibly causes students to think that electrons should move through solution to complete the circuit in electrochemical cells. Second, the language, representations or symbols used in textbooks could cause students to misinterpret concepts. They gave example statements quoted from a textbook (e.g. “electrons will flow through the cell from the right electrode to the left electrode”, p. 31) which could be correctly understood by students who are advanced in chemistry but could be misinterpreted by beginners in chemistry.

Ogude and Bradley also found that students have problems about the function of salt bridge and neutrality of the solutions. Students think that the purpose of the salt bridge is to let electrons move from one half cell to other half cell. They also think that cations gathered in one half cell and anions in other, and the overall

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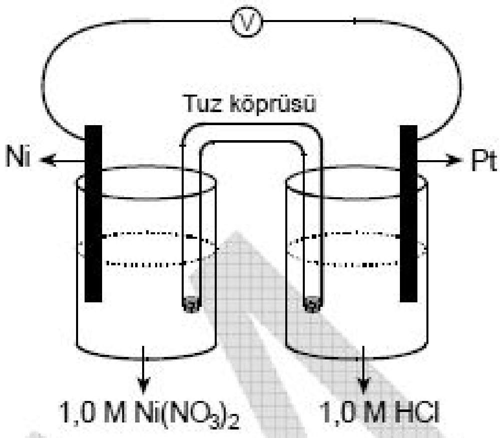
17. 1,0 M $Ni(NO_3)_2$ çözeltisine Ni çubuk, 1,0 M HCl çözeltisine de Pt çubuk daldırılarak şekildeki pil oluşturuluyor.



Bu pil ile ilgili aşağıdakilerden hangisi <u>yanlıştır</u>?

$$\left(\begin{array}{ll} Ni^{2+}{}_{(suda)} + 2e^- \rightarrow Ni_{(k)} & E^\circ = -0,25\ V \\ 2H^+{}_{(suda)} + 2e^- \rightarrow H_{2(g)} & E^\circ = 0,00\ V \end{array}\right)$$

A) Ni çubuğun daldırıldığı hücre anottur.

B) Katotta H_2 gazı çıkışı olur.

C) Tepkime süresince elektron akışı Pt çubuktan Ni çubuğa doğrudur.

D) Pildeki net tepkime denklemi
$Ni_{(k)} + 2H^+{}_{(suda)} \rightarrow Ni^{2+}{}_{(suda)} + H_{2(g)}$ dır.

E) Pil gerilimi $\left(E^\circ_{pil}\right)$ 0,25 volttur.

Figure 2.1 A sample question appeared in 2010 Lisans Yerleştirme Sınavı-2 electrochemical cell is neutral. Ogude and Bradley stated that the source of these misconceptions could be lack of explicit information about salt bridge and neutrality of the solutions in textbooks.

Sanger and Greenbowe (1997a) did an extensive research on misconception in electrochemistry by replicating and extending two studies of Garnett and Treagust (1992a, 1992b). They identified 28 misconceptions under three labels – galvanic cells, electrolytic cells, and concentration cells. The sample of Sanger and Greenbowe consisted of volunteered undergraduate students who took introductory college chemistry courses. 16 students participated this study. Sanger and Greenbowe interviewed each student using an interview protocol developed by Garnett and Treagust (1992a, 1992b). The study showed that students have misconceptions similar to those in Garnett and Treagust (1992a, 1992b). However, they also stated that, for most of the students, lack of conceptual knowledge is not big problem because, in United States, assessments in electrochemistry topic are mainly based on algorithmic problems. Therefore, students do not focus on concepts in electrochemistry. Sanger and Greenbowe claimed that if teachers (or instructors) believe in the importance of teaching concepts in electrochemistry, they teach and assess concepts, so that conceptual knowledge of the students will also improve.

In a parallel study, Sanger and Greenbowe (1999) investigated college chemistry textbooks as a source of misconceptions. After analyzing ten college-level chemistry textbooks they found that these books could indeed caused some misconceptions. They suggested authors (a) avoiding using simplification like always drawing anode as the left-hand half cell, (b) avoiding using misleading statements, (c) using different method to calculate cell potentials, (d) avoiding simple electrostatic arguments to predict the direction of electron and ion flow, and (e) showing all possible reactions in electrolysis.

A number of studies proposed strategies to facilitate conceptual change in students' understanding of electrochemistry. Niaz (2002) used an in-class activity based on conceptual change model proposed by Posner et al. (1982). He designed specific experiments that generate situations which lead the students to cognitive conflict. He found that problems based on memorized formula do not contribute to students' conceptions of electrochemistry. However, engaging students in situations where cognitive conflict occurred helped students develop better understanding of concepts.

Yang, Andre and Greenbowe (2003) compared the effectiveness of two strategies: a lecture with static diagrams presented and a lecture with animations presented. Animations with the narration of instructor facilitate students' understanding of electrochemistry by allowing them visualize electron and ion movement, and electrode reactions. However, the results showed that, though animations improved students' performance overall, students with high spatial ability showed higher performance than students with low spatial ability.

Similarly, in another study, Sanger and Greenbowe (2000) used computer animations to improve students' understanding of concepts about electrochemistry. They suggested an instruction including conceptual change and computer animations, especially targeting students' misconception regarding electron flow in aqueous solutions. Two groups were compared in terms of their understanding about concepts of electrochemical cells. In experimental group, three theories proposed regarding electron flow in solutions. First theory was that "electron moves freely in solutions". Second theory was that ions receive electron(s) at one electrode, move to other electrode, and release it (them) at the electrode (some what similar to transportation vehicles). Third theory was the scientifically accepted one, namely that "electrons cannot exist in solution alone, ions move in solutions constituting electrical current". Three demonstrations were presented to cause conflict among students' ideas. In control group, students were taught traditional instruction where no misconception was confronted, they were just instructed that electrical current in solutions occur with the ion flow. Results of this study showed that conceptual change instruction with animations was more effective at dispelling students' misconceptions about electron flow in electrochemical cells. However, the effectiveness could be attributed to conceptual change instruction rather than animations.

A number of studies regarding misconceptions in electrochemistry were conducted in Turkey (Gedik, Ertepınar, & Geban, 2002; Özkaya, 2002; Özkaya, Üce, Sarıçayır, & Şahin, 2006; Yılmaz, Erdem, & Morgil, 2002; Yuruk & Geban, 2001). Yılmaz et al. (2002) investigated 31 preservice teachers regarding their concepts about electrochemistry. They identified 20 misconceptions about electrochemistry. These concepts were compared with the misconceptions found in literature (i.e. Garnett & Treagust, 1992a, 1992b; Sanger & Greenbowe, 1997a, 1997b) and they stated that the misconceptions they found in the study were similar to those found in the literature.

Özkaya et al. (2006) investigated 74 freshman students' concepts about electrochemistry. They found that most of the students have problems understanding (a) why potential of a single cell cannot be measured, (b) why the sign of the reduction potentials are not related to spontaneity of the half-cell reactions, (b) why no current occurs when salt bridge is replaced by a metal wire, and (d) why cathode is labeled as (+) although electrons move from anode to cathode. Özkaya et al. designed a treatment to eliminate misconceptions and to help better understanding of electrochemistr concepts. They implemented conceptual explanation texts and conceptual questions in experimental group and traditional instruction in control group and compared the effectiveness of both instructional designs. The results showed that students taught with conceptual explanation texts and conceptual questions developed better concepts of electrochemistry.

Yuruk and Geban (2001) investigated the effectiveness of conceptual change text as a supplemental tool to facilitate conceptual change in electrochemistry. Two groups with total 64 students were compared in terms of their scores obtained from electrochemical cell concepts test. In experimental group, conceptual change texts were used whereas in control group traditional instruction was used. They found that conceptual change text help students develop better concepts about electrochemical cells than the students in control group.

Gedik et al. (2002) investigated the effect of demonstration method based on conceptual change model on students' understanding of concepts about electrochemistry. Demonstration method based on conceptual change model was implemented in experimental group and traditional instruction was used in control group. The results showed that demonstration method based on conceptual change model significantly improved students' understanding of concepts about electrochemistry.

2.7 Attitude toward Chemistry

Attitude was defined by Simpson, Koballa, Oliver, and Crawley (1994) as "predisposition to respond positively or negatively to things, people, places, events, or ideas" (p. 212). It is a general feeling (positive or negative) about something or someone. The words like "I hate chemistry" are a sign of negative attitude of someone toward chemistry. Attitude is one of the constructs of the affective domain. Researchers have already accepted the importance of affective domain but cognitive domain has dominated science literature. The reason was, according to Alsop and Watts (2003), the characteristics of science itself, higher importance to reasoning than feeling and long time cognitive tradition of science education.

Beginning from 1970 and 1980, attitude toward science has been seen as facilitators and product of science learning and the relationship of attitude with science achievement has become interest of science education research (Koballa & Glynn, 2007). There was, according to Koballa and Glynn, a drop of number of research on attitude in 1990's but research on attitude again has gained interest in science education community in recent years.

Given the importance of attitude on science education, researchers investigated the relations of attitude with learning science. For example, Freedman (1997) investigated how a hands-on laboratory program improves student attitude toward science and increases student achievement levels in science knowledge. Freedman found a moderate, positive correlation (.406) between attitude toward science and science achievement. In another study, having analyzed data collected as a part of the Third International Mathematics and Science Study (TIMMS), Webster and Fisher (2000) have found that attitude towards science have positively effected students achievement.

Many studies investigated attitude toward science general. However, increasing number of studies showed that students' attitudes towards science declined through grades (George, 2006), gender affect attitude towards science (Barnes, McInerney, & Marsh, 2005) and even the attitudes were different towards physics, chemistry and biology (Osborne, Simon, & Collins, 2003).

George (2006) investigated the relation of attitude toward science and grade level. George conducted a longitudinal study and examined 444 students over middle and high school years. The results showed that although the students had positive attitude towards science in general, their attitude declined as their grades increased.

Osborne et al. (2003) have reviewed literature about attitude toward science. They have found that the male to female ratio was high in physics favoring boys, the ratio was almost equal in chemistry and the ratio was favoring girls in biology.

Although not enough, the number of studies about attitude toward chemistry has been increasing. For example, Salta and Tzougraki (2004) examined 11th grade Greek students' attitude towards chemistry. No difference was found between girls and boys in terms of interest, usefulness and importance of chemistry. However, girls showed negative attitude in terms of difficulty of chemistry. Salta and Tzougraki also found that there was a low positive correlation between attitude toward chemistry and students' chemistry achievement.

In a recent study, Cheung (2009) investigated interaction between gender and grade level with respect to students' attitudes toward chemistry. He examined 954 students in grades secondary 4-7 in Hong Kong. The results showed that male student in early grades show more positive attitude toward chemistry theory lessons than their female counter parts. However, male students liking chemistry laboratory work declined when their grade increased. On the other hand, female students showed no difference about chemistry laboratory work in different grades.

In recent years, as importance of attitude research has increased, interventions, which target changing attitude positively, have been increasingly more popular. Some of these interventions are, according to Koballa and Glynn (2007), activity-based practical works, learning cycle classes, video technologies and computer-assisted instruction. One these interventions, computer-assisted instruction, was investigated by Soyibo and Hudson (2000) with respect to its effect on attitude towards biology. Their sample consisted of 77 11th grade female students. They give computer-assisted instruction to experimental group and traditional instruction to control group. The results indicated that the students in experimental group developed significantly more positive attitude towards biology than the students in traditional group did.

The summary of literature showed that students have misconception about chemistry concepts and interventions should target these misconceptions and eliminate them. Conceptual change texts are effective materials to eliminate misconceptions. If conceptual change texts are supported with computers' audio-visual properties they can be more effective on students understanding of chemistry concepts as well as help students develop more positive attitude toward chemistry.

CHAPTER 3

METHOD

In this chapter, population and sample, variables, instruments, design of the study, data collection and analysis of the study will be explained briefly.

3.1 Population and Sample

The target population in this study was 11^{th} grade students of Anatolian High School's in Ankara who took chemistry classes. There are 71 Public Anatolian High Schools in Ankara (Milli Eğitim Bakanlığı, 2010). There are 9th, 10th, 11th and 12th grade levels in Anatolian High Schools. All 9th and 10^{th} grade students take chemistry classes. However, students are supposed to choose science, social, math or language classes. Only science class programs contain chemistry lessons therefore target population was limited to science classes.

The accessible population was two science classes in an anotolian high school in Ankara and other populations similar to characteristics of the classes described here. This school was established in 2005. First graduates completed the school in 2009. The school had relatively advanced technological facilities to use in education. They had an active computer lab with 30 computers, which means each student could use a computer alone, and a projector in it. There were interactive smart boards in Chemistry/Biology Lab and Physics Lab. There were computers set up on the desks just outside of the classrooms connected to the internet and available to all students during break times. In addition, in some classes, there were projectors with laptops which the teachers could use to discuss the topics with multimedia and computer software. The school had also separate rooms for social activities like music, painting, chess (there was also a very big chess set on one of the floors which students could play during lesure time).

Two intact science classes were used in this study. The sample was supposed to consist of 70 students. However, due to mortality the number decreased to 66. Each class was assigned to either control group or experimental group. The control group was composed of 15 female and 16 male students and the experimental group 14 female and 21 male students.

3.2 Variables

Two independent variables and two dependent variables were used in this study. The independent variables were instructional methods and gender. Both independent variables were categorical and each independent variable included two groups. Observations related to these groups were compared.

Two dependent variables used in this study were conceptual change measured by Electrochemistry Concept Test and attitude toward chemistry measured by Attitude Toward Chemistry Scale. Both dependent variables were continuous.

There were also potentially confounding variables in this study. These variables were previously existing concepts measured by Electrochemistry Concept Test before treatment and science process skills measured by Science Process Skill Test. These confounding variables were analyzed to check whether they were potential threat to internal validity. If any of them was a potential threat, it was controlled using statistical methods.

3.3 Instruments

Four instruments were used to collect data in this study. These were Electrochemistry Concept Test (ECT), Attitude Toward Chemistry Scale (ATCS) and Scientific Process Skill Test (SPST), and a semi-structured interview protocol based on ECT.

3.3.1 Electrochemistry Concept Test

Electrochemistry Concept Test (Appendix C) is a concept test developed by the researcher. The development procedure of the concept test started with identification of the misconceptions about electrochemical cells and electrolysis. Misconceptions about electrochemistry were studied by a number of researchers. Garnett and Treagust investigated students' misconceptions about electrochemistry in two studies (1992a, 1992b) and identified misconceptions. Sanger and Greenbowe (1997a) replicated this study and obtained further findings. Misconceptions reported by Sanger and Greenbowe (p. 384) were examined and some of the misconceptions were selected and used in this study to develop ECT. Misconceptions related to electrochemical cells and electrolysis were first selected and then among them, which were not proper (especially algorithmic misconceptions) to represent and dispel by means of computer simulation, were eliminated. The table of misconceptions and corresponding item options in ECT is shown in Appendix F.

The test consisted of 15 multiple question items. There were eight visual items and seven verbal items. One of the evidences for content validity was that most of the questions were taken from Sanger and Greenbow (1997b, 2000) and Sanger (1996), which were previously tested in classroom settings. The items 1, 2, 3, and 4 were counterparts of the items 2, 3, 4, and 5 taken from the test of Sanger and Greenbowe (2000, p. 526). The items were same except different compounds were used in electrochemical cells. The items 5 and 7, which were same items actually, were adopted from the item 1 in Sanger and Greenbowe (2000, p. 526); the coumpunds were changed and open-ended item was converted to multiple-choice items. The counterpart of the Item 6 was the item with the same number in Sanger and Greenbowe (2000, p. 527). Two more distractors were added to the original item. Item 8 was adopted from Item 9 in Sanger and Greenbowe (2000, p. 527); in which a figure related the question was addedd, and assertion and reason in the question were removed and added to the options. Item 9 was the counterpart of the item 7 in Sanger and Greenbowe (2000, p. 527) and it was taken without any changes. Item 3 in Sanger and Greenbowe (1997b, p. 821) was used as Item 10 in ECT test. The figures C and D in the original item were removed and a different figure was added. Furthermore, the figures were put as options. The items 11, 12, 13, and 14 was adopted from the questions and figures in Sanger (1996, p. 48 and p.49). The possible responses to the original questions were used as options in the corresponding items of ECT test as well as in the figure in page 49 in Sanger (1996) different, instead of Cu, Zn electrodes and the salt of Zn were used. Another content related evidence was provided by the chemistry teacher and chemistry education experts who checked the content of the test for appropriateness to the instructional objectives. The test was checked for their grammatical errors and understandability by the researcher and by the chemistry teacher to provide more content related evidence of validity. For the reliability of the test, internal consistency coefficient was calculated. Cronbach alpha was found to be .69.

3.3.2 Attitude Toward Chemistry Scale

The Attitude Toward Chemistry Scale (Appendix E) was developed by Geban et al. (1992) using a Likert-type scale (fully agree, agree, undecided, partially disagree and fully disagree). The scale was composed of 15 items. The items are rated on a Likert-type scale with 1 – fully disagree to 5 – fully agree. Negative items were coded reversely, namely from 1 to 5. The researchers made a factor analysis and identified two factors of attitude measured: attitude toward chemistry as subject matter and attitude toward chemistry laboratory. The reliability coefficient found by Geban et al. (1992) was .93. The reliability coefficient (Cronbach's alpha) calculated for this study was found to be .83.

3.3.3 Scientific Process Skill Test

The Science Process Skills Test (Appendix C), originally developed by Okey, Wise, and Burns (1982), and Geban et al. (1992) translated and adapted it into Turkish. There are 36 multiple-choice items in this test. The five subtests are identifying variables, identifying and stating hypotheses, operationally defining, designing investigations, and graphing and interpreting data. Geban et al. calculated reliability coefficient as .81. The reliability coefficient calculated in this study was .59.

3.3.3 Interview

To measure students conceptions qualitatively, a semi-structured interview protocol was used. The protocol consisted of the questions of ECT (Appendix C). There were no orders of the questions but the researcher generally asked questions about electrochemical cells at first; then, questions about salt bridge, concentration cells and electrolysis were asked. Fourteen students attended interview sessions; seven from experimental group and seven from control group. The interview took 20 to 30 minutes depended on students anxiety and readiness. The sessions were done during school hours. It was the beginning of the semester and the classes did not begin, yet. The interviews were done during class periods with the permission of class teachers. All sessions were audiotaped and students were convinced that the records would not be listened by anyone except the researcher.

3.4 Design of the Study

Before preparing materials and starting the implementation of the treatment relevant studies were searched. Several approaches were adopted in order to access the most number of relevant primary studies. In this study, two key electronic databases, Educational Resources Information Center (ERIC), and UMI's Digital Dissertation Abstracts Database were searched most extensively. ERIC provides unlimited access to more than 1.3 million bibliographic records of journal articles and other education-related materials, with hundreds of new records added twice weekly. The other database, UMI's Digital Dissertation Abstracts Database, has more than 2 million entries. It is the one central, authoritative source for information about doctoral dissertations and master's theses. Other databases were searched as well (e.g., Wiley Online Library, Taylor & Francis Online Journals, SAGE Journals Online, ScienceDirect, Ebrary, Ebscohost and SSCI).

For literature review, the above-mentioned databases have been searched with the keywords “Conceptual Change”, “Computer Assisted Instruction”, “Conceptual Change Text”, and “Electrochemistry” separately or in combination. To find sample materials for in-class use, Google Search Engine has been searched using keywords of “misconceptions”, “electrochemical cell”, “electrolysis” and “flash animations” separately or in combination.

The aim of the study was to compare and contrast conceptual change between the students who are instructed with traditional methods and who are instructed with conceptual change oriented instruction accompanied by CBICCT therefore a Nonequivalent Groups Pretest-Posttest Design was used in this study. Table 3.1 shows the design of the study.

Table 3.1 Design of the study

Groups	Pretest	Treatment	Posttest
CG	ECT	CCOI	ECT ATCS SPST
EG	ECT	TI	ECT ATCS SPST

Nonequivalent Groups Pretest-Posttest Design was used where random assignment was not applicable. Two preestablished, or intact, groups (classes) were used in this study. Since no random assignment was used, to decrease the effects of threats of extraneous variables, possible covariates were investigated and analysis of covariances (ANCOVA) was used to balance the effects.

ECT was administered as pretest the week before the instruction begins. Students finished the test in 30 minutes. One week after the treatment was finished, posttests were administered. ATCS and ECT were applied to both groups. One class period was enough for both instruments. Additionally, SPST was applied to both groups. Students needed a class period plus break time, 55 minutes total, for these instruments.

Both groups were instructed by the same teacher. The teacher had been teaching chemistry for 10 years. She had B.S. in Chemistry Teaching and M.S. in Chemistry. The treatment took four weeks. Each group had three Chemistry periods per week. The main materials in this study were Computer-Based Interactive Conceptual Change Texts (CBICCT's). The materials were checked by two educators, the chemistry teacher of the two classes and a faculty staff from Secondary Science and Mathematics Department, Middle East Technical University. For control group no materials were prepared because the teacher was supposed to have the materials that she previously used for her students.

After administration of the test, 14 students were interviewed; seven students from each group. Each interview session lasted about 20-30 minutes. All interviews were recorded with an Mp3 Sound Recorder Device.

3.4.1 Experimental Group Treatment

Before the treatment started, the teacher told the students that they would visit the computer laboratory one period every week for the last four weeks as a part of the lecture and use computer applications about electrochemistry.

Each week, first and second periods of the lecture took place in the classroom. The teacher generally started with explaining the topic that she wanted to give. For example in first period of the first week, she drew an electrochemical cell and explained the components and the reactions of the cells. Students visit computer laboratory in third period. They sat down in front of the computers. While most of the students (about 25 students) used computers individually, eight to ten students shared five computers. The students who shared the computers were changed throughout the study, i.e. no student shared a computer twice throughout the implementation. At the beginning of the laboratory session, CBICCT 1 and CBICCT 2 were examined by the students. It took about 20 minutes to examine both CBICCT's. Students carefully examined the animations and read the texts within the CBICCT's. A discussion took place after they finished examining the CBICCT's. The discussions comprised four conditions of conceptual change model. It started generally with the comparison of the ideas students had about and the scientific view about the cases given in the CBICCT's. Students were asked which options they chose in CBICCT's and what happened in the next step. They generally said that they saw the screen which told them they were wrong. They admit that this screen let them question their idea, i.e. they asked themselves why their idea was wrong (dissatisfaction). Next, these students were asked about next screen(s) of the CBICCT's. They said they saw an explanation of why their idea was wrong and which idea was better. For example, for the first CBICCT, they said that they understood well that placement of anode and cathode depends on whether the electrode is reduced or oxidized (intelligible) and they found the example of battery was very logical (plausible). They were asked to give more example from daily life. They gave examples like electronic devices which didn't work if the batteries were not properly placed (fruitful).

In second week, first period started with the discussion from the previous week. When the discussion was completed, the teacher continued explaining more concepts about the topic until the end of the second period. In third period, students visited the laboratory again. They examined CBICCT 3. After that, a discussion was conducted, which was essentially similar to the previous one. The discussion continued in the following week just like the one in the first week. In third and fourth weeks, similar procedures were carried out. CBICCT 4 and

CBICCT 5 were implemented in the third week, and CBICCT 6 was implemented in fourth week. The time allocated for the examination of the CBICCT's depended on students. They examined as much as wanted. Generally, 15 to 25 minutes were enough. The lab session was conducted by the teacher and the researcher.

3.4.2 Control Group Treatment

In control group, traditional instruction, which is generally teacher oriented, was implemented. The teacher was already using traditional instruction therefore the researcher did not make any changes on the instruction of control group. There was only one exception; in third week of the treatment, students of control group visited computer lab and watch animations related electrochemical cells in a class period (45 minutes). This intervention was used to get rid of the novality effect associated with the usage of computer. Except this one period long lecture, the teacher gave her lecture as she did usually before.

Part of the traditional lecture was similar to the lecture given to experimental group: First, the teacher explained the concepts with drawings or formulas. Students wrote down the notes. Some times, they asked questions about points that they did not understand. When the teacher finished with the concepts, she solved problems related to the concepts that she gave. Generally, after solving a few problems if there was time like 25 minutes or something, either the teacher allow the students to solve test questions for university entrance exam or she let them ask test questions about any topic of chemistry. Most of the time students preferred to solve test questions themselves. The teacher and the students used textbooks rarely. Instead, they used test books for university entrance exams, which mainly contained very short explanation of concepts and many test questions that contained algorithmic problems. Very few test questions in those books were related to concepts of chemistry. During four week treatment no discussion about concepts occurred. Students did not show their ideas about the concepts. They listened their teacher while she was explaining the concepts and there was no sign of whether they accept the idea or not.

3.4.3 Computer-Based Interactive Conceptual Change Texts

The CBICCT's used in this study were text-based conceptual change materials which were basically similar to Conceptual Change Texts. The only difference was that CBICCT's were electronic texts which include not only texts and pictures but also interactive media (i.e. animations, images and sounds which were played during the treatment). Same procedure explained in Chambers and Andre (1997) was used to create CBICCT's: (a) students were asked explicitly to predict what would happen in a situation before being presented with information that demonstrates the inconsistency between common misconceptions and the scientific conception. (b) students' misconceptions were challenged by introducing common misconceptions followed by evidence that they were wrong. (c) the instruction presented the correct scientific explanation.

Six CBICCT's were developed in this study. Each CBICCT covered one or more misconceptions which were contrasted with the scientific conceptions. Macromedia Flash MX software was used to create animation of the phenomena occurred in electrochemical cells and electrolysis and to embed animations and text in the CBICCT's. The CBICCT's were composed of pages. Each page consisted of texts and/or animations presenting the situation, questions, misconceptions or scientific conceptions. There were *backward* and *forward* push buttons in pages to navigate between screens so that students could go backward and experience the conceptual change process again. At the end of each CBICCT a *start over* push button was added to go first page of the CBICCT. In a traditional conceptual change text, students write down their predictions on the papers. In CBICCT's, however, figures which represented students misconceptions or scientific conceptions, or push button on which students misconceptions or scientific conceptions were written were shown to students to make their predictions. Students selected a prediction and clicked on it. Based on their selection, next screen was either a "Congratulations" screen or screens that contained conceptual change process steps. In both ways, scientific concepts were presented to students at the end.

All CBICCT's started with situation on the first screen and then questions related to this situation were asked to reveal students misconceptions. The options were given to the students to select. One of the options was scientifically accepted idea and the others were misconceptions. If the student select one of the misconceptions the next screen told the student that his/her idea was wrong and why their idea was wrong was explained (dissatisfaction). In the next screens, scientific idea was given and explained (intelligible and plausible). At the end examples from daily life was given (fruitful).

One of the CBICCT (Appendix A) was developed to eliminate the misconception of "the identity of the anode and cathode depends on the physical placement of the half-cells." In first and second screen, a situation was presented. It was an image of electrochemical cells. A question was asked about what would happen when the half cells and the system all were switched. In the next two screens, students were asked to make a prediction. The prediction was made by clicking on one of the two figures on the screen. If the figure representing the misconception was selected than next pages introduced the misconception and why it was wrong so that the misconception was refuted. After that, the scientific concept was introduced. If scientific concept was selected, a congratulation screen appeared. It did not stop here. Even though the scientific concept was selected refutation screen and introduction of scientific concept were still presented to the students.

3.5 Data Analysis

In this study, descriptive and inferential statistics were used to analyze the data gathered from the test and scales. The pretest scores and the posttest scores ECT and was collected for each student participating in the study. The pretest scores were collected prior to beginning the treatment and the posttest scores were collected immediately after the four-week treatment.

Total scores of each subject for pre- and posttests were calculated first, and using descriptive statistics pre- and post ECT were interpreted. Pretest scores of ECT gave information about students' previously existing concepts about electrochemistry. The posttest scores of ECT in combination with pretest scores showed whether there were improvement of students' understanding of electrochemistry concepts.

Student's t-test and Analysis of Covariance (ANCOVA) were used in order to test each hypothesis. Student's t-test was used to analyze the pretest scores of ECT to see possible significant difference between the control groups and experimental groups. Additionally Pearson Pruduct-Moment Correlation was used to check correlation between SPST scores and dependent variables. Two way analysis of covariance (ANCOVA) was used to further analyze the data. The level of alpha for ANCOVA was set to a significance level of .05 (α =.05). Gain scores were calculated by subtracting pretest scores from posttest scores of ECT. The analysis was responsible for removing any variables that would have established additional differences between the control and experimental groups. These differences would have included variables that the researcher may not have been able to account for during the study. In this study, the confounding variable was science process skill. This statistical model was used to find out whether there was a significant difference between control and experimental groups, whether there was a significant difference between male and female students or whether there was a significant interaction between instruction method and gender.

ATCS was analyzed with two way analysis of variances (ANOVA). Just like two way ANCOVA, this model was used to check significant difference between control group and experimental group or between males and females, or to check significant interaction between methods and gender.

Other than statistical significance, practical significance was also calculated. Effect size values and statistical power were calculated for the results of ECT gain scores and ATCS scores. Cohen's f was reported as effect size.

All data treatment was carried out by using SPSS software (version 13). Microsoft Excel (version 2003) was used to plot the graphs. Since SPSS v.13 reports partial eta squared and does not calculate Cohen's *f*, another sofware, G*Power (Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007a, 2007b)), was used to convert partial eta squared to Cohen's *f*.

CHAPTER 4

RESULTS AND CONCLUSIONS

4.1 Analysis of Misconceptions

This study mainly focused on elimination of misconceptions about electrochemical cells. However, before investigating the effects of the treatments, a close look at students existing concepts about electrochemistry cell could be helpful to interpret both descriptive and inferential analysis. ECT was administered prior the treatment for mainly two reasons. First, to check whether both groups were equal in terms of their previously existing conceptions about electrochemical cells and accordingly, to select suitable statistical model for analysis. Second, to explore the nature of the misconceptions students could have.

Research on misconceptions about electrochemistry was dominated by the studies of Garnett and Treagust (1992a, 1992b), and Sanger and Greenbowe (1997a). Target misconceptions in this study were selected from the misconceptions in the research of Sanger and Greenbowe.

One of the misconceptions observed in this study was that “the identity of the anode and cathode depends on the physical placement of the half-cells”. Fifth and seventh items were actually the same, and the half-cells were switched. The students were supposed to give same responses to both items in ECT pretest. In seventh item, anode was on the left and cathode was on the right whereas in fifth item they were opposite. The percentages of options of experimental group for fifth and seventh items, in which the physical placement of electrodes were shown correctly were close (34.3 % and 51.4 %, respectively) whereas the percentages of correct responses of experimental group for fifth and seventh items differ very much (32.3 % and 71 %, respectively). It seems that when anode was on the left (seventh item) a high percentage selected the correct option. However, when anode was on the right the percentage dropped. High frequency of "no answer" response showed that students were confused and selected none of the options.

Second misconception observed in this study was that "electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit" (Figure 4.1). Students held this misconception exactly (e.g. from one electrode through the solution and salt bridge to another electrode) or complementary (e.g. from one electrode through the solution and salt bridge to another electrode, then through wire to the first electrode to complete the circuit). The first misconception was little less common than the second one among the total number of students (22.7% and 23%, respectively) when sixth item in ECT was taken into account. Results from other items such as Item 1, Item 2, Item 3, Item 4 and Item 15 partially support this view.

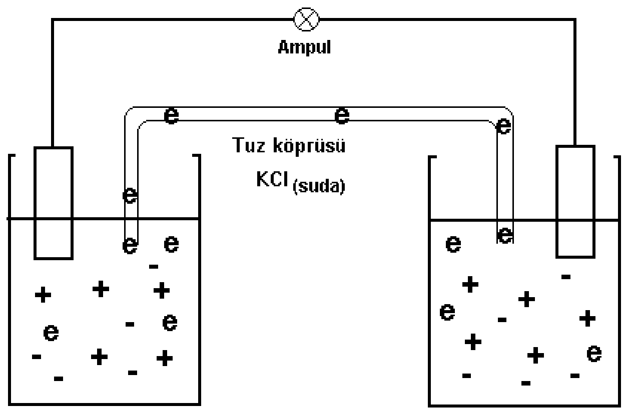


Figure 4.1 Students concept of cations, anions and electrons in electrochemical cells

A misconception was not mentioned in the literature and observed in this study was that “in concentration cells, the direction of the current is from more concentrated cell to less concentrated cell.” 28.8 % of the total number students selected the corresponding option in eleventh item.

Students had few conceptions regarding electrochemical cells in general. The percentage of no answer was higher in items related to electrolysis. There was one exception, however. In 12th item, 30.3 % of the students thought that “no reaction would occur if inert electrodes were used”. The word “inert” could have deceived students in a way that students might think that since inert metals do not undergo reactions very easily they do not allow electrolysis reaction at electrodes.

The misconceptions mentioned above have been observed with higher percentages among the subjects used in this study. More students’ conceptions other than mentioned above were observed, with lower percentages, though. These less frequently observed misconceptions, corresponding items and options, and percentages were:

- Electrons can flow through aqueous solution without assistance from the ions (9e – 19.7 %).
- In electrolytic cells with identical electrodes connected to the battery, the same reactions will occur at both electrodes (13d – 9.1 %)
- When two or more oxidation or reduction half-reactions are possible, there is no way to determine which reaction will occur (13b, 12.1 %).
- Inert electrodes can be oxidized or reduced (12d, 15.2 %).

Posttest results of ECT showed that experimental group obtained higher scores in nine items (out of fifteen) as shown in Figure 4.3. As seen in the bar graph, experimental group scored higher than control group in nine items (2, 4, 5, 6, 7, 10, 11, 13 and 14) and control group scored higher than experimental group in six items (1, 3, 8, 9, 12, and 15). A comparison of scores before and after treatment could give us some ideas about the effectiveness of both traditional method and conceptual change oriented instruction accompanied by CBICCT.

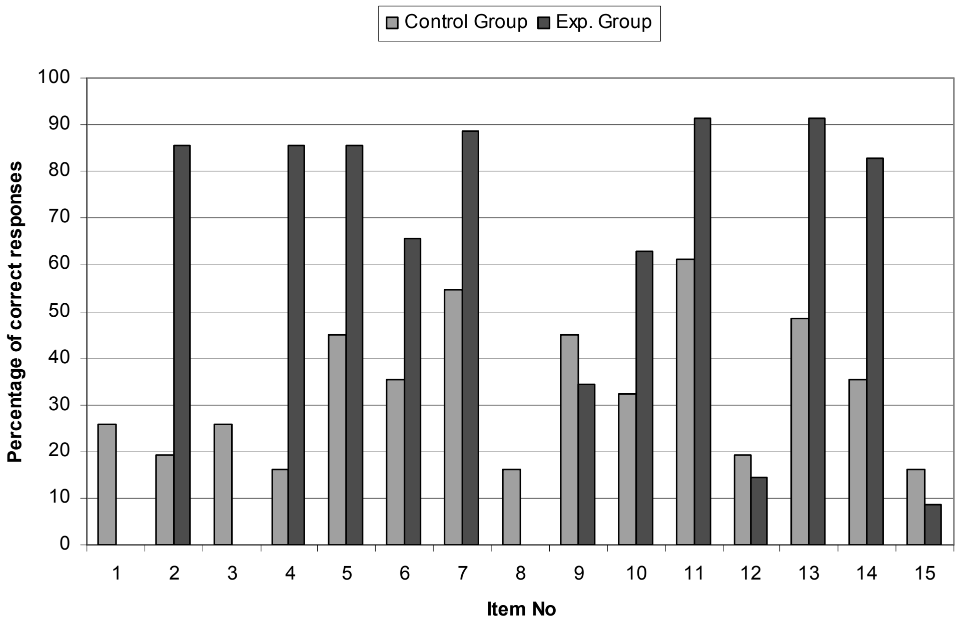


Figure 4.2 Bar graph of posttest scores of ECT for both groups

Before treatment, 32 % of the control group answered correctly while none of the experimental group chose correct option. In item 2, as seen from the graph, after treatment the percentage of correct responses of the control group decreased to 19.4 % while the percentage of correct responses of the experimental group dramatically increased to 87.1 %. After treatment, more students in the control group selected the wrong option that “electrons move from the salt bridge.” On the other hand, students in experimental group who selected the options that “electrons move from the salt bridge” (45.7 %) and “electrons move to the salt bridge” (45.7 %) greatly changed their view as these percentages dropped to 3.7 % and 7.4, respectively.

In Item 10, before treatment, 16.1 % of the control group and 11.4 % of the experimental group answered correctly. After treatment, the percentage of control group increased to 32.3 % while the percentage of experimental group increased to 62.9 %. It is clearly seen that experimental group increased number of correct responses much more than the control group. However, after treatment, relatively high number of students, 32.3 % of the control group and 34.3 % of the experimental group selected the option that shows electrons moving freely in the solution.

Control group scored higher than experimental group in six items. However, results of these six items showed that students from both groups selected the incorrect options with highest percentages. These results suggested that after treatment both groups held some misconceptions.

The posttest scores showed that experimental group showed some improvement about their view of salt bridge. In second and fourth items, they selected the option in which the salt bridge supplies the solution with cation and anion. However, in 15th item, they selected the options representing misconceptions. The difference between items was that second and fourth items contained visual element whereas the fifteenth item was verbal. Computer-based interactive conceptual change texts contained both visual (animations) and verbal (texts) elements but it is possible that visual elements were more influential for students' conceptions. After treatment, control group seemed holding their misconceptions about salt bridge, as their posttest scores were same or lower than pretest scores on second, fourth and fifteenth items.

Pretest and posttest scores of fifth and seventh items were investigated to reveal whether treatments affected on students' misconception that "the identity of the anode and cathode depends on the physical placement of the half-cells." Before treatment, 71 % of the control group selected the correct options of seventh item and 32.3 % selected same options for fifth item. After treatment, the percentages became 74.1 % and 61.3 %, respectively. An improvement was observed among the students who answered the seventh item correctly as the difference between percentages dropped from 38,7 % to 12.8 % . This improvement either could be due to the correct responses coming from students with no answer in pretest or due to the students changed their view from misconception to correct view. For fifth and seventh items, experimental group had 51.6 % and 32.3 % before treatment. After treatment, the percentages increased to 90.3% and 83.9 %. This result suggested that both students with no answer and students with misconceptions changed their view to correct one.

Students' representations of electrochemical cells and the solutions inside the cells were also changed. Before treatment, experimental group had the misconceptions that electrons move in solution freely from one cell to other through salt bridge (34.2 %) and that only cations existed in anode solution while only anions existed in cathode solution (25.7 %). The percentage of correct response was 11.4 %. After treatment, the correct responses were increased to 62.9 %. Despite this improvement, there were still students who believed that electrons freely existed in the solutions of both cells (34.2 %). Control group also improved their view. Before treatment, the percentage of correct responses was 16.1 %, after treatment, the percentage was increased to 32.3 %. The misconception existed among experimental group also existed in control group that they believed electrons freely existed in the solutions of both cells (31.5 %).

The results of 13th and 14th items showed that both control group and experimental group improved their views about electrolysis. Experimental group increased their percentages of correct responses from 28.6 % to 91.4 % for thirteenth item and from 0 % to 82.9 % for fourteenth item. Control group increased their percentages of correct responses from 16.1 % to 48.4 % for thirteenth item and from 9.6 % to 35.5 % for fourteenth item. Obviously, experimental group had better improvement than control group.

4.2 Electrochemistry Concept Test Results

This test was administered before and after treatment to both experimental and control group. The minimum and maximum scores that can be obtained from this test is 0 and 15, respectively. Table 4.1 presents the descriptive statistics of the pretest and posttest scores of the ECT in the study.

Table 4.1 Descriptive statistics related to scores of the ECT

	Pretest		Posttest	
	CG	EG	CG	EG
N	31	35	31	35
Mean	2.71	1.94	5.00	8.11
Median	3	2	5	8.0
Mode	4	2	3	9
Std. Deviation	1.616	1.434	2.944	1.937
Min.	0	0	1	3
Max.	6	6	13	12
Skewness	0.152	0.487	1.014	-0.763
Kurtosis	-0.450	0.364	0.986	0.894

Before treatment, while the mean score of control group was higher than the mean score of the experimental group, after treatment, the mean score of experimental group became higher than the mean score of control group. The increase of the mean score of control group is 2.28 while the increase of the mean score of experimental group is 6.11. This increase suggests that the students in experimental group developed better understanding of electrochemistry concepts than the students in control group did.

Although the experimental group had better overall mean score than control group, it can be seen from Figure 4.3 that experimental group had less gain scores than control group in some items. For example, number of correct responses for third and eighth items decreased and no gain had obtained in first and fifteenth items. This items were generally related to electron movement in cell solutions. In 9th and 12th items, both groups had positive gain. However, control group had better gains than experimental group in these items.

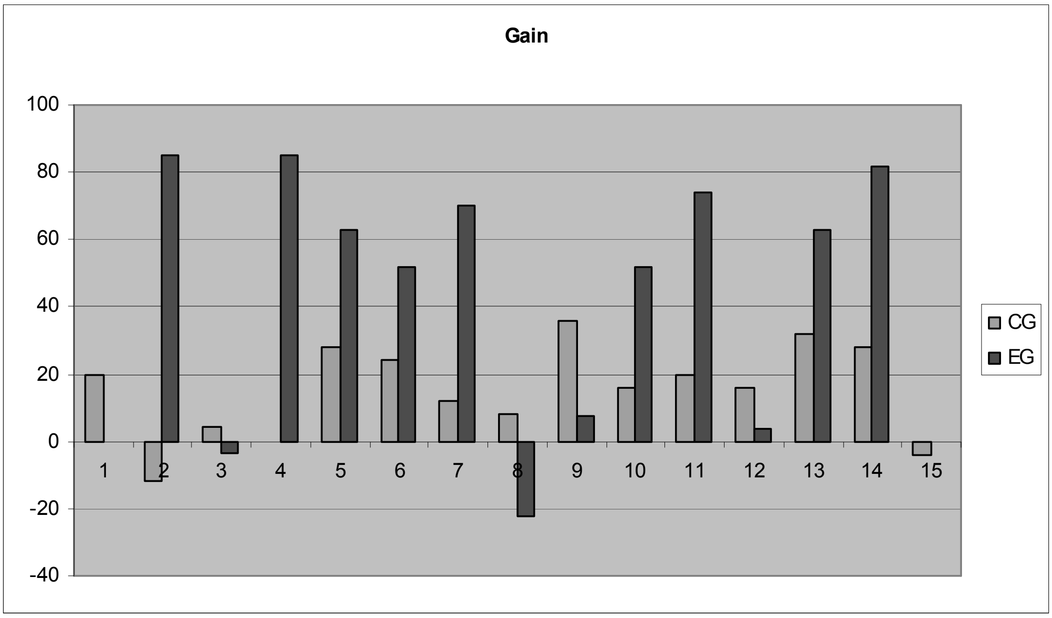


Figure 4.3 Bar graph of gain scores of ECT for both groups

Before testing first three hypothesis, pretest scores of ECT was analyzed with t-test to check whether there was a significant mean difference between control and experimental group. Table 4.2 shows that there was a significant mean difference between control and experimental group ($t(64)$, $p < .05$).

When pretest mean scores are significantly different from each other, Stevens (2002) suggested three model of analysis for pretest- posttest research designs: (a)

ANCOVA, (b) one within and one between Repeated Measures ANOVA (c) ANOVA done on gain scores (Posttest scores – Pretest scores). The third model was preferred in this study. So, a new dependent variable called as "gain scores" was established by subtracting ECT pretest scores from ECT posttest scores. However, since science process skill was covariate ANCOVA done on gain scores was used instead of ANOVA to control SPST scores as covariate.

Table 4.2 Independent t-test of ECT Pretest

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig.
Equal variances assumed	1.108	.296	-2.043	64	.045
Equal variances not assumed			-2.028	60.468	.047

ANCOVA has five assumptions. The first assumption, independency of observation, was ensured by providing necessary conditions to prevent interaction. During treatment in computer laboratory, students intraclass interaction was kept minimum as each student was engaged in reading and watching the interactive conceptual change text on computer screen. In addition, both control and experimental group were observed during test administration to ensure that each student filled the tests without any influence of his/her classmates or teacher (even the researcher). So, the first assumption was met.

Second assumption is normality distribution of population for any levels of factors. To test this assumption, skewness and kurtosis values in Table 4.3 was used. Skewness and kurtosis values between -2 and +2 could be accepted as normal

(George & Mallery, 2003). The values were all between acceptable range of of ±2 so second assumption was met.

Table 4.3 Descriptive statistics of gain scores of ECT related to groups and gender

Group	Gender	Mean	SD	N	Skew.	Kurtos.
Experimental	Female	6.36	1.781	14	0.607	-0.132
	Male	6.05	2.133	21	-.137	-1.319
	Total	6.17	1.978	35	.014	-0.916
Control	Female	2.27	2.658	15	0.959	1.839
	Male	2.31	3.737	16	1.069	1.744
	Total	2.29	3.206	31	1.035	1.786
Total	Female	4.24	3.055	29	-.068	-0.616
	Male	4.43	3.444	37	-.178	-.349
	Total	4.35	3.258	66	-.126	-.460

The third assumption was that the variances of dependent variable and covariate are the same for all populations. To test this assumption Levene's Test of Equality of Error Variances was conducted. The results indicated that the assumption was met ($F(3, 62) = 2.388$, $p > .05$).

Fourth assumption was that dependent variable and covariate should be linearly dependent, there should be a significant correlation between dependent variable and covariate. Table 4.4 shows a significant correlation between ECT gain scores and SPST scores at 0.01 level. Fourth assumption was met.

Table 4.4 Correlations between potential covariates and dependent variables

	SPST	Gain scores ECT	ATCS
SPST	1.000		
Gain Scores - ECT	.368*	1.000	
ATCS	.219	.146	1.000

*. Correlation is significant at the 0.01 level (2-tailed)

The last assumption was that there should be no significant interaction between covariate (SPST) and the independent variables (instructional method and gender). To test this assumption, a custom ANOVA design was conducted in which interaction between groups (method) and SPST scores, and between gender and SPST scores were evaluated. The results were shown in Table 4.5 and Table 4.6. The results indicated that there was no custom interaction between methods and SPST scores ($F(1, 62) = 0.617$, $p > .05$), and between gender and SPST scores ($F(1, 62) = 1.192$, $p > .05$). So last assumption was met.

Table 4.5 Tests of Between-Subjects Effects (Custom Model)

Source	Type III Sum of Squares	df	Mean square	F	Sig.
group	0.730	1	0.730	0.107	0.745
SPST	1.330	1	1.330	0.195	0.661
group * SPST	4.215	1	4.215	0.617	0.435
Error	423.744	62	6.835		
Total	1929.000	66			
Corrected Total	582.231	65			

Dependent Variable: gain

Table 4.6 Tests of Between-Subjects Effects (Custom Model)

Source	Type III Sum of Squares	df	Mean square	F	Sig.
gender	14.006	1	14.006	1.513	0.223
SPST	102.070	1	102.070	11.028	0.002
gender * SPST	11.033	1	11.033	1.192	.279
Error	389.316	62	9.255		
Total	1929.000	66			
Corrected Total	582.231	65			

Dependent Variable: gain

After checking ANCOVA assumptions, the main analysis was conducted. A two-way ANCOVA analysis was run. The results are shown in Table 4.7. The first null hypothesis stated that there was no significant mean difference between students taught with conceptual change oriented instruction accompanied by CBICCT and students taught with traditional instruction with respect to their gain scores obtained from Electrochemistry Concept Test when science process skill was controlled as covariate. The results showed that there was a significant difference between gain scores of the students taught with conceptual change oriented instruction accompanied by CBICCT and students taught with traditional instruction when science process skill was statistically controlled ($F(1, 61) = 21.699$, $p < .05$). Mean scores of the students in experimental group was significantly higher than the meas scores of the students in control group. So, first null hypothesis was rejected. The partial eta squared value (partial eta squared = .26) from Table 4.7 was converted to Cohen's f ($f = .60$). This calculated effect size was classified as large with respect to Cohen's classification as Cohen classified effect sizes with f value larger than 0.40 as large. Also, Table 4.7 showed that power ($1-\beta$) was found to be .996 which is larger than .80 that Cohen suggested. So, it is safe to assume that the significance detected here was less likely biased by Type II error.

Table 4.7 Tests of Between-Subjects Effects (Main Model)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
SPST	5.962	1	5.962	0.837	.364	0.014	.147
group	154.585	1	154.585	21.699	.000	.262	.996
gender	0.006	1	0.006	0.001	.978	0.000	0.050
group*gend.	0.469	1	0.469	0.066	.798	0.001	0.057
Error	434.576	61	7.124				
Total	1937.000	66					
Corrected Total	688.985	65					

Dependent Variable: gain

The second null hypothesis stated that there was no significant mean difference between males and females with respect their gain scores obtained from ECT when science process skill was controlled as covariate. Table 4.7 showed that there was no significant mean difference between males' and females' test scores ($F(1, 61) = 0.001$, $p > .05$). So, second hypothesis was not rejected.

The third hypothesis stated that there was no significant interaction between method and gender with respect to gain scores obtained from ECT when science process skill was controlled. The results in Table 4.7 showed that there was no significant interaction between method (group) and gender with respect to their gain scores obtained from ECT when science process skill was controlled ($F(1, 61)$

= 0.066, p > .05). A profile plot was given in Figure 4.2 to show possible interaction. The figure also showed that the interaction was not significant

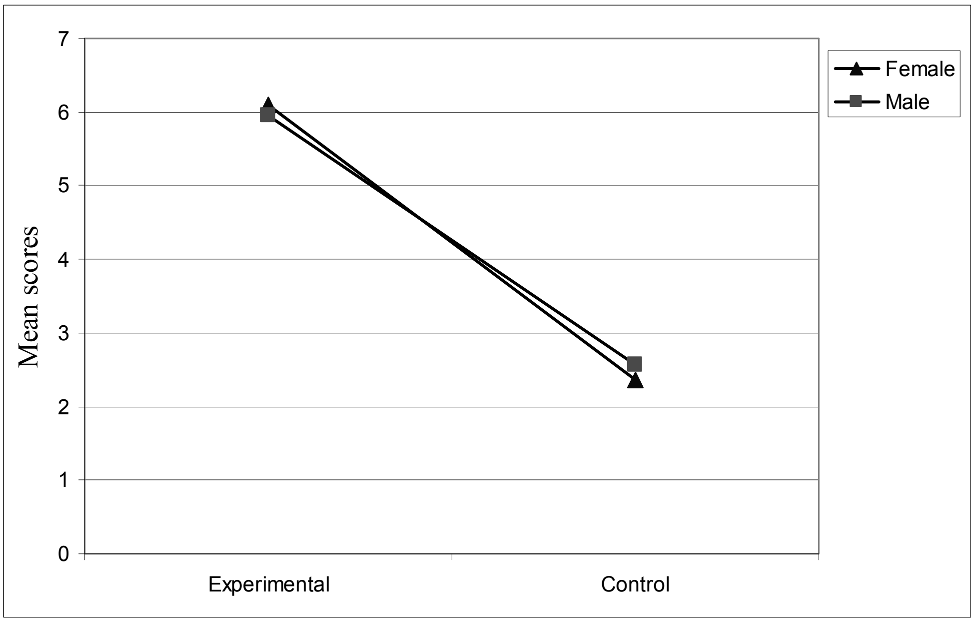


Figure 4.4 Profile plot of two-way ANOVA for gain scores of ECT

4.3 Attitude Towards Chemistry Scale Results

ATCS was applied after the treatment. The descriptive statistics related to ATCS was shown in Table 4.8. The control group scores ranges from 1.87 to 3.47 and the mean is 2.40 which indicates that students in control group have negative attitude towards chemistry overall. On the other hand, experimental group scores ranges from 2.13 to 4.40 and the mean is 3.15 which indicates more positive attitude toward chemistry among experimental group.

Fourth null hypothesis stated that there was no significant mean difference between experimental group and control group in terms of their ATCS scores. To test mean difference between control and experimental group as well as mean difference between males and females (null hypothesis 5), and the interaction between gender and group (null hypothesis 6), two way ANOVA was used. Before conducting the analysis, assumptions were tested.

Table 4.8 Descriptive statistics related to the ATCS scores

	Control Group	Experimental Group
N	31	35
Mean	2.43	3.09
Median	2.40	3.20
Mode	2.20	3.20
Std. Deviation	0.414	0.447
Min.	1.87	2.13
Max.	3.47	4.40
Skewness	0.674	0.247
Kurtosis	0.207	1.333

First assumption, independency of observations, were tested in previous section and it was met. Second assumption is normality distribution of population for any specific value of covariate and levels of factors. To test this assumption, skewness and kurtosis values in Table 4.9 was used. The values were all between acceptable range of of ±2 except the scores of males in experimental group. The kurtosis of males in experimental group exceeded acceptable range. However, this was not a serious violation and the analysis was conducted as normality assumption was met.

The third assumption is that the variances of dependent variable and covariate are the same for all populations. To test this assumption Levene's Test of Equality of

Table 4.9 Descriptive statistics of ATCS related to gender and groups

Group	Gender	Mean	SD	N	Skew.	Kurtos.
Experimental	Female	2.91	0.451	14	-0.580	-1.403
	Male	3.21	0.414	21	1.195	2.253
	Total	3.09	0.447	35	.247	1.333
Control	Female	2.47	0.481	15	0.449	-0.144
	Male	2.40	0.353	16	1.022	1.041
	Total	2.43	0.414	31	0.674	0.207
Total	Female	2.68	0.513	29	-0.065	-1.190
	Male	2.86	0.558	37	.424	.181
	Total	2.78	0.541	66	.268	-.148

Error Variances was conducted. Levene's Test showed that variances were equal ($F(3, 62) = 1.033$, $p > .05$).

Since all assumptions were met, two way of ANOVA were conducted. The results are shown in Table 4.10. The results showed that there was a significant mean difference between experimental and control group in terms their ATCS scores ($F(1, 48) = 19.938$, $p < .05$). The attitude scores of experimental group was significantly higher than the attitude scores of control group. So, seventh null hypothesis was likely false and should be rejected. The partial eta squared value (partial eta squared = .363) from Table 4.9 was converted to Cohen's f ($f = .75$). This effect size could be classified as large. Also Table 4.10 showed that power ($1-\beta$) was found to be approximately 1.000. So, it is safe to assume that the significance detected here was less likely biased by Type II error.

Fifth null hypothesis stated that there was no significant mean difference between males and females in terms of their scores obtained from Attitude Towards Chemistry Scale. The results in Table 4.10 showed that there was no significant mean difference between males and females (F(1, 62) = 1.173, p > .05). So, this hypothesis was not rejected.

Table 4.10 Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
group	6.387	1	6.387	35.322	.000	.363	1.000
gender	0.212	1	0.212	1.173	.283	0.019	.187
group*gender	0.509	1	0.509	2.813	.099	0.043	.379
Error	11.211	62	0.181				
Total	530.693	66					
Corrected Total	19.117	65					

Dependent Variable: attitude
R Squared = .414 (Adjusted R Squared = .385)

Sixth hypothesis stated that there was no significant interaction between instruction method used and the gender in terms of the scores obtained from Attitude Towards Chemistry Scale. Table 4.10 shows two way ANOVA results related to interaction between gender and groups (instructional method). The results indicated that there was no significant interaction between gender and groups F(1, 62) = 2.813, p > .05). A profile plot was drawn to investigate possible interaction (Figure 4.4). While males in control group scored a little lower than females, they scored higher in experimental group. An interaction was observed on the plot. However, the results in the Tests of Between Subjects Effects table (Table 4.10) showed that this interaction was statistically not significant.

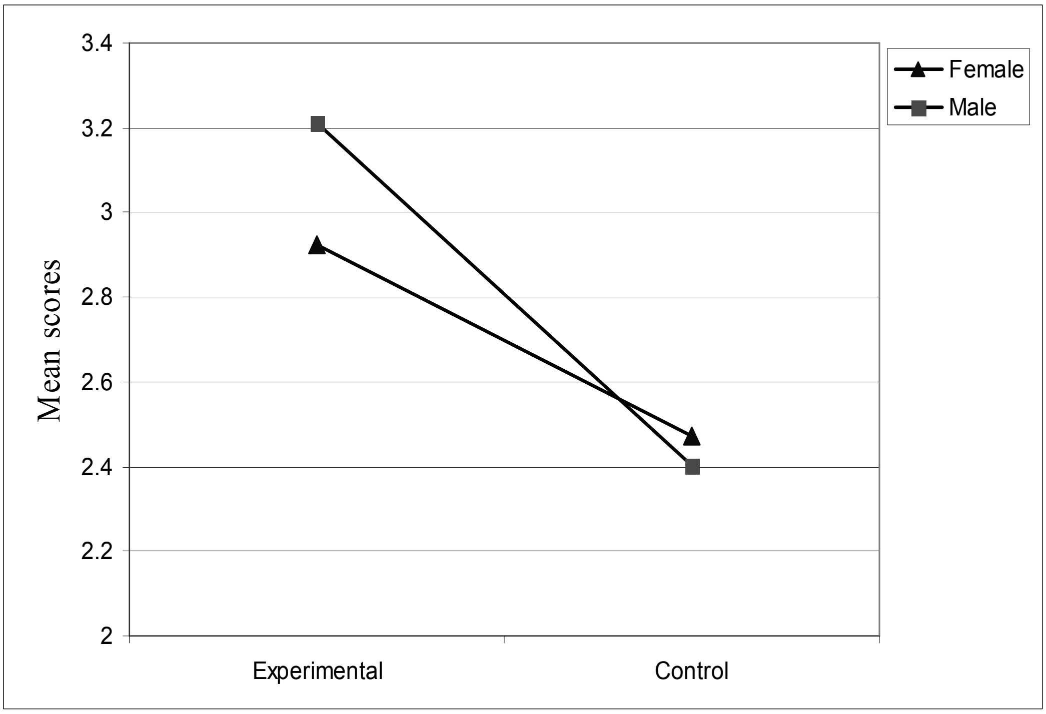


Figure 4.5 Profile plot of two way ANOVA for ATCS scores

4.4 Analysis of Interview Questions

In this study, an interview was conducted with 14 volunteered students to obtain detail information about students' understanding of concepts about electrochemical cells and electrysis. The researcher transcriptet the recorded interview sesions. After transcription process, the researcher examined the transcripted data and coded them with help of the table of misconceptions in Appendix F. Thirteen coding categories were identified based on interview transcripts. These coding categories were as follows:

- *EC-Movement*: Students' responses related to electron movement in electrochemical cells.
- *EC-Saltbridge*: Students' responses related to the purpose of the salt bridge in electrochemical cells.

- *EC-Charge*: Students' responses related to charge of the electrode in electrochemical cells, i.e. whether the anode and the cathode are charged negatively or positively.

- *EC Potential*: Students' responses related to the sign of the electrochemical cell potential.

- *EC-Placement*: Students' responses related to whether the identity of the electrodes in electrochemical cells change when physical placement changes.

- *EC-Reaction*: Students' responses related to the reactions at anode and cathode in electrochemical cells.

- *ConC-Potential*: Students' responses related to the cell potential in concentration cells.

- *ConC-Current*: Students' responses related to direction of the current in concentration cells.

- *EL-Placement*: Students' responses related to identity of the electrodes when lacement of the electrode changes.

- *EL-Identity/same*: Students' responses related to the identity (being anode or cathode) of electrodes when same electrodes used in electrolytic cells.

- *EL-Potential*: Students' responses related to sign of the cell potential in electrolytic cells.

- *EL-Reactions*: Students' responses related to the reactions at anode and cathode in electrolytic cells.

- *EL-Reactions/inert*: Students' responses related to the reactions at anode and cathode when inert electrode was used.

Each coding categories were classified as Correct (scientific idea), Limited Conceptions, Misconceptions, and No Conceptions. Table 4.11 shows coding categories identified by the researcher and the distribution of students in experimental and control group across the coding categories.

4.4.1 Concepts about Electrochemical Cells and Concentration Cells

The items of 1, 2, 3, 4, 6, 9 and 10 in ECT were asked to reveal students' concepts about electron movement. Only one student in experimental group stated that the ions move in solution, not the electrons. Other students in experimental and control group (13 students) stated that electrons move in cell solution(s). Among these 13 students, while nine students believed that "electrons move freely in solutions" four students believed that electrons move with the help of the ions either by moving from one ion to other (3 students) or by "sticking" to ions (one student). The student who believed that the electrons stick to ions claimed that "electrons do not move without ions, therefore, no electron flow occurs in pure water".

Regarding the purpose of the salt bridge four students in experimental group had correct idea about the purpose of the salt bridge. They stated that "salt bridge keeps the ion balance in electrochemical cells". When the figure (figure in Item 8 in ECT, see Appendix C) was shown to them, they stated that the bulb would not glow because without the salt bridge the ion balance was not kept. However, their idea about electron movement interfered with their idea about the purpose of the salt bridge. Three students among these four students believed that electrons flow through the salt bridge. They said "the bulb doesn't glow but the electrons move through platin wire". Only the student who had scientific idea about electron

Table 4.11 Coding categories and the distribution of students in experimental and control group across the coding categories. (C: Scientific conceptions, LC: Limited Conceptions, M: Misconceptions, N: No Conceptions)

	Control group (n=7)				Experimental group (n=7)			
	C	LC	M	NC	C	LC	M	NC
EC-Movement	0	0	7	0	1	0	6	0
EC-Saltbridge	0	3	1	3	4	0	2	1
EC-Charge	1	0	4	0	4	0	1	2
EC-Potential	5	0	2	0	5	0	2	0
EC-Placement	5	2	0	0	5	2	0	0
EC-Reaction	4	0	1	0	5	0	0	0
ConC-Potential	0	0	3	4	1	0	0	6
ConC-Current	0	0	1	4	1	0	0	4
EL-Placement	3	0	0	4	3	0	0	4
EL-Identity/same	0	2	2	3	1	0	0	6
EL-Potential	0	0	2	5	1	0	1	5
EL-Reactions	0	0	0	7	0	0	0	7
EL-Reactions/inert	2	0	1	4	1	0	0	6

movement (i.e. through wire) did not talk about electron movement through platin wire. Three students in control group also stated that, in the figure, the electrons move through platin wire but the bulb would not glow. When the reason was asked, they did not have any idea. They said “I don’t know, there should a reason that a salt bridge was put here instead of a wire”. They reasoned that there should be another function of the salt bridge as it was used instead of a simple wire.

All 14 students stated that the cathode and anode did not change when their placement was changed. Students in both groups seemed to change their view of the identity of electrodes depending on physical placement. The reason could be that students focused on algorithmic problems and therefore they easily identify electrodes by calculations. Whenever a student was asked about identity of the electrodes they immediately used reduction potentials and reactions. However, four students (two in experimental group and two in control group) stated that when the placement of the anodes was changed the sign of the electrochemical cell potential also changed (i.e. plus sign becomes minus or vice versa).

Students were also asked what they see in an electrochemical cell when time stops at an instance and they have an imaginary microscope showing atom or ions (Item 10 in ECT). Four students in experimental group and one student in control group stated that cations and anion would exist in both half cell solutions. However, four students in control group and one student in exoerimental group stated that “plus charged ions should be in anode solution and minus charged ions should be in cathode solutions” because “anode lost electrons so plus ions should be in anode solution and cathode gained electrons so minus ions should be in cathode solution”

During interview, a new misconception which was not mentioned in literature was found. One of the students said that electrons move through the wire from anode to cathode and accumulated in cathode and since electrons were accumulated in cathode the mass of the cathode would be increased.

4.4.2 Concepts about Electrolytic Cells

The results of interview showed that students were less familiar with the concepts of electrolysis than the concepts of electrochemical cells. Most of the time questions related to electrolysis were not answered. Students were more familiar with the identity of the electrodes than other concepts of electroysis; three students in control groups and three students in experimental groups had correct idea that "the identity of electrodes depends on the connection with power source (e.g. battery)". However, four students in control group and four students in experimental group had no idea about how the electrodes were identified as anode and cathode. Just like in electrochemical cells, students stated that the identity of the electrode did not change when the placement of the electrodes changed providing that the connection with power source remained the same.

When students were asked whether a reaction occurred when same electrodes used, only one student from experimental group had correct idea. Two students from control group had misconception and believed that no reaction occurs since same electrodes were used. Additionally, two students from control group had limited conceptions about same electrodes. These students believed that electrodes should be always the same. One of them stated that if different electrodes were used, this system would become electrochemical cells and the other stated that since both electrodes were in the same cell they should be the same. Other students (three student from control group and six student from experimental group) stated that they did not know anything about that.

Students also have little idea about potential in electrolysis. Five students from control group and five students from experimental group had no idea about potential in electrolytic cell. Only one student from experimental group had the correct idea that the potential was negative. Three students had misconceptions about the potential of the electrolytic cell. Two of them (one from control and another from experimental group) stated that the potential was positive because the electrolytic cell was connected to battery. The third student from control group stated that the potential was not positive and it could not be negative, too. So he said that the potential was zero.

About other concepts of electrolysis, the collected data were not very concrete. Since students had little idea about electrolysis therefore they tried to guess instead of stating their idea.

4.4.3 Summary of the Interview

In conclusion, the interview results showed that students mainly focused on algorithmic problems rather than concepts. They use same reasoning in solving concept problems as they used in algorithmic problems. Some students who selected wrong answer at first found correct answer later during interview when he or she focused on concepts and use reasoning accordingly. Students had more conceptions about electrochemical cells than they had about electrolysis. The reason could be that the algorithmic aspect of electrolysis was more emphasized in the class. Only algorithmic problems about electrolysis were solved and therefore students only focused on algorithmic aspect of the electrolysis.

4.5 Conclusions

The conclusions derived from the results are as follows:

- Conceptual change oriented instruction caused better understanding of electrochemical cell and electrolysis concepts. Gain scores of experimental group was significantly higher than of control group when science process skill was controlled as covariate. However, conceptual change oriented instruction was not completely successful as posttest results and interviews showed that experimental group still had some misconceptions.
- ANCOVA results showed that there was no significant difference between males and females and no significant interaction between gender

and treatment. This results suggested that conceptual change oriented instruction was equally effective on both males and females.

- The mean of experimental group was higher than control group in terms of their ATCS scores. ANOVA results showed that the difference was significant. It can be concluded that conceptual change oriented instruction caused students developed more positive attitude towards chemistry.

- ANOVA results also showed that there was no mean difference between males and females, and there was no interaction between gender and treatment. It can be concluded that conceptual change oriented instruction was equally effective on males and females attitude towards chemistry

- An item-by-item analysis of ECT posttest showed that experimental group scored higher than control group in nine items (2, 4, 5, 6, 7, 10, 11, 13 and 14) whereas control group scored higher than experimental group in six items (1, 3, 8, 9, 12, and 15)

- The result of interview showed that students in experimental group have more correct conceptions about the purpose of the salt bridge in electrochemical cells and about the notion that anode and cathode were electrically charged. Both groups had similar ideas about the identity of electrodes in electrochemical cell and electrolysis when the placement of the electrodes was changed. The results also showed that students in both groups had little idea about concentration cells and electrolytic cells.

CHAPTER 5

DISCUSSION, IMPLICATIONS AND RECCOMMENDATIONS

In this chapter, in discussion section, the results of descriptive and inferential results, threats to internal and external validity were discussed. Then potential implication of the study and recommendation for further research were presented.

5.1. Discussion

In the previous section, data about the characteristics of the sample in this study discussed. The results showed differences between two groups. In this section, inferential results will be interpreted to generalize them to populations with similar characteristics of the sample used in this study.

The effectiveness of conceptual change texts has long been investigated in numerous studies as indicated in Chapter 2. This study was meant to contribute existing conceptual change text research. However, a modified or rather enhanced version of conceptual change text was developed for this study. The idea was, as Skinner (1958) stated before, “Education must become more efficient” (p. 969). The enhanced conceptual change texts – in other words, Computer-Based Interactive Conceptual Change Texts (CBICCT) were applied to experimental group as a supplementary tool for instruction. Since pretest scores of ECT showed that groups were uneven in terms of their previous conceptions (M (CG) = 2.84, M (EG) = 1.85) posttest scores of ECT were converted to gain scores by subtracting pretest scores from posttest scores. The means of gain scores of both control groups (M = 2.29) and experimental group (M = 6.17) were compared with ANCOVA analysis controlling science process skill as covariate. The analysis showed that there was a significant difference between groups in favor of students in experimental group. As a result, it can be concluded that instructions enhanced students' conceptions when they were supplemented with CBICCT's. This result agrees with the findings about effectiveness of paper-based conceptual change texts (e.g. Chambers & Andre, 1997a), conceptual change text accompanied by animations (Özdemir, et al., 2009) and the findings of other conceptual change strategies based on computer applications (e.g. Çetin, 2009; Windschitl & Andre, 1998; Ardac & Akaygun, 2005). Yang and Andre (2003) partially agree with the current findings. In their study, they found out that computer animations were effective in enhancing students conceptions, however, for students with high spatial ability. There are also studies in disagreement with the current findings. For example, Sanger and Greenbowe (2000) did not find significant effect on students understanding of current flow in electrolyte solutions when they were taught with computer animations. They stated that the reason that no effect was found could be that students were unfamiliar with the questions used in the study.

The mean difference between control groups and experimental group could be attributed to the instructional methods used in this study. In this study conceptual change oriented instruction accompanied by CBICCT was used in experimental group. Students in experimental group used CBICCT's which were conceptual change texts supported by animations and interactive interface. Conceptual change texts was found to be effective in improving students understanding in previous studies (Chambers & Andre, 1997; Yürük & Geban, 2001; Ozmen, et al., 2009; Çetin, 2009). Posner, et al. (1982) claimed that four conditions should be met for a successful conception change; dissatisfaction, intelligibility, plausibility and fruitfulness. In this study, students were told that their idea was wrong, so that they reconsidered their ideas about electrolysis with the help of CBICCT's (dissatisfaction). After that they were provided scientific explanation (intelligibility). They watched animations explaining the scientific ideas. The animations draw their attention and let them watch the explanations carefully. CBICCT's also provided examples of why scientific explanations were more logical (plausibility). Examples were given with the help of animations. To make it more meaningful, examples from daily life was given (fruitfulness). After CBICCT's were read and watched, a class discussion was conducted. Students shared their ideas about what happened when they used CBICCT's, e.g. what they thought when they saw that their ideas were wrong. The discussion showed that students' misconceptions were revealed better when students studied themselves with CBICCT's as they were free of the feeling that they would be judge if they shared their ideas with the teacher and the classmates. With the classroom discussion four conditions of conceptual change model that CBICCT's presented were met better.

In control group, however, traditional design let the students to receive concepts without four conditions were met. Students did not get opportunity to share their ideas as students preconceptions were not considered, the focus was on explanation of scientific ideas. Instead, students just listened or wrote down the scientific ideas without any interpretation of the ideas or without comparison their ideas with scientific counterparts. Even in class discussion only scientific ideas were discussed and students did not question their ideas.

Although conceptual change oriented instruction provided conditions to change misconceptions, there were some misconceptions that students in experimental group still had. The results of first, third, and nineth questions as well as the interview showed that students strongly kept their idea about free electron movment in half cell solutions and therefore no gain was observed in hese item scores. Animations showed that "electrons do not move through solution freely" but students still prefer the idea that "electrons move freely in the solution". The reason could be that either students have misconceptions about previous concepts – about the structure of atoms and ions – or they found their idea less complex than the scientific explanation because CBICCT's might not well provide the intelligibility condition. Hewson and Thorley (1989) stated that intelligibility raises someones concept status. If a concept is not intelligible, it cannot become plausible and fruitful. There is a possibility that CBICCT's could not satisfy the condition of intelligibility for some of the students. Unfortunately, this study was not extensive enough to investigate whether the conditions were met for all concepts. The misconception of free electron movement also affected students' correct conception about the purpose of the salt bridge. For example, in eigth item, students in experimental group chose the option which was consistent with both the idea of free electron movement and the purpose of the salt bridge. As a result, they chose the wrong option and this shows that the misconceptions can negatively affect students' existing correct ideas.

Experimental group kept their misconceptions about electrolysis, too. They sometimes confused concepts of electrolysis with the concepts of electrochemical cells. Some of the students thought that "no reaction occurred because both electrodes were identical in electrolysis" or "no reaction occurred because inert electrodes were used." Some of the student also thought that "no reaction occurred because no salt bridge existed." The reason could be that students could not understand the relation and difference between electrolysis and electrochemical cells because these concepts were given separately and the relations were not appropriately discussed. More CBICCT's could be created to present electrochemical cells and electrolysis together with similarity and differences.

Although control groups had almost all misconceptions examined here, two misconception were very obvious; they thought that electrons move freely (like the students in experimental group) and they thought that salt bridge was a bridge in which electrons moved through it. The word "bridge" probably let the students think that something should flow though it. Therefore, they assumed that electrons should flow though the bridge because electrons were free in solution and when electrical current exist electrons move through bridge. Since no proper explanation was given to the students in control group about reactions in solution, students strongly had these two misconceptions. They also had either misconceptions or no conceptions about electrolysis like experimental group as they mostly focused on algorithmic aspect of the topic instead of the concepts.

In this study, possible interaction between method and gender was investigated, too. Two way ANOVA was used to analyze the data. The analysis showed that there was no significant interaction between method and gender. Although profile plot showed an interaction, this interaction was not significant. It can be concluded that text manipulation was equally effective for both males and females. This result was in agreement with similar studies (Chambers & Andre, 1997; Çetin, 2009).

Affective constructs and especially attitude toward chemistry have been an important component of learning chemistry. Research has confirmed that achievement is positivelycorrelated with attitude (Freedman, 1997; Salta & Tzougraki, 2004). Thus, the effect of CBICCT on students was also investigated in this study. The scores of Attitude Towards Chemistry Scale was analyzed with two way ANOVA model to see main effects and interactions. Analysis showed that there is significant mean difference between control group and experimental group in terms of student attitude scores. Students taught with conceptual change oriented instruction accompanied by CBICCT developed significantly more positive attitude toward chemistry than students taught with traditional instruction. Interviews with students of both groups also support this results, as students from experimental group stated that they liked to have the chemistry course with CBICCT. They said that they were more interested in chemistry topic because of the interactive interface of the CBICCT' and animations in it. It can be concluded that animations and interactive feature increased students attention on the topic and let them developed better positive attitude toward chemistry. This result is also in agreement with previous studies (Morgil, Seyhan, Alsan, & Temel, 2008; Çetin, 2009).

Analysis related with gender showed that there was no mean difference between males and females. In addition, no significant interaction was found between gender and method. These results suggested that CBICCT has equal effect on attitudes of both males and females. These findings are in accordance with some of the previous findings in literature (e.g. Çetin, 2009; Pabuçcu, 2004; Cheung, 2009; Osborne, Simon, & Collins, 2003).

5.2 Internal Validity

Ideally, a design of the study is best when all variables are controlled by the researcher. However, there could be some extraneous variables that can confound the results of the studies. Internal validity of a study is defined by McMillan and Schumacher (2001) as "the extent of control over extraneous variable" (p. 186). These extraneous variables which could be a threat to the internal validity of a study are subject characteristics, mortality, location, instrumentation, testing (or pretesting), history, maturation, subject attitudes, regression, implementation. In this section, the possibility of the threats and how the researcher controlled them is discussed.

This study is a quasi-experimental study. Random assignment is a powerful method to minimize the threat of subject characteristics and a study cannot be a true experimental research unless random assignment was used. Due to restrictions and ethical issues, no random assignment was used in this study; two intact classes were assigned as control and experimental groups. Since science process skill and previously existing knowledge were designated as threats to study. Two tests were administered to measure these characteristics: ECT to measure previously existing concepts and SPST to measure science process skills. ECT pretest and SPST scores both showed that there were significant mean differences between experimental and control group. To overcome this difficulties two technics was applied. First, gain scores for ECT was used, namely the differences between posttest and pretest were taken as ECT scores. Second, the possible confounding effect of science process skill was statistically controlled by using ANCOVA, i.e. the means of gain scores were compared while the SPST scores were taken as covariate.

Before conducting the implementation, mortality was considered as a serious threat because the treatment was implemented at the end of the second term in which 11th grade students shifted their focus from school to private courses for university examinations. However school administration convinced that the students will less likely missed the classes because the administration had strict rules against absencies and they worked in corporation with parents to control students attendances. Indeed, the mortality effect was less than expected. Three students from control group and one student from experimental group were either missed the tests or the treatment. The results related were excluded from the analysis of the data.

Subject attitudes were a serious threat to the study. One of the expected treat was novelty effect which was very common threat for studies involving computer-assisted instruction. Using computer at school is a new experience for many students and therefore they are generally motivated by just using computers. In this study, novelty effect was not eliminated instead, it was counterbalanced. Just as the experimental group went to computer lab to use computer-based interactive conceptual change text, control group went once to computer lab. Each student watched an animation about electrochemical cells. The animation was different from computer-based interactive conceptual change text used in experimental group. Thus, it was assumed that the novelty effect motivated both groups equally. The design to counterbalance novelty effect also helped to decrease possible John Henry effect. Since control group visited computer lab they thought they got same instruction as the other group their teacher reported that they did not try harder than before.

Instrumentation threat appears mainly in three forms: (a) Instrument decay, (b) Data collector characteristics (c) Data collector bias. Since all measurement were done through multiple choice tests, instrumentation decay was less likely a threat. Data collector characteristics threat was controlled by using same data collector. All tests were administered, evaluated, and analyzed by the researcher. To minimize data collector bias, the researcher did not start analyzing data during treatment. The teacher who attended treatment wanted to see the mean differences of ECT pretest scores. However to control data collector bias all results were kept hidden until the end of the treatment.

Location could be a threat because students in experimental group took part of the course in computer laboratory which they hardly visited before. However, this threat was not very serious. The laboratory was as big as their classroom and there was nothing which could affect learning such as high sound or poor light.

Testing could be a threat for this study because ECT was administered as pretest. Students had some clues from the questions or they might be alerted when the treatment started. However, this threat was equal for both groups, as both groups have given pretest.

Implementation threat was controlled by the researcher. Same teacher instructed in both classes so the the difference from implementation of method was eliminated. In addition, same teacher effect was controlled. The researcher attended both control and treatment class of the teacher and tried to make sure that the teacher did not favor either of the classes.

During the treatment, no history treat was observed. Since the treatment did not last long, no maturation threat observed, either. Regression threat was not present for this study if the ECT scores were considered. Before treatment experimental group was significantly lower than control group but after treatment experimental group scored significantly higher than control group. This result could not be attributed to regression threat.

5.3 External Validity

The sample of the study was taken from an anatolian high school. Generally, students attending anatolian high schools are medium to high achievers depending on the school because anatolian schools accepting students based on their success in junior high schools. The school where the implementation occurred is a new school therefore it is not so popular. There are 71 anotolian high school in Ankara and its towns (Milli Eğitim Bakanlığı, 2010). If these anatolian high schools are classified as high, medium and low achievers, the school that the study conducted in will be among medium achievers and the sample used in this study will be representing the students who attend 11th grade science classes in medium level anatolian high school. The number of student (n=66) represented about 5 % of the accessible population. However, in terms of school facilities this school was higher than most of the schools. There were rooms for school projects, music and painting. Students had free access to internet at the computers during breaks. The number of computers (30 computers) in computer lab was sufficient for each student of a class. In addition, there were smart boards and projectors in chemistry-biology and physics labs. These facilities narrow accessible population. In conclusion, the results of this study can be generalized to 5-10 % of the students in anatolian high school who attend 11th grade science classes and other populations who have similar characteristics as described above.

The study took place in May. The topic was the last one of the semester. However, students were more concerned about next year than the summer holiday because they focused on the university entrance exam, i.e. their study plan for university entrance exam, their university and department selection, and the private courses that they want to attend to prepare for university entrance exam. These characteristics are very similar to most of the 11th grade science classes in Turkey. However, unlike many schools, the attendance of this school was very high and classes were not very crowded so students were concentrated on the classes as well as on university exam. As a result, the results could be generalized to the ecological settings described here.

5.4 Implications

The findings in this study suggest the following implications for chemistry education in secondary schools.

- Students come to the class with their concepts about chemistry topics. Teachers need to identify students' ideas before they start with any topic. Identifying misconceptions could guide the teacher to develop a strategy to eliminate misconceptions.

- One of the strategies that teachers could use to eliminate misconceptions is conceptional change text based on conceptional change model of Posner et al. (1982). Several studies mentioned in this study showed that conceptual change texts are effective in eliminating misconceptions and let students gain proper understanding of concepts.

- To increase the effectiveness of the conceptual change texts, the format could be changed to computer-based interactive text. Computer-based interactive conceptual change (CBICCT) could have benefit of both conceptual change texts and computer-based instruction.

- CBICCT have flexible usage. Any method used in the class could be accompanied by CBICCT. Two drawbacks about effective usage of CBICCT could be lack of equipments and teachers who cannot use computers. However, currently most of the schools have already obtained computer labs and some projects aim to increase the teachers' and students' knowledge of computer and technology (e.g. Project FATIH of Ministry of National Education). The increasing tendency towards using computers in education more effectively indicates that computer-based course materials like CBICCT will be indispensable for teachers in the very near future.

- CBICCT also showed that audio-visual and verbal materials help the students develop better attitude toward chemistry. Students generally find chemistry very abstract and difficult and therefore they develop negative attitude toward chemistry. Audio-visual representation of chemistry let the students learn difficult concepts easier and enjoy them.

- CBICCT could ease teachers' burden since students are able to use CBICCT without help of the teacher. The teachers could easily control students learning during implementation of the method without worrying about giving the concepts.

- Both males and females could benefit equally from CBICCT. This increase CBICCT's usability in classrooms.

5.5 Recommendations for Further Research

Based on the experiences during the study, the researcher will like to suggest following points to be considered for further researches:

- Most important drawback of this study was sampling method. Intact groups were used in this study therefore generalizability was low. A study with random sampling will provide better generalizability and the sample could represent larger population.

- This study was quasi-experimental because groups were not randomly assigned. However, a true experimental research is always needed to see the relation between the variables. Therefore, a study with randomly assigned groups will provide more reliable results.

- A study with larger sample size ($n > 66$) will be better. With larger samples, statistical power will increase to get better statistical results.

- Two way ANOVA and ANCOVA was used to analyze the data in this study. There were two dependent variables in this study and univariate statistics was used although multivariate statistics could be used. However, it was not used because the assumptions for two way MANOVA and MANCOVA were not met. With a different sample and larger sample size, the assumption will probably be met and both univariate and multivariate analysis together give more reliable and better results.

- In this study attitude was investigated. In further researches, other affective variables such as motivation, self-efficacy and self-regulation can be investigated.

- Students' conceptual change and metacognition can be investigated together to see more complete picture of the effectiveness of CBICCT on students conceptions.

- Research on development of teacher training programs about preparing and implementing CBICCT in classrooms and effectiveness of this program can be conducted. While investigation of effectiveness of the method is important, in order to practice this method in classrooms, it is equally important and necessary to train teachers about this method.

- Although the method was not interacted with the gender in this study, in further studies possible interaction of treatment and gender should be investigated. More support is needed to conclude that this method is equally effective on both males and females.

- In this study, the effectiveness of CBICCT on conceptual understanding was investigated. However, in university entrance exam, most of the questions are based on algorithmic problems. Therefore, the effectiveness of CBICCT on students' algorithmic problem solving abilities should be investigated. Unfortunately, because of the university entrance exam students are not easily motivated unless they believe that CBICCT is equally effective on algorithmic problem solving. Strong empirical support about effectiveness of CBICCT will make it easier to introduce this method to classroom.

- CBICCT is not meant to replace the teacher. It is a supplementary material for any method teachers use in their classes. It is not recommended to impose CBICCT as an alternative to teachers.

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APPENDIX – A

COMPUTER-BASED INTERACTIVE CONCEPTUAL CHANGE TEXT: SAMPLE -1

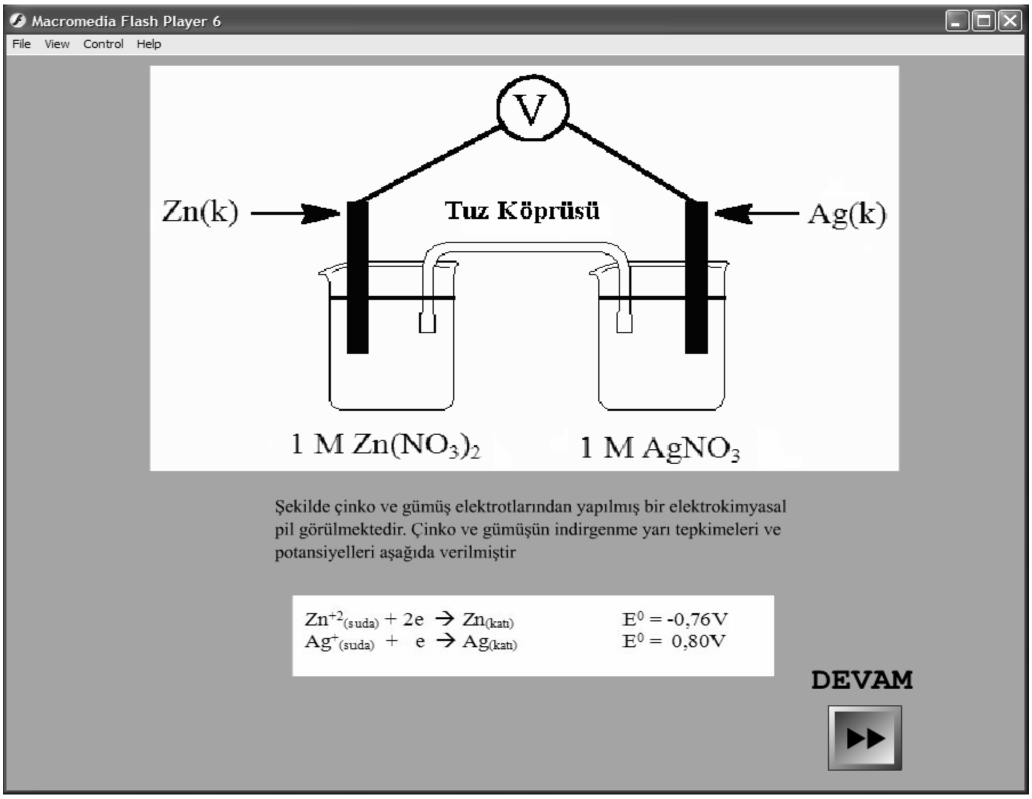


Figure A.1 A screen taken from CBICCT-1

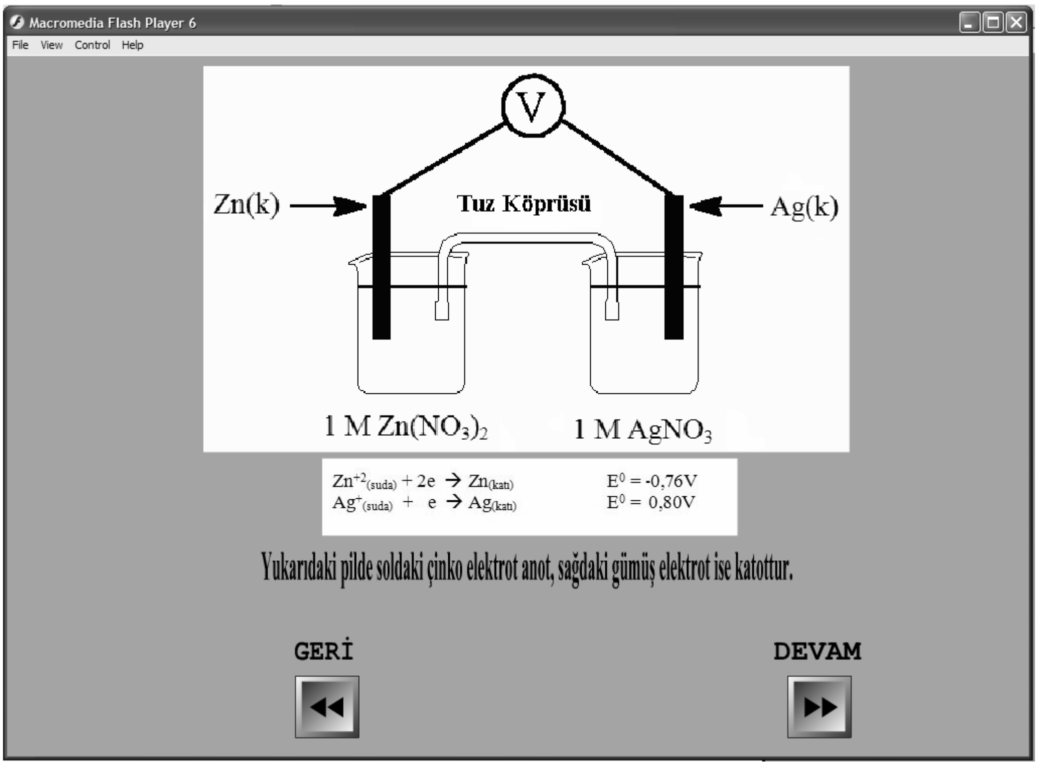


Figure A.2 A screen taken from CBICCT-1

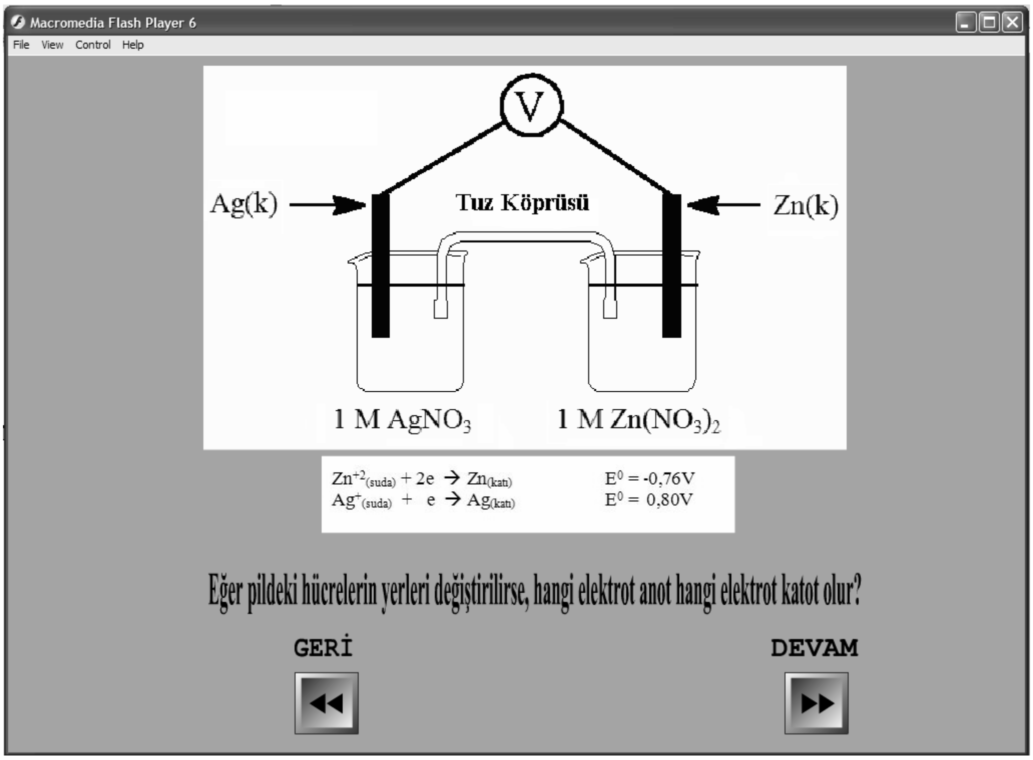


Figure A.3 A screen taken from CBICCT-1

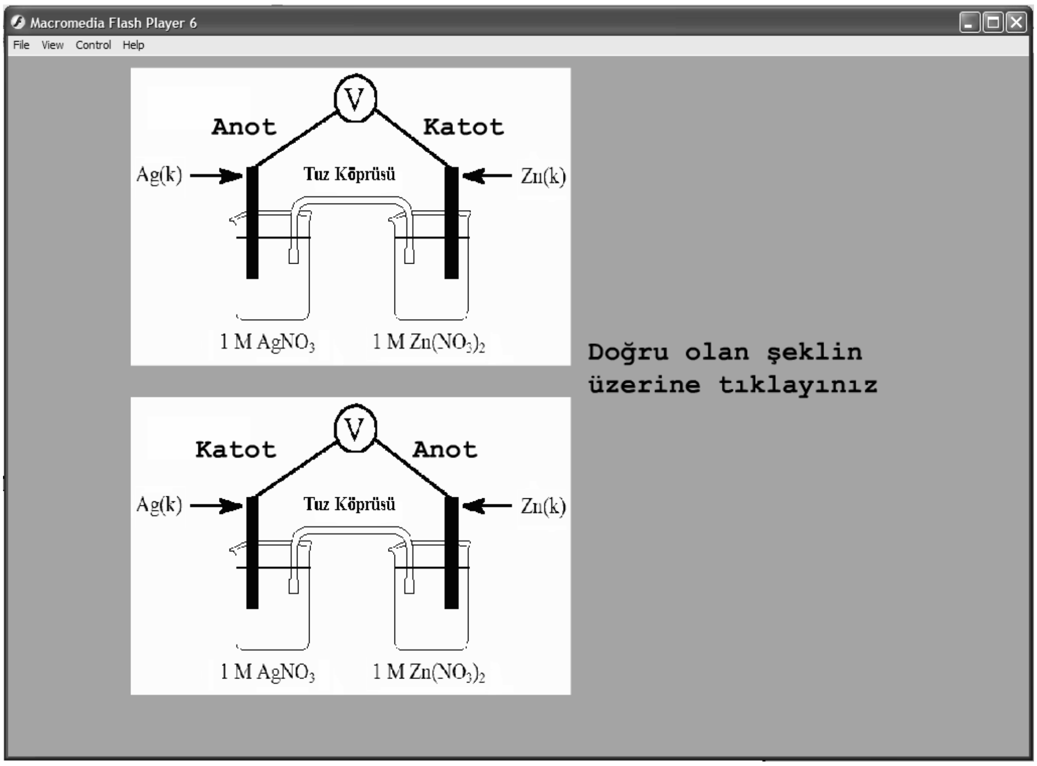


Figure A.4 A screen taken from CBICCT-1

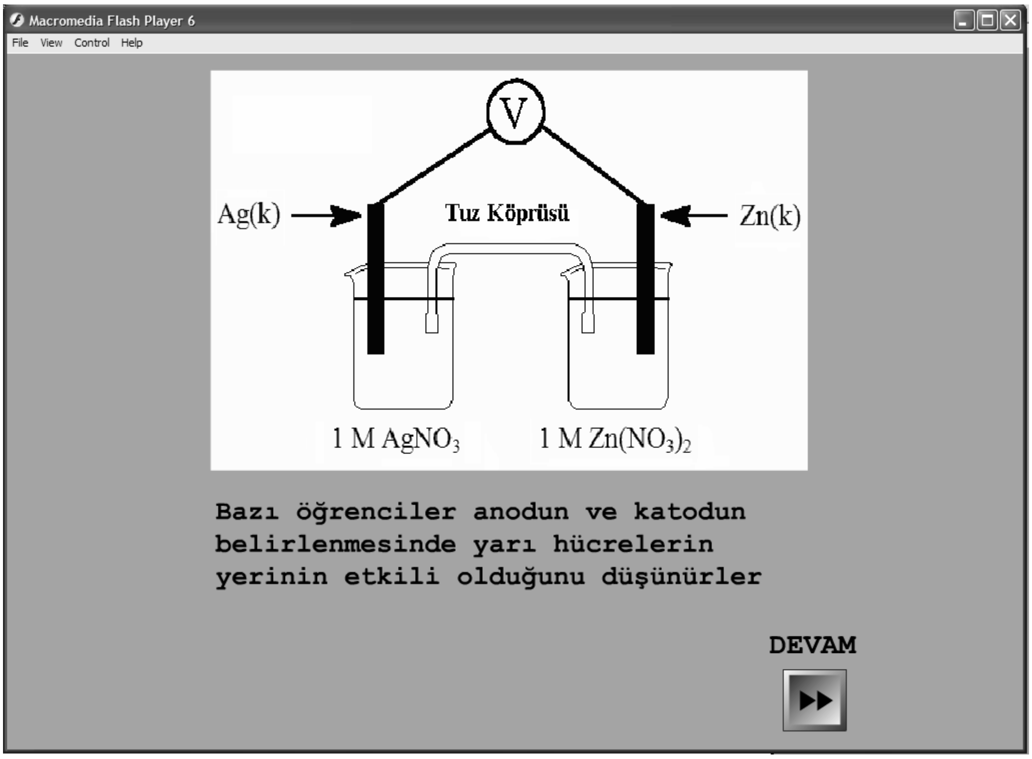


Figure A.5 A screen taken from CBICCT-1

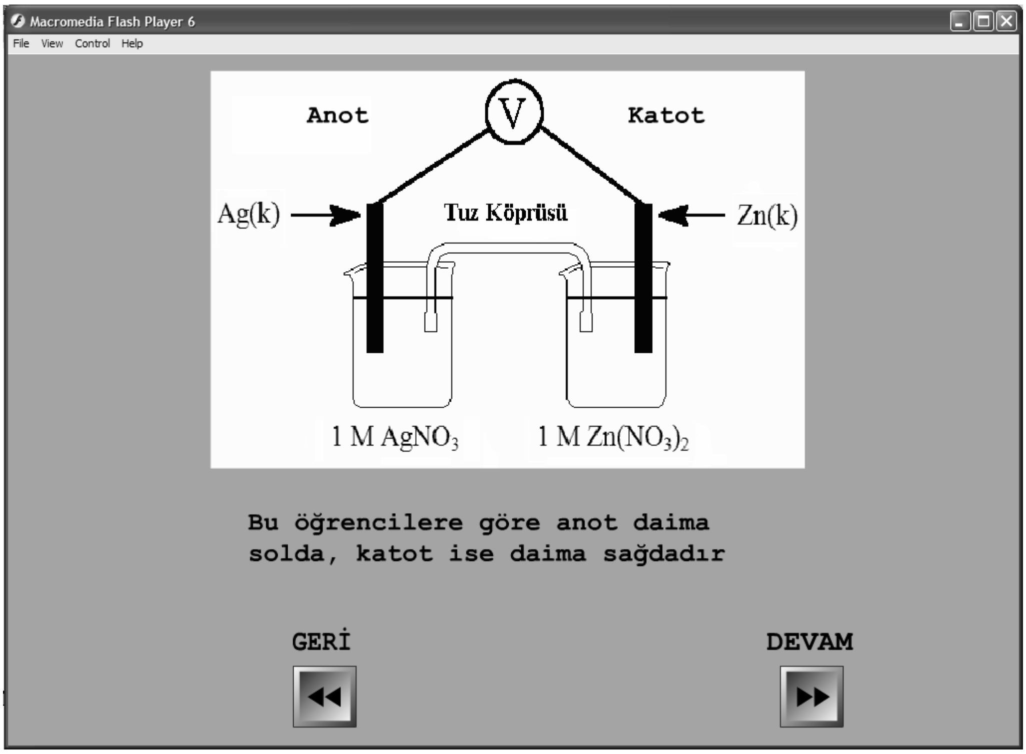


Figure A.6 A screen taken from CBICCT-1

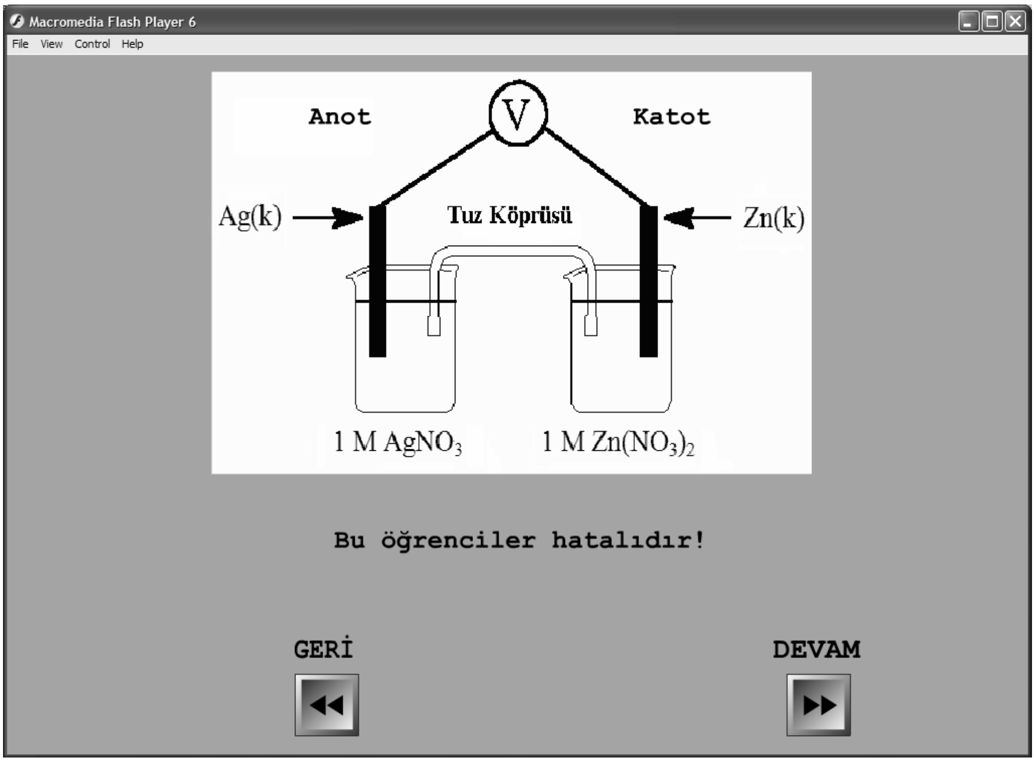


Figure A.7 A screen taken from CBICCT-1

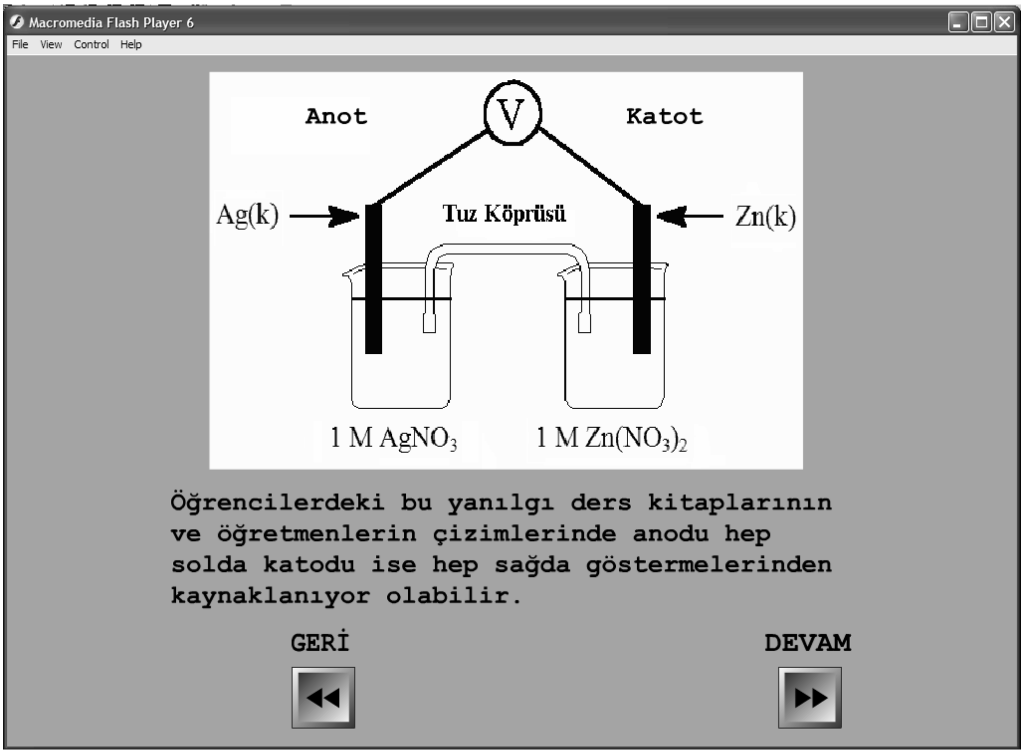


Figure A.8 A screen taken from CBICCT-1

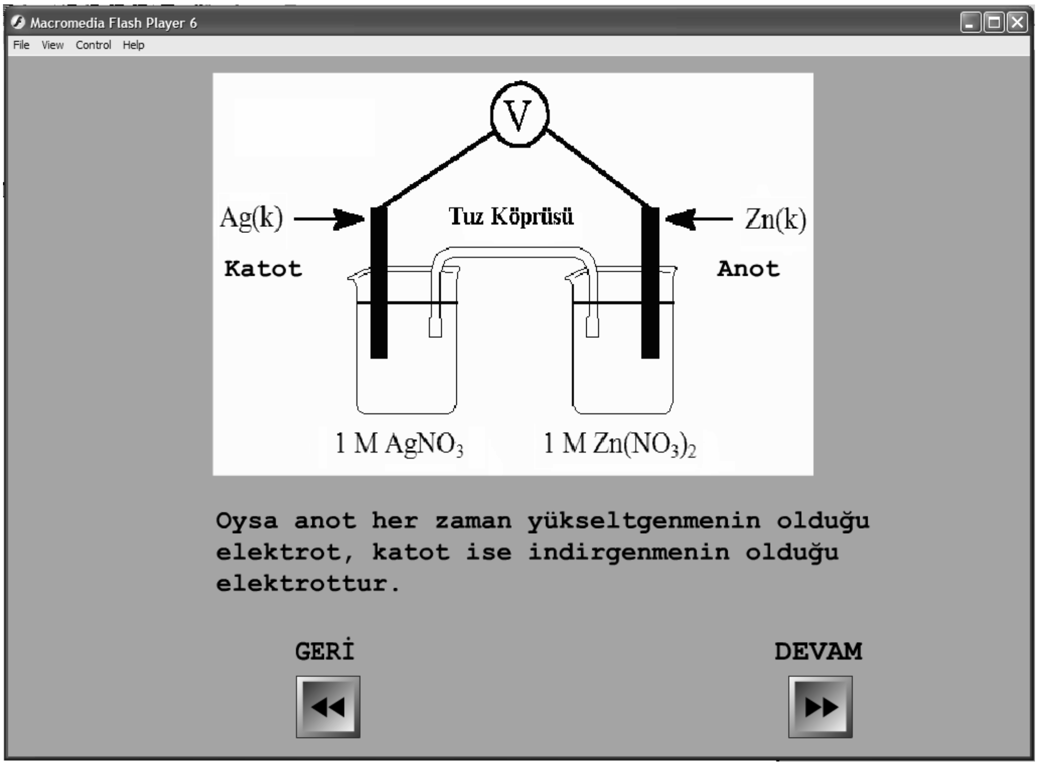


Figure A.9 A screen taken from CBICCT-1

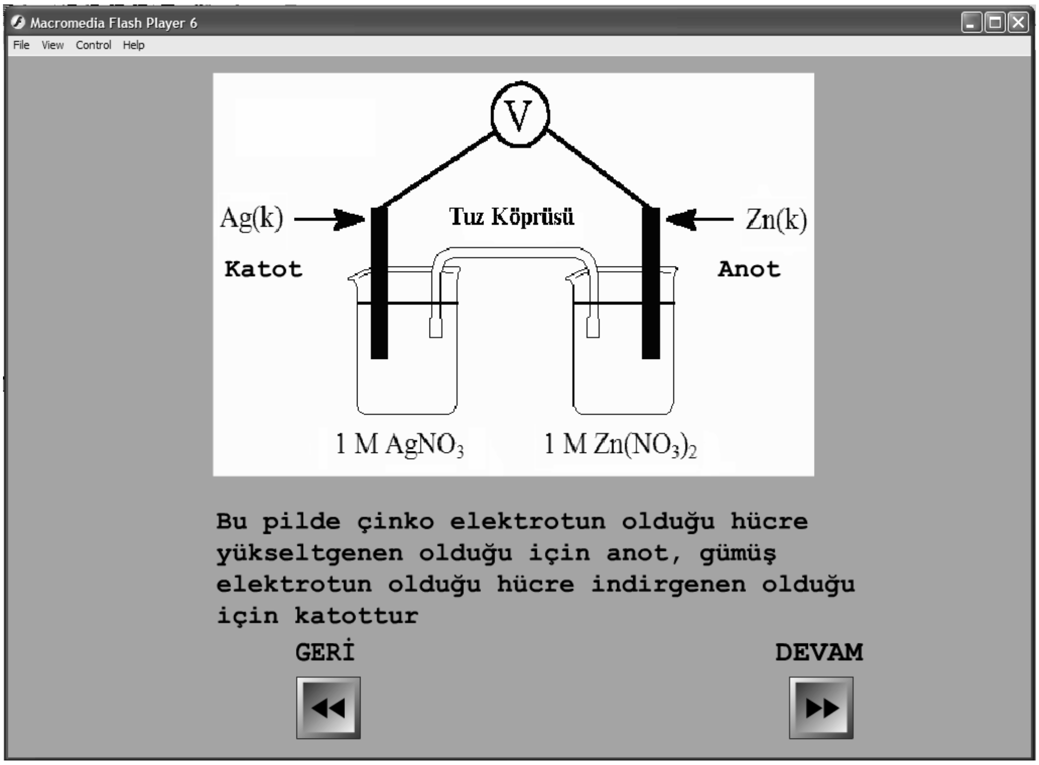


Figure A.10 A screen taken from CBICCT-1

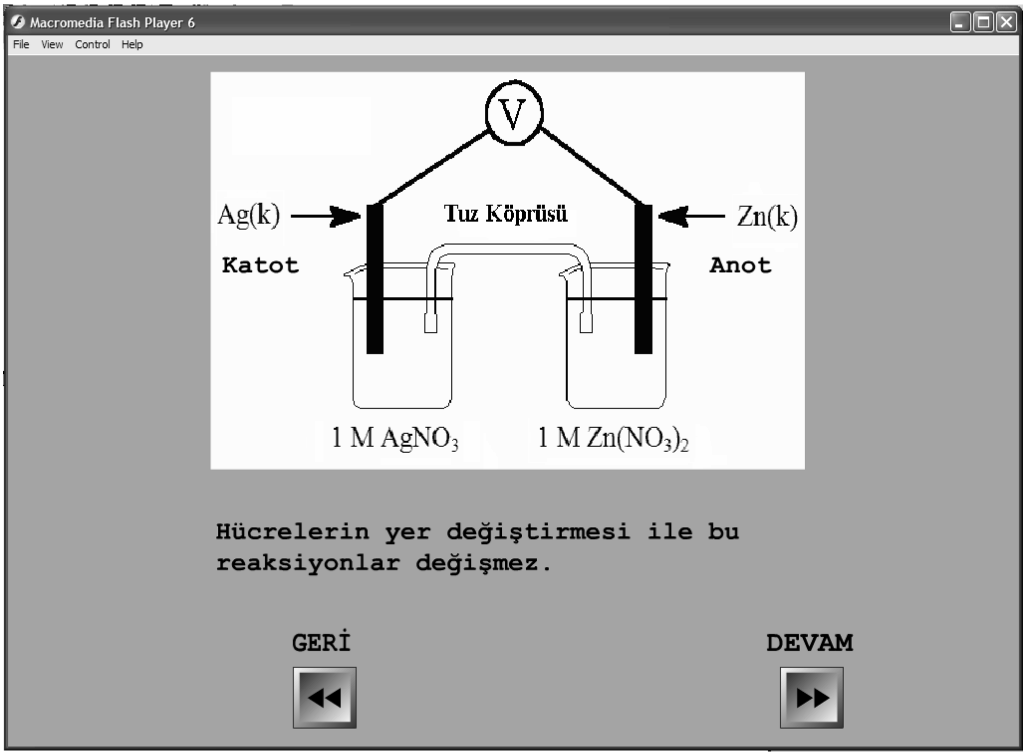


Figure A.11 A screen taken from CBICCT-1

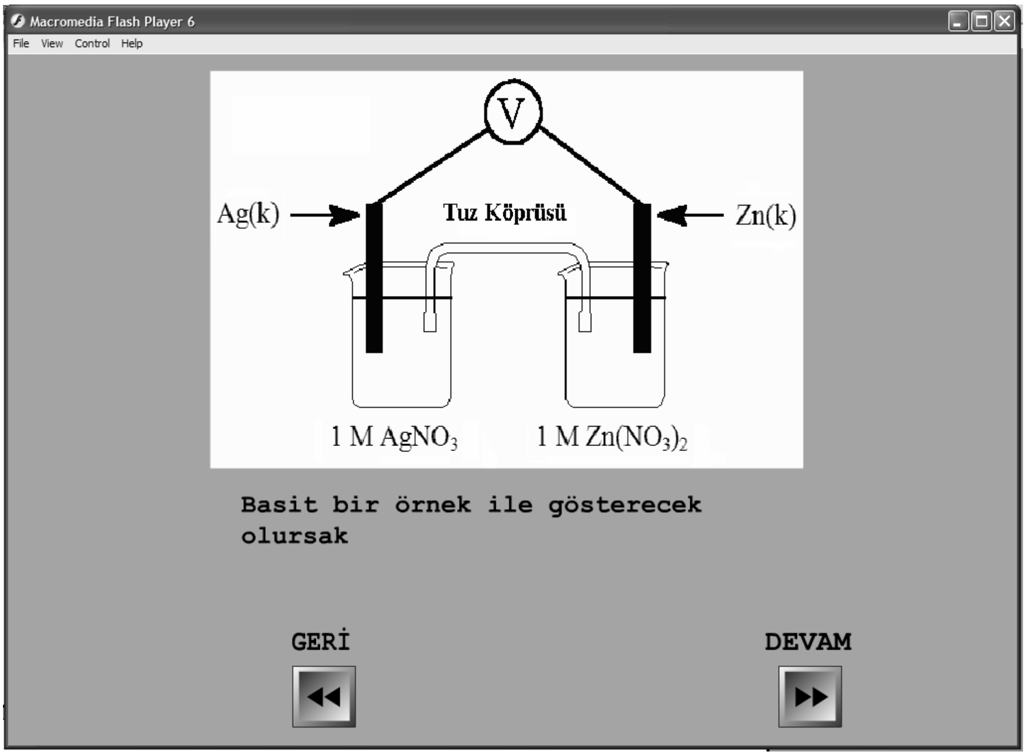


Figure A.12 A screen taken from CBICCT-1

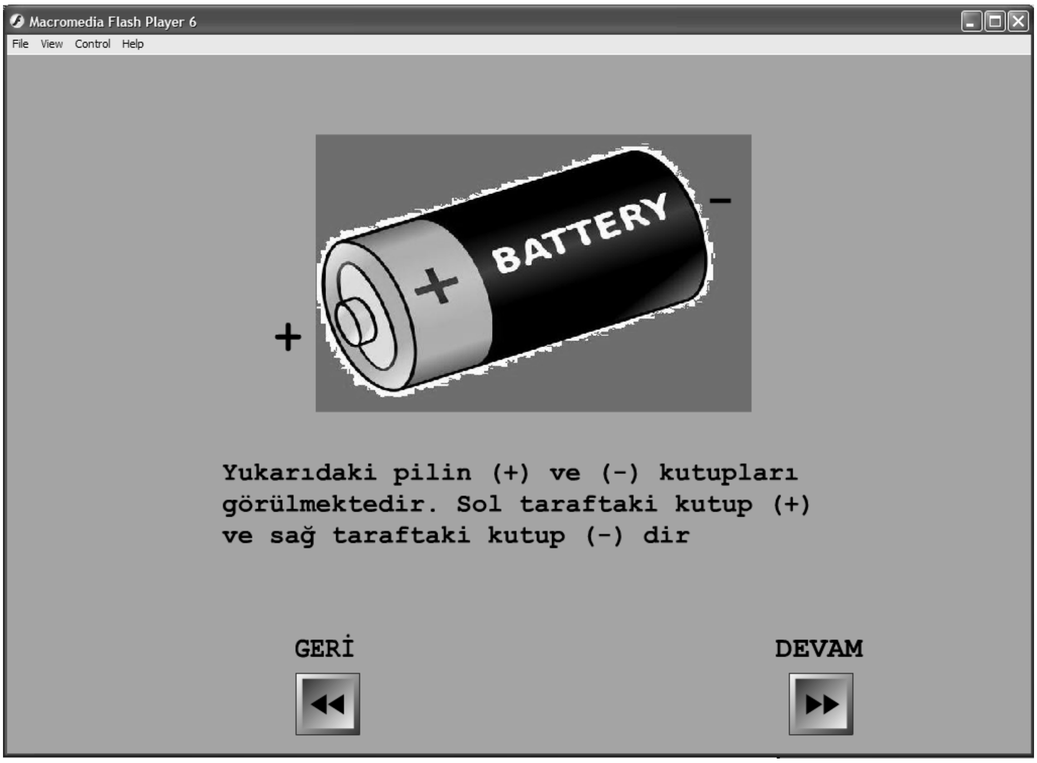


Figure A. 13 A screen taken from CBICCT-1

Figure A.14 A screen taken from CBICCT-1

Figure A.15 A screen taken from CBICCT-1

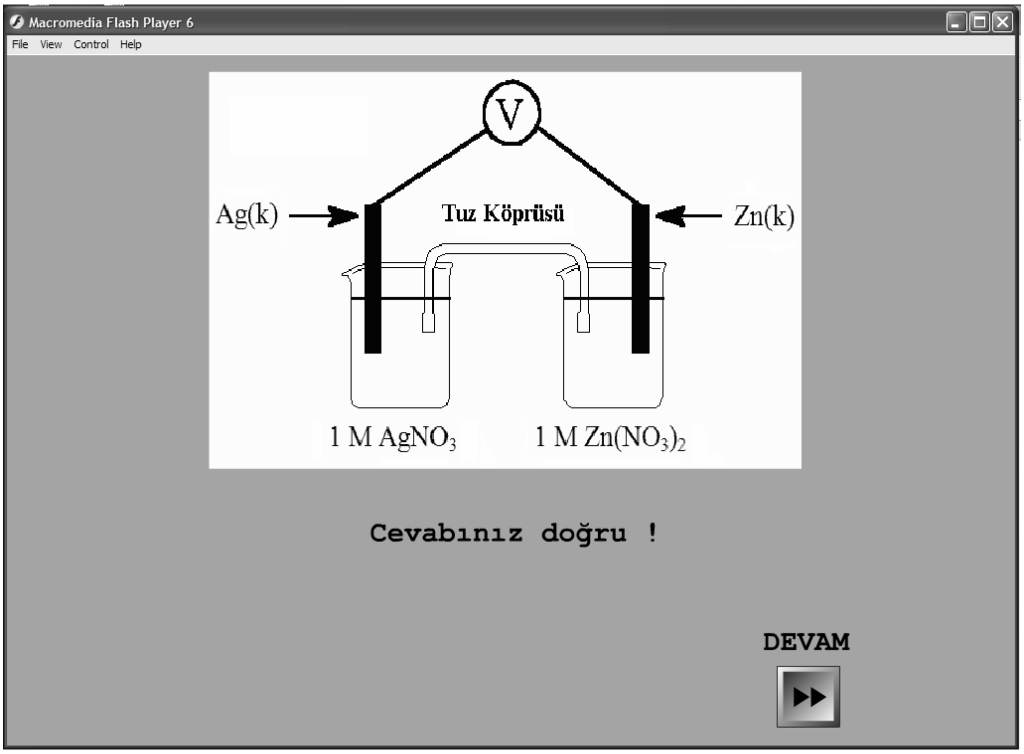


Figure A.16 A screen taken from CBICCT-1

APPENDIX – B

COMPUTER-BASED INTERACTIVE CONCEPTUAL CHANGE TEXT: SAMPLE - 2

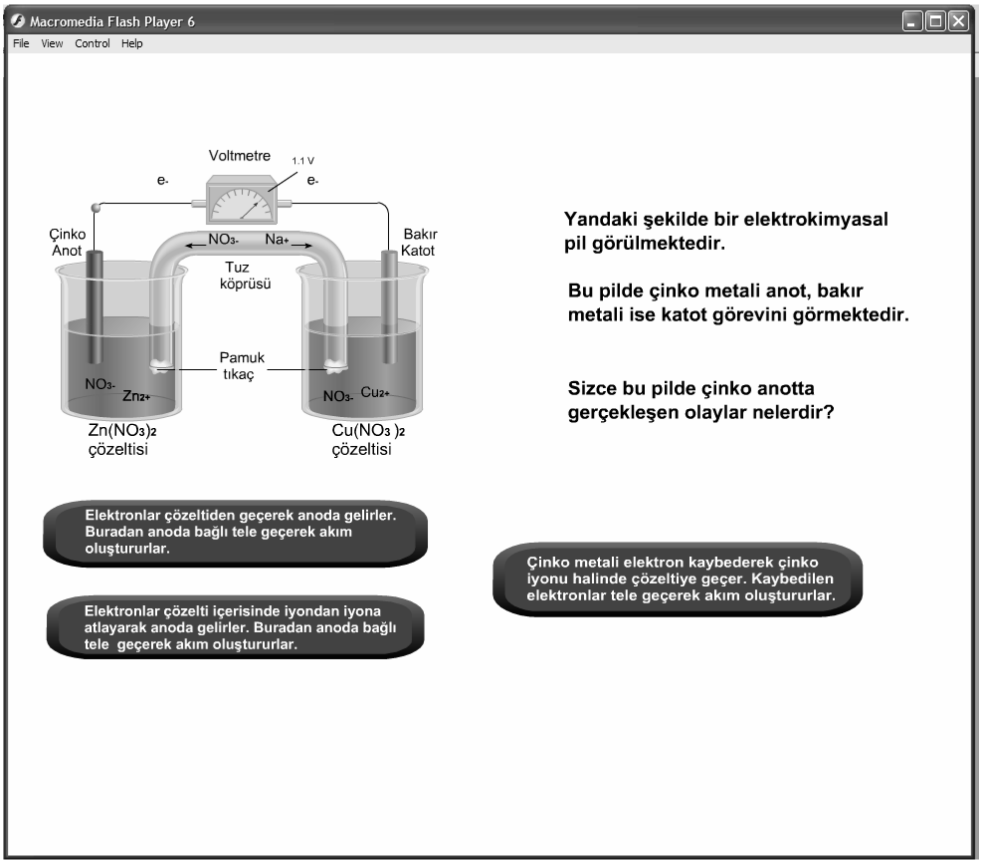


Figure B.1 A screen taken from CBICCT-2

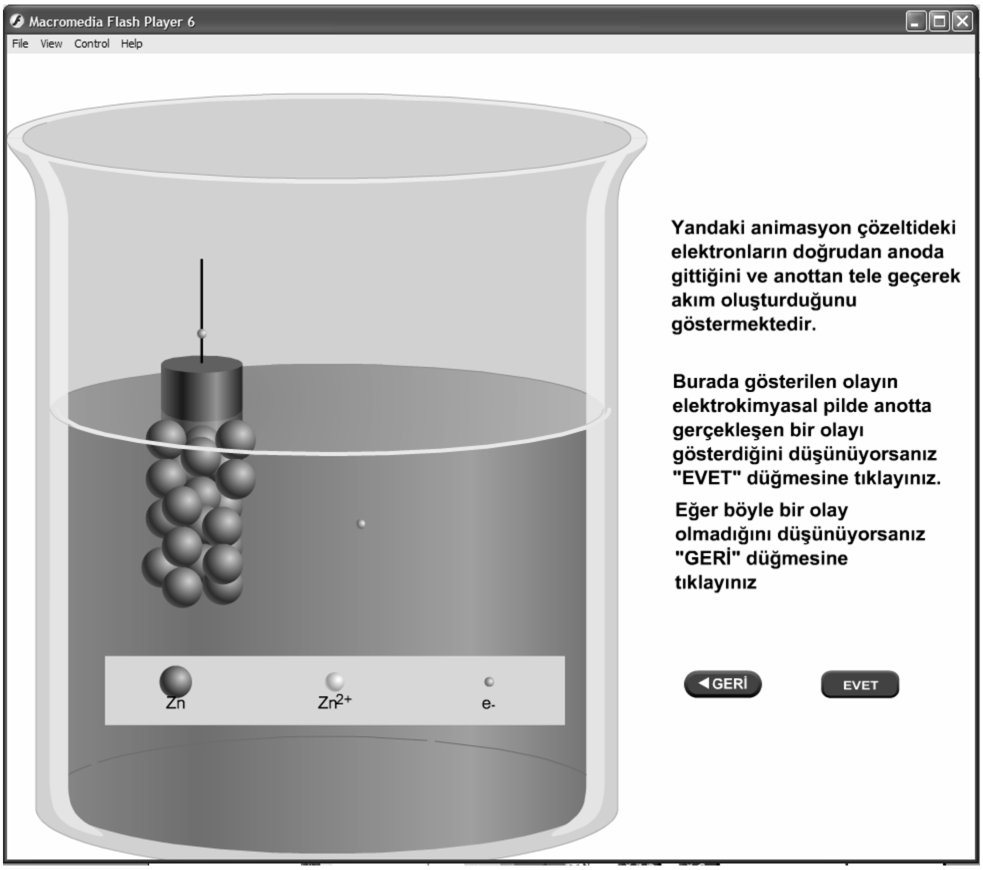


Figure B.2 A screen taken from CBICCT-2

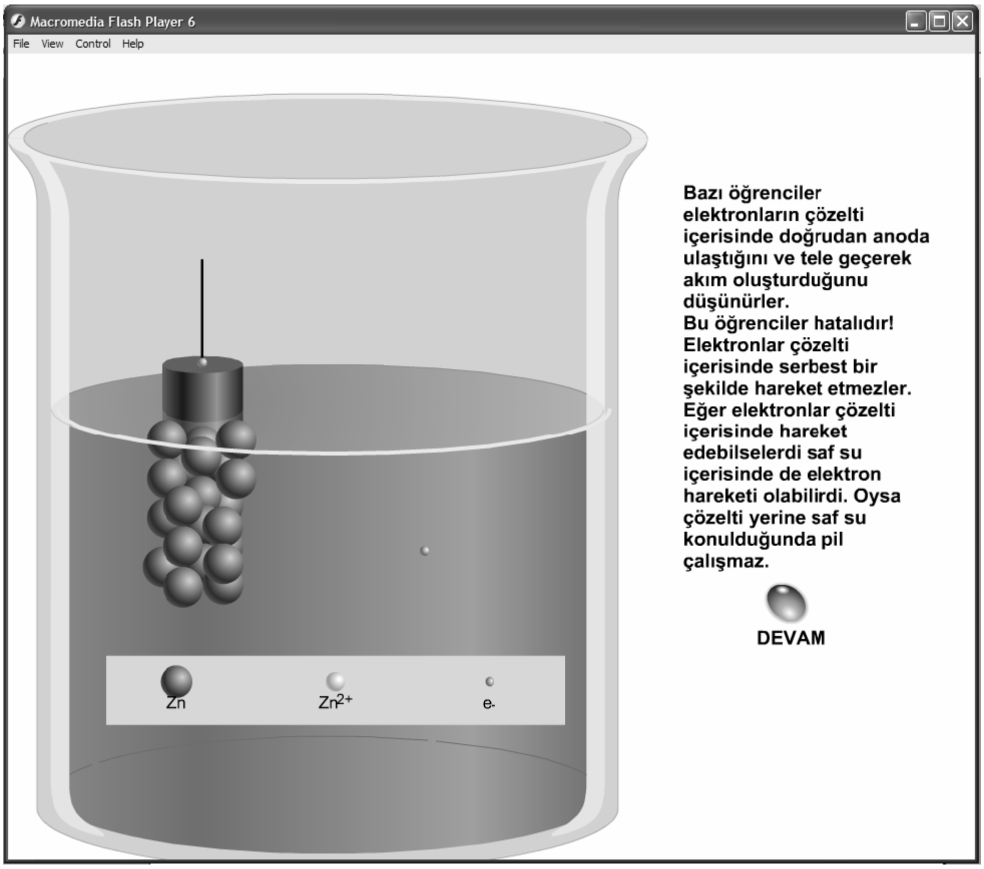


Figure B.3 A screen taken from CBICCT-2

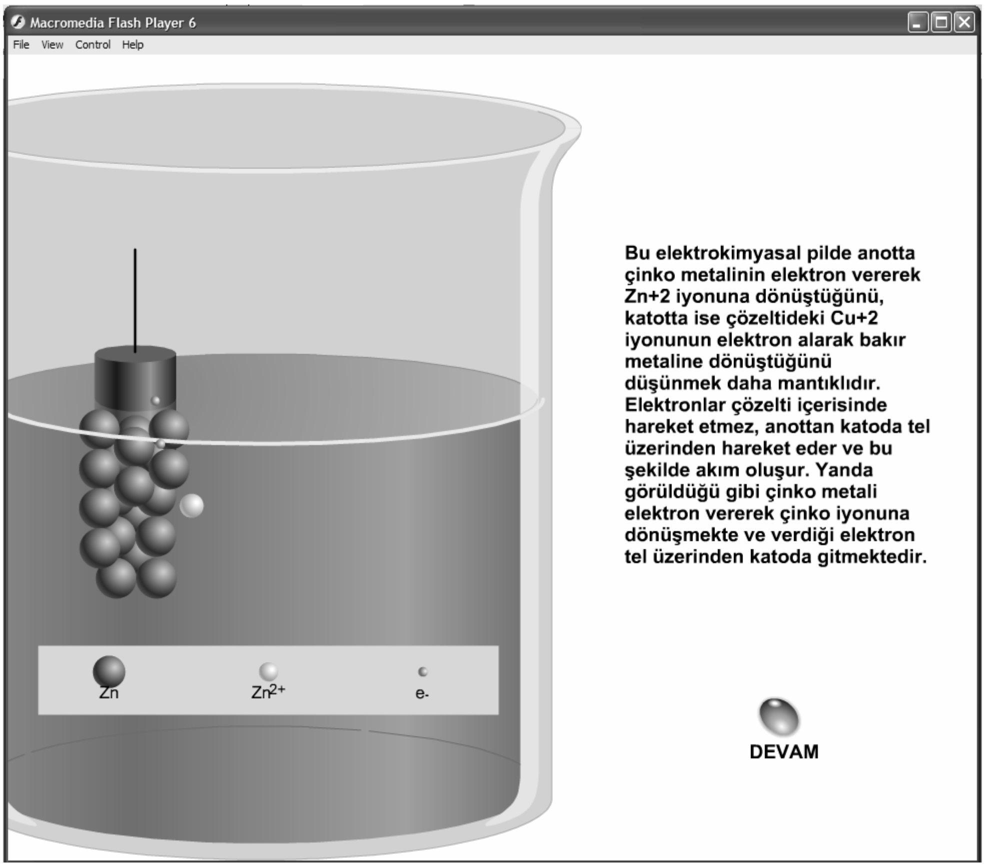


Figure B.4 A screen taken from CBICCT-2

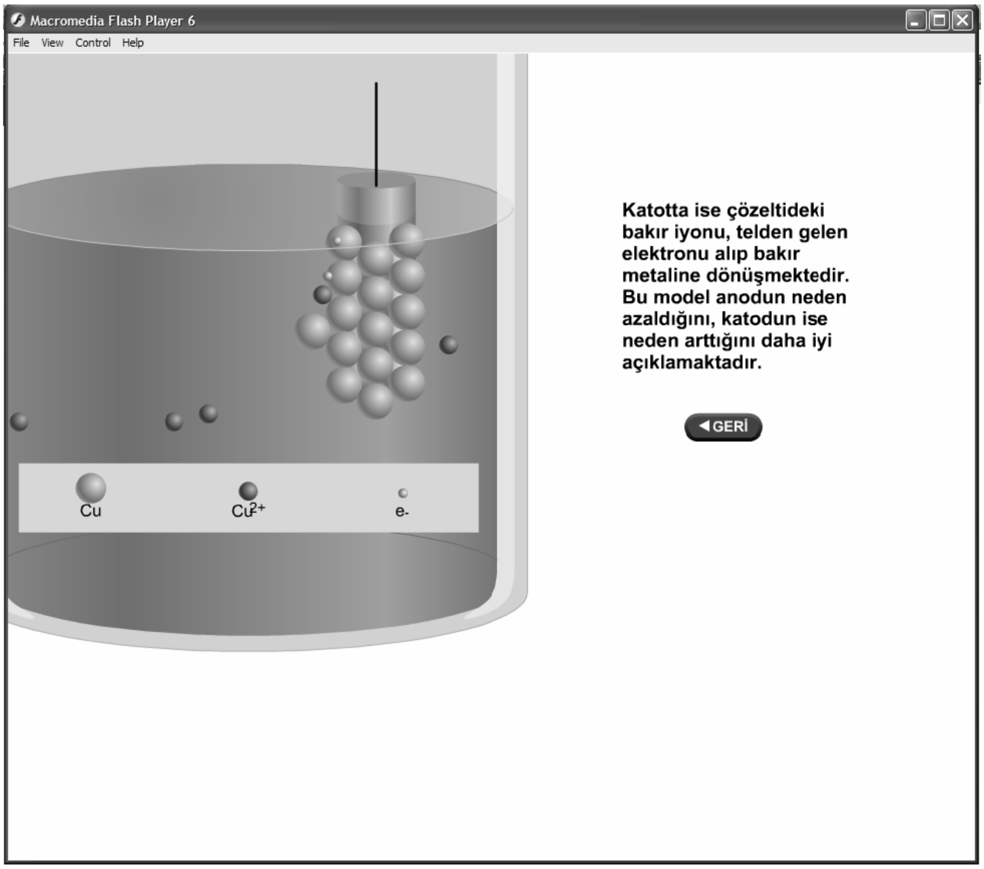


Figure B.5 A screen taken from CBICCT-2

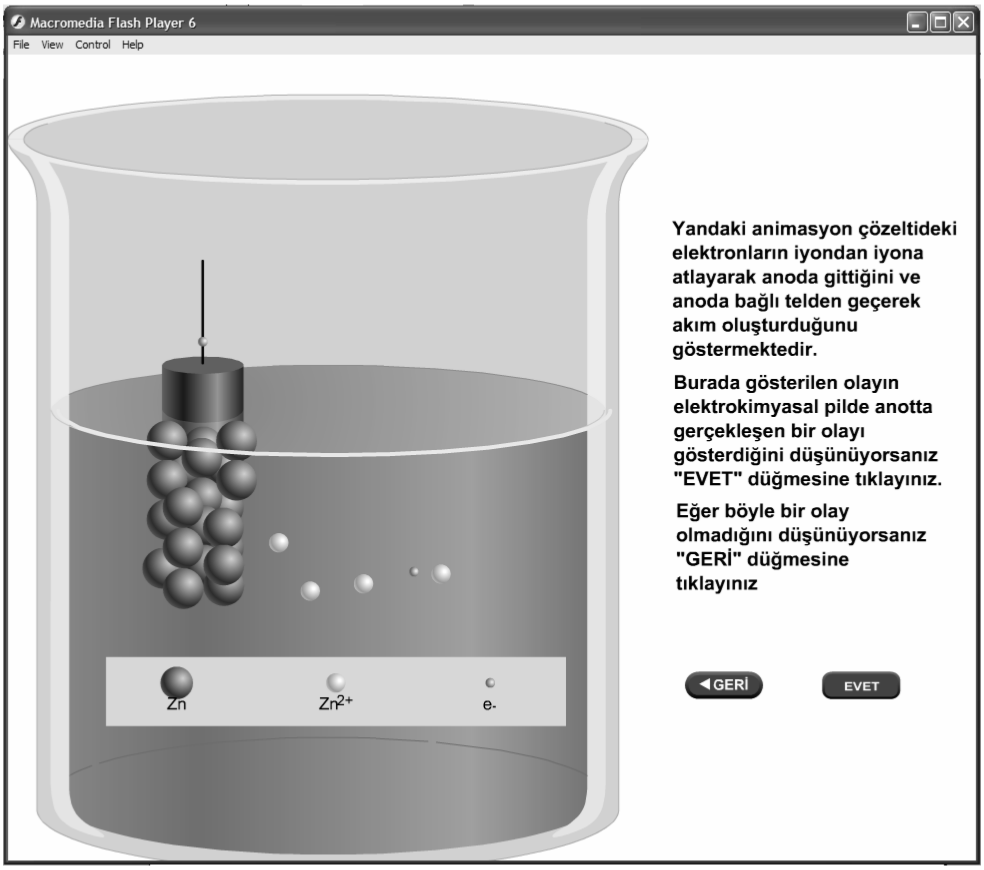


Figure B.6 A screen taken from CBICCT-2

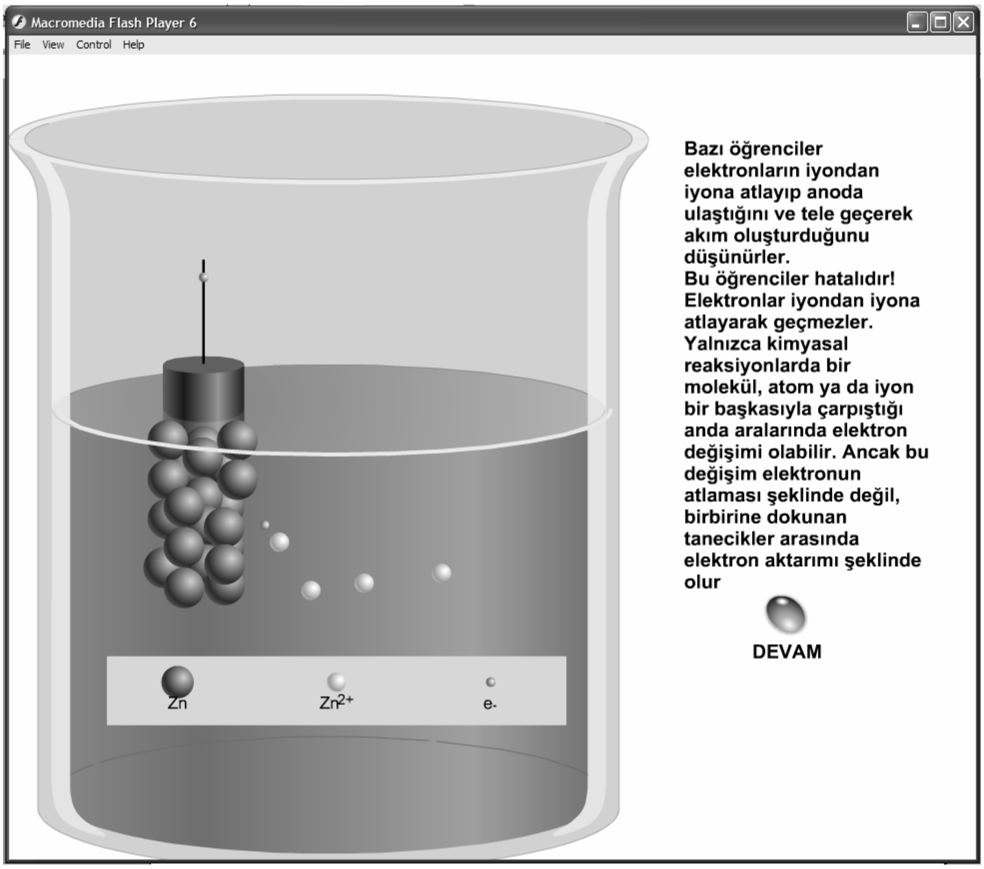


Figure B.7 A screen taken from CBICCT-2

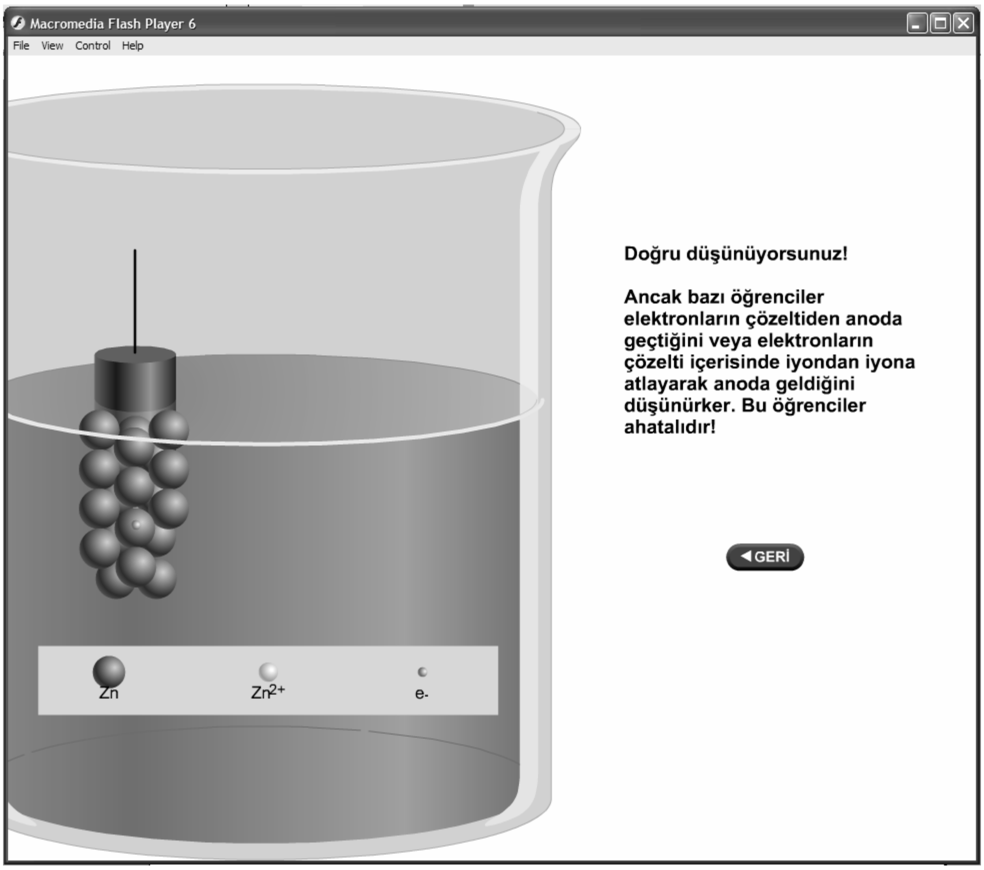


Figure B.8 A screen taken from CBICCT-2

APPENDIX – C

ELEKTROKİMYASAL PİL VE ELEKTROLİZ KAVRAM TESTİ

AÇIKLAMA : Bu testte Elektrokimyasal Pil ve Elektroliz konuları ile ilgili sorular bulunmaktadır. Bütün sorular çoktan seçmeli olup seçeneklerden sadece bir tanesi doğrudur. Şıklardan size göre en doğru olanı işaretleyiniz. Teşekkür ederim.

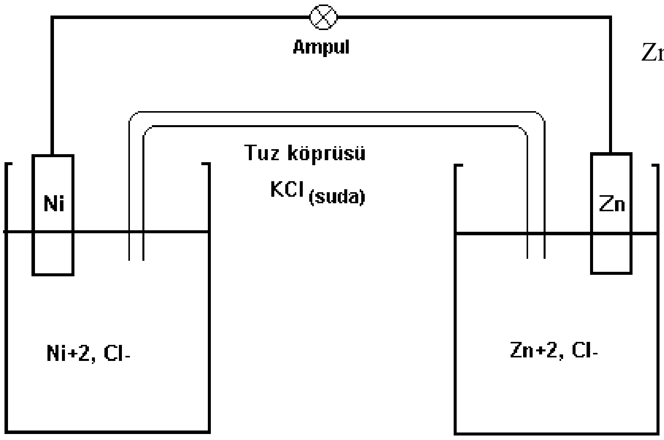
Örnek işaretleme:

20	a	b	c	d	e

CEVAP KAĞIDI

1	**a**	**b**	**c**	**d**	**e**	**f**
2	**a**	**b**	**c**	**d**	**e**	**f**
3	**a**	**b**	**c**	**d**	**e**	**f**
4	**a**	**b**	**c**	**d**	**e**	**f**
5	**a**	**b**	**c**	**d**	**e**	**f**
6	**a**	**b**	**c**	**d**	**e**	**f**
7	**a**	**b**	**c**	**d**	**e**	**f**
8	**a**	**b**	**c**	**d**	**e**	**f**
9	**a**	**b**	**c**	**d**	**e**	**f**
10	**a**	**b**	**c**	**d**	**e**	**f**
11	**a**	**b**	**c**	**d**	**e**	**f**
12	**a**	**b**	**c**	**d**	**e**	**f**
13	**a**	**b**	**c**	**d**	**e**	**f**
14	**a**	**b**	**c**	**d**	**e**	**f**
15	**a**	**b**	**c**	**d**	**e**	**f**

1-6. soruları aşağıdaki şekle göre cevaplandırın.

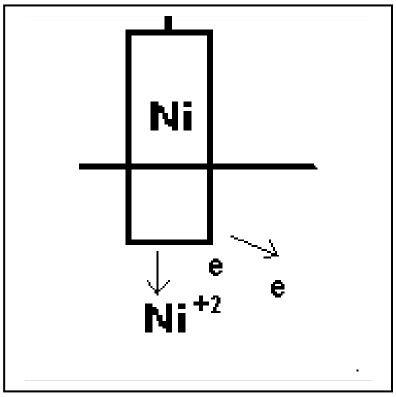


$Ni^{+2}_{(suda)} + 2e \rightarrow Ni_{(k)}$ $E^0 = -0,25$ V

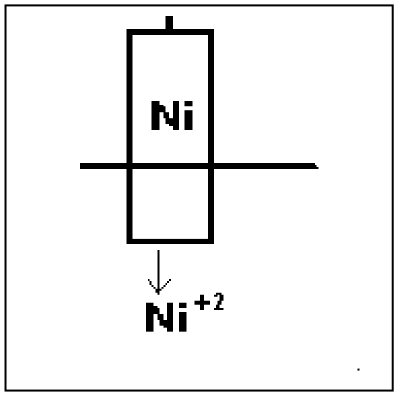
$Zn^{+2}_{(suda)} + 2e \rightarrow Zn_{(k)}$ $E^0 = -0,76$ V

1. Aşağıdaki şekillerden hangisi soldaki kaptaki elektroda ait reaksiyonları gösterir?

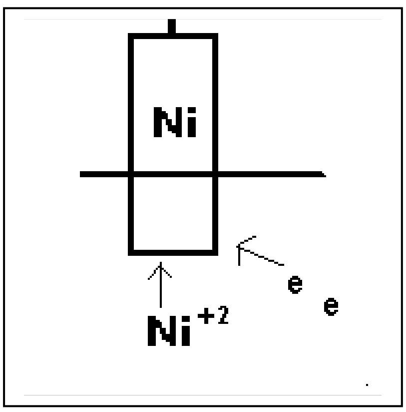
a.



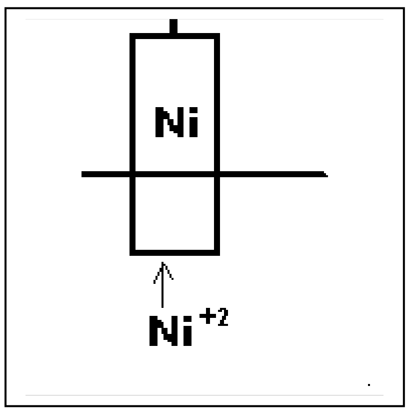
b.



c.

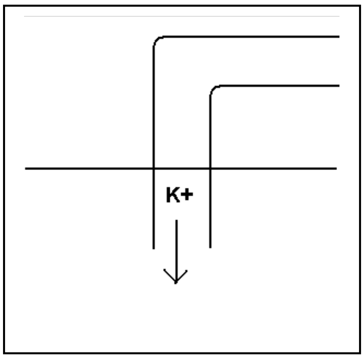


d.

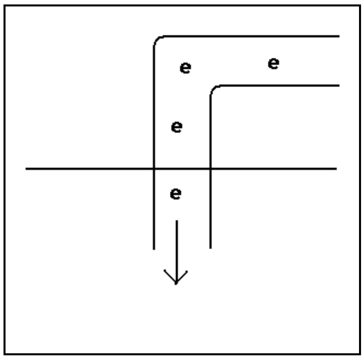


2. Aşağıdaki şekillerden hangisi soldaki kaptaki tuz köprüsüne ait reaksiyonları gösterir?

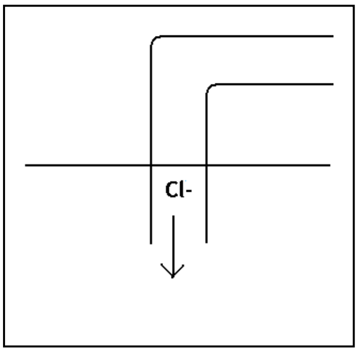
a.



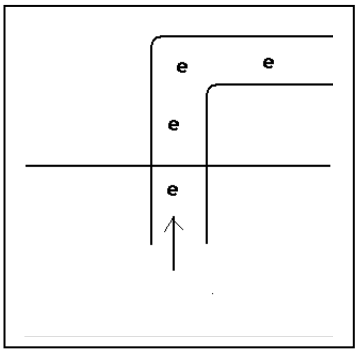
b.



c.

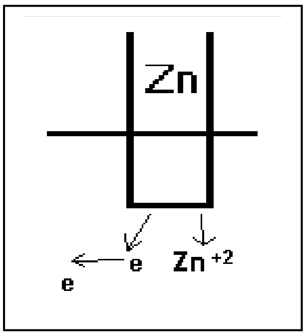


d.

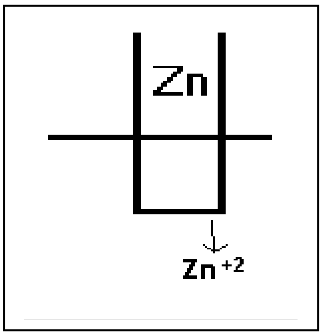


3. Aşağıdaki şekillerden hangisi sağdaki kaptaki elektroda ait reaksiyonları gösterir?

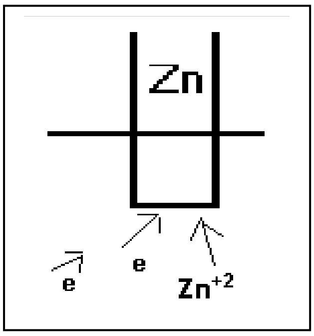
a.



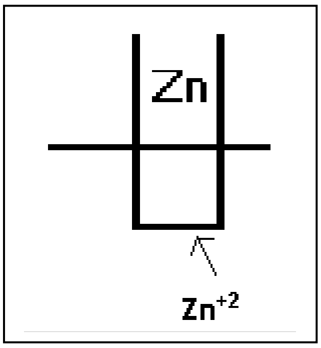
b.



c.

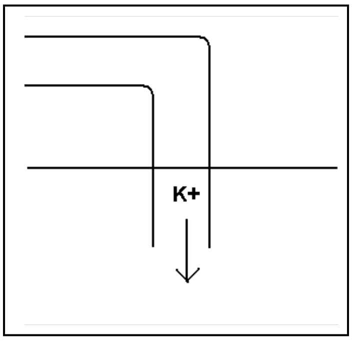


d.

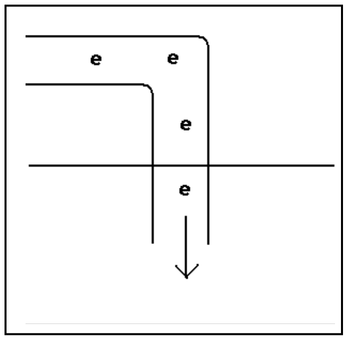


4. Aşağıdaki şekillerden hangisi sağdaki kaptaki tuz köprüsüne ait reaksiyonları gösterir?

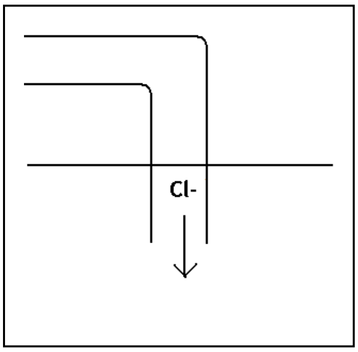
a.



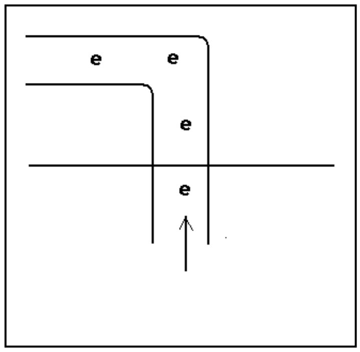
b.



c.



d.



5. Bu elektrokimyasal pilde hücre potansiyelini, katot ve anodu doğru olarak gösteren şık hangisidir?

a. E^0_{pil} = 0,51 V, Zn anot, Ni katot
b. E^0_{pil} = - 0,51 V, Ni anot, Zn katot
c. E^0_{pil} = 1,01 V, Ni anot, Zn katot
d. E^0_{pil} = - 1,01 V, Zn anot, Ni katot

6. Elektrokimyasal pildeki elektron hareketi nasıldır?

a. Nikel (Ni) elektrottan çıkar telden geçerek Çinko (Zn) elektrota ulaşır.

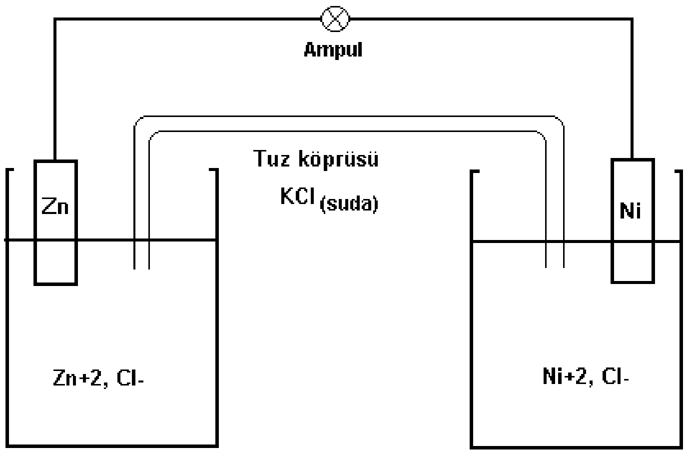
b. Çinko (Zn) elektrottan çıkar telden geçerek Nikel (Ni) elektrota ulaşır.

c. Nikel (Ni) elektrottan çıkar çözelti ve tuz köprüsünden geçerek Çinko (Zn) elektrota ulaşır.

d. Çinko (Zn) elektrottan çıkar çözelti ve tuz köprüsünden geçerek Nikel (Ni) elektrota ulaşır.

e. Nikel (Ni) elektrottan çıkar telden geçerek Çinko (Zn) elektrota ve çözelti ve tuz köprüsünden geçerek tekrar Nikel (Ni) elektrota ulaşır.

f. Çinko (Zn) elektrottan çıkar telden geçerek Nikel (Ni) elektrota ve çözelti ve tuz köprüsünden geçerek tekrar Çinko (Zn) elektrota ulaşır.



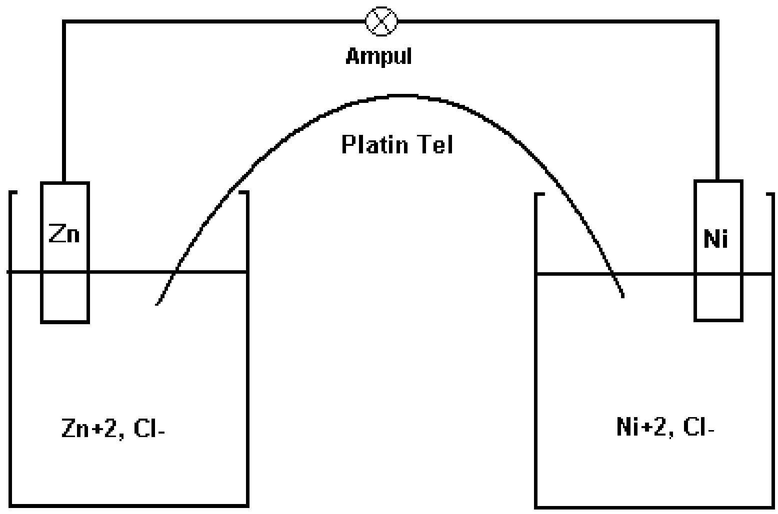
$Zn^{+2}_{(suda)} + 2e \rightarrow Zn_{(k)}$ $E^0 = -0,76$ V

$Ni^{+2}_{(suda)} + 2e \rightarrow Ni_{(k)}$ $E^0 = -0,25$ V

7. Yukarıdaki elektrokimyasal pilde hücre potansiyelini, katot ve anodu doğru olarak gösteren şık hangisidir?

a. $E^0_{pil} = 0,51$ V, Zn anot, Ni katot
b. $E^0_{pil} = - 0,51$ V, Ni anot, Zn katot
c. $E^0_{pil} = 1,01$ V, Ni anot, Zn katot
d. $E^0_{pil} = - 1,01$ V, Zn anot, Ni katot

8. Yukarıdaki şekilde tuz köprüsünü kaldırıp yerine platin tel koyarsak aşağıdaki şekilde bir düzenek oluşur:



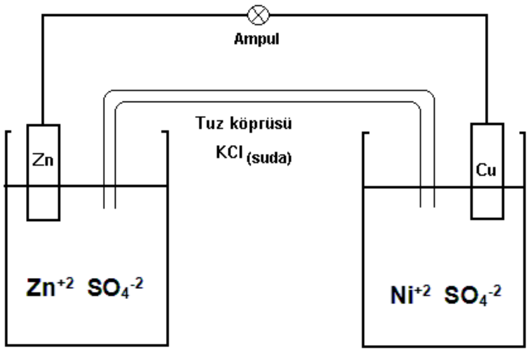
Bu düzenekle ilgili olarak aşağıdakilerden hangisi doğrudur?

a. Ampul yanar, elektronlar bir çözeltiden diğer çözeltiye platin tel üzerinden geçerler.
b. Ampul yanar, elektronlar platin tel üzerinden geçmezler.
c. Ampul yanmaz, elektronlar platin tel üzerinden geçerler.
d. Ampul yanmaz, elektronlar platin tel üzerinden geçmezler.

9. Elektrokimyasal pilde, çözeltilerin içerisindeki elektriksel yüklerin iletimi nasıl olur?

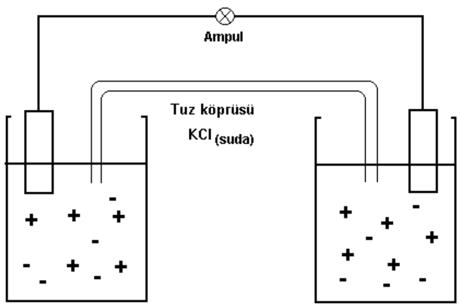
a. Elektronlar katyonlara yapışarak bir elektrottan diğer elektrota ilerlerler.
b. Elektronlar iyondan iyona atlayarak bir elektrottan diğer elektrota ilerlerler.
c. Artı ve eksi iyonların hareketi ile.
d. Su moleküllerinin hareketi ile.
e. Elektronlar bir elektrottan diğerine çözelti içerisinde serbestçe harekete ederler.

10. Aşağıdaki şekilde bir elektrokimyasal pil görülmektedir.

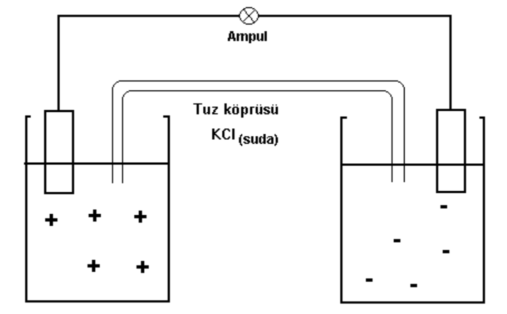


Bu pilde sağdaki hücre katot soldaki ise anottur. Bu şekilde devre kapatıldığında herhangi bir anda çözeltilerdeki elektrik yüklerini gösteren şık hangisidir? (<u>*Katyonlar (+), anyonlar (-), elektronlar ise (e) ile gösterilmiştir.*</u>)

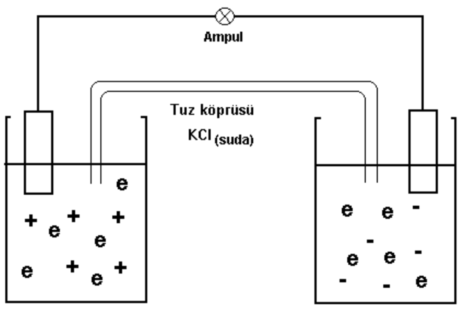
a.



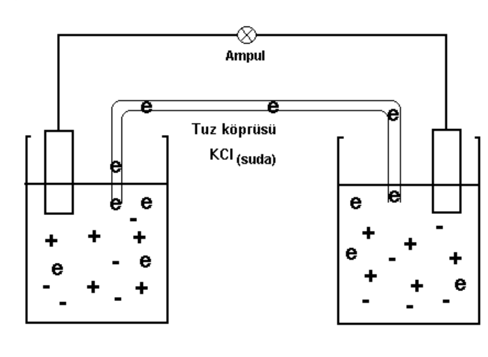
b.



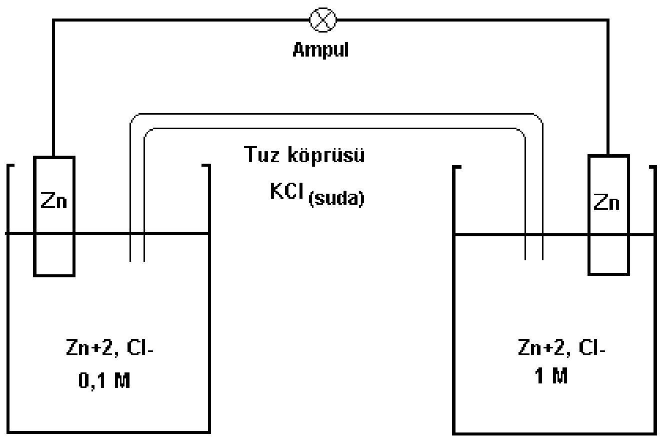
c.



d.



11.



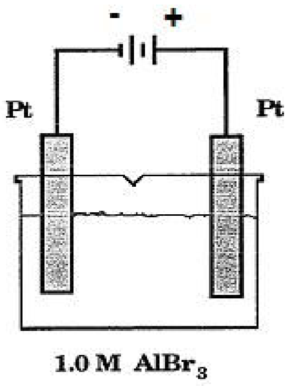
Yukarıda verilen derişim pili ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

a. Soldaki elektrot anot, sağdaki katottur.
b. Her iki elektrot da aynı olduğu için akım oluşmaz
c. Tuz köprüsüne gerek yoktur.
d. Çözeltiler arasındaki derişim farkının potansiyele etkisi yoktur.
e. Akımın yönü derişimi çok olan hücreden derişimi az olan hücreye doğrudur.

12. Elektroliz devresi ile ilgili olarak aşağıdakilerden hangisi doğrudur?

a. Tuz köprüsü olmazsa devre çalışmaz
b. Soy metalden yapılmış elektrot kullanılırsa herhangi bir tepkime olmaz, dolayısıyla elektroliz gerçekleşmez.
c. Sulu çözelti kullanılan bazı elektroliz devrelerinde su, tepkimeye katılabilir.
d. Soy metalden yapılmış elektrotlar da indirgenir veya yükseltgenir.

13. Aşağıdaki şekil ile ilgili olarak verilen ifadelerden hangisi doğrudur?



Standart indirgenme potansiyelleri:

$Al^{+3} < H_2O < Br_2 < O_2$

a. Yukarıdaki düzenek elektrik üretir.
b. Yukarıdaki düzenekte oluşacak maddeler önceden tahmin edilemez çünkü birden fazla indirgenme veya yükseltgenme oluşabilir.
c. Yukarıdaki düzenekte devrenin kutupları değiştirildiğinde oluşan maddelerin yerleri de değişir.
d. Yukarıdaki düzenekte her iki elektrot aynı metal olduğu için elektrotlarda oluşan maddeler de aynıdır.
e. Yukarıdaki düzenekte üretecin kutupları değiştirilse bile anot ve katodun yerleri değişmez.

14. 13. sorudaki şekil ile ilgili olarak aşağıdaki ifadelerden hangisi ya da hangileri doğrudur?

I) Yukarıdaki düzenekte $AlBr_3$ çözeltisi yerine sıvı $AlBr_3$ kullanıldığında katot veya anotta farklı maddeler oluşabilir.
II) Yukarıdaki düzenekte E^0 değeri negatiftir.
III) Yukarıdaki düzenekte elektrotlar aynı olduğu için herhangi bir reaksiyon oluşmaz.
IV) Yukarıdaki düzenek çalışmaz çünkü Pt soy metaldir reaksiyona girmez.

a. I ve II b. II c. III d. III ve IV e. II, III ve IV

15.

I) Elektronların çözelti içerisinde hareket etmelerini sağlar.
II) Elektrokimyasal pildeki yük dengelerini sağlar.
III) Pildeki devreyi tamamlayarak anottan çıkan elektronların tekrar anoda dönmesini sağlar.
IV) Tuz köprüsü içindeki katyon ve anyonlar elektronları katottan anoda taşırlar.

Yukarıdaki ifadelerden hangisi ya da hangileri tuz köprüsünün görevidir?

a. I b. II c. II ve III d. I, III ve IV e. I, II, III ve IV

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 kabiliyetlerini ölçebilen sorular bulunmaktadır. Her soruyu okuduktan sonra kendinizce uygun seçeneği yalnızca cevap kağıdına işaretleyiniz.**

1. Bir basketbol antrenörü, oyuncuların güçsüz olmasından dolayı maçları kaybettiklerini 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 araştırmana yapılmaktadır. Sınanan hipotez, benzine katılan bir katkı maddesinin arabaların verimliliğini artırdığı 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 arabanın gittiği mesafe ile.
c. Kullanılan benzin miktarı ile.
d. Kullanılan katkı maddesinin miktarı ile.

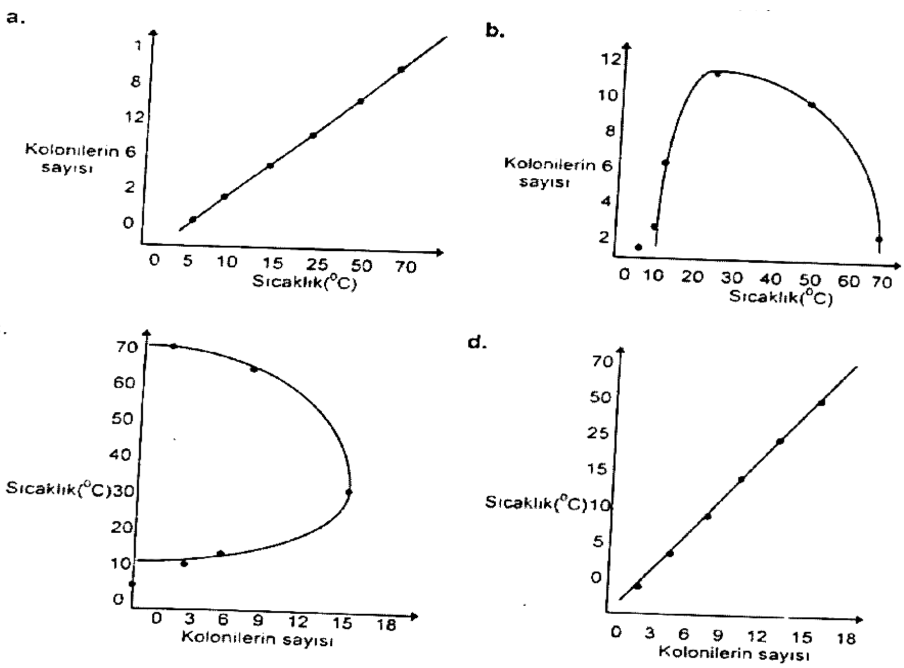
3. Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değişkenleri araştırmaktadırlar. Aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?
a. Arabanın ağırlığı.
b. Motorun hacmi
c. Arabanın rengi
d. a ve b

4. Ali Bey, evini ısıtmak için komşularından daha çok para ödemesinin sebeplerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez **<u>değildir</u>?**

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



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. Yollarda 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. Bir oyuncak arabaya geniş yüzeyli tekerlekler takılır, önce bir rampadan (eğik 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 genişlikleri 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?

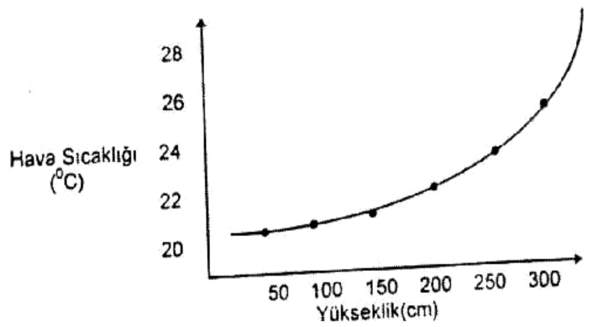
a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.

b. Ne kadar çok mısır elde edilirse, kar 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 ilgili bir çalışma yapılmış ve elde edilen veriler aşağıdaki grafikte gösterilmiştir. Değişkenler arasındaki ilişki nedir?



a. Yükseklik arttıkça sıcaklık azalır.

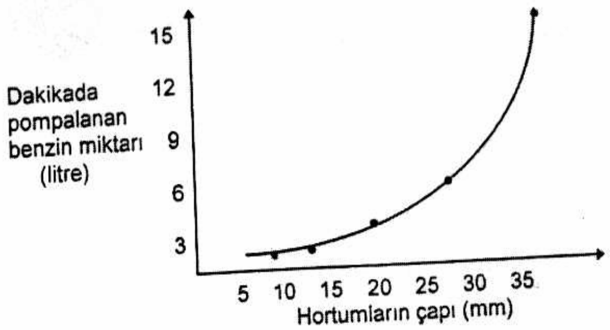
b. Yükseklik arttıkça sıcaklık artar.

c. Sıcaklık arttıkça yükseklik azalır.

d. Yükseklik ile sıcaklık artışı arasında bir ilişki yoktur.

10. Ahmet, basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçrayacağını 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 farklı 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. Bunlardan 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 maddeleri 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. Her bir 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. Her bir 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. Her bir 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 başlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?
a. Hava sıcakken çim biçmek zordur.
b. Bahçeye atılan gübrenin 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 inci soruları aşağıda verilen paragrafı okuyarak cevaplayınız.

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın her birine 50 şer mililitre su koyar. Bardaklardan birisine 0 °C de, diğerine de sırayla 50 °C, 75 °C ve 95 °C sıcaklıkta su koyar. Daha sonra her bir 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. Kullanılan 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. Araştırmanın 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 alanlardaki 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 litre soğuk su koyar ve 10 dakika süreyle ısıtır. Ebru, alevin meydana getirdiği ısı enerjisini nasıl ölçer?
a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kaydeder.
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. Her biri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

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

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

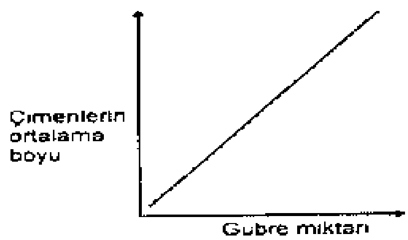
d. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

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

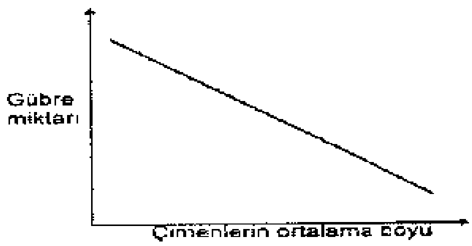
Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

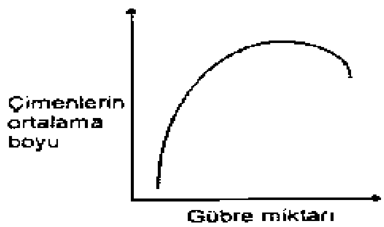
a.



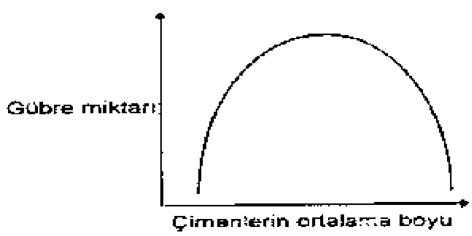
b.



c.



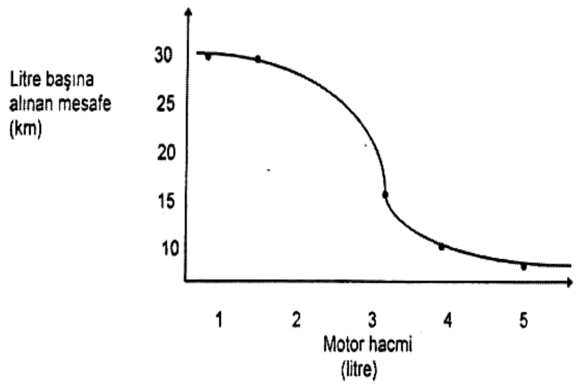
d.



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. Her gün fareleri tartar.
d. Her gün 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 fazla karıştırmak gerekir.
c. Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.
d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştırma grubu, değişik hacimli motorları olan arabaların randımanlarını ölçer. Elde edilen sonuçların grafiği 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 gittiği mesafe artar.
d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

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

Toprağa karıştırılan 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 elde 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 toprak miktarı.
d. Çürümüş yaprak karıştırılan saksı sayısı.

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

32. Araştırmadaki bağımsız değişken hangisidir?
a. Her saksıdan elde edilen domates miktarı
b. Saksılara karıştırılan yaprak miktarı.
c. Saksılardaki toprak miktarı.
d. Çürümüş yaprak karıştırılan saksı sayısı

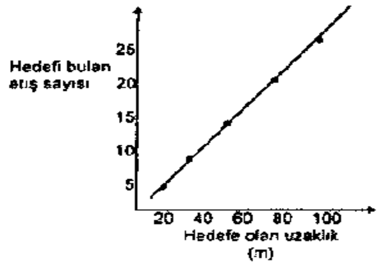
33. Bir öğrenci mıknatısların kaldırma yeteneklerini araştırmaktadır. Çeşitli boylarda ve şekillerde birkaç mıknatıs alır ve her mıknatısın çektiği demir tozlarını tartar. Bu çalışmada mıknatısın kaldırma yeteneği nasıl tanımlanır?
a. Kullanılan mıknatısın büyüklüğü ile.
b. Demir tozlarını çeken mıknatısın ağırlığı ile.
c. Kullanılan mıknatısın şekli ile.
d. Çekilen demir tozlarının ağırlığı ile.

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

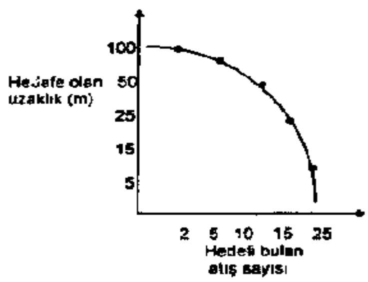
Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

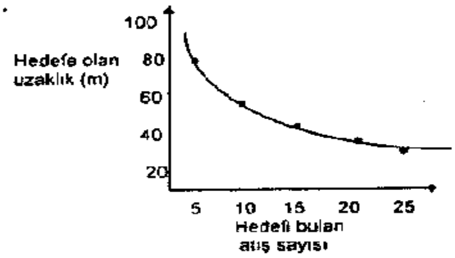
a.



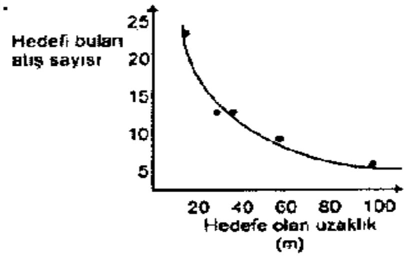
b.



c.



d.



35. Sibel, akvaryumdaki balıkların bazen çok hareketli 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. Suda 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 elektrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker. Kullanılan elektrikmiktarını 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.

BİLİMSEL İŞLEM BECERİ TESTİ CEVAP ANAHTARI

SORU	A	B	C	D
1				X
2		X		
3				X
4				X
5		X		
6	X			
7	X			
8	X			
9		X		
10		X		
11	X			
12			X	

SORU	A	B	C	D
13				X
14		X		
15			X	
16			X	
17			X	
18		X		
19	X			
20				X
21	X			
22				X
23	X			
24			X	

SORU	A	B	C	D
25			X	
26			X	
27				X
28			X	
29				X
30			X	
31	X			
32		X		
33				X
34				X
35				X
36				X

APPENDIX – E

KİMYAYA KARŞI TUTUM ÖLÇEĞİ

AÇIKLAMA : Bu ölçekte, Kimya ve kimya dersine ilişkin tutum cümleleri ile her cümlenin karşısında ***Tamamen Katılıyorum, Katılıyorum, Karasızım, Katılmıyorum, Hiç Katılmıyorum*** olmak üzere beş seçenek verilmiştir. Her cümleyi dikkatle okuduktan sonra kendinize uygun olan tek bir seçeneği işaretleyiniz. Teşekkür Ederim.

Adı-Soyadı:
Sınıfı:

	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 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. Düşünme sistemimizi geliştirmede Kimya öğrenimi önemlidir.	○	○	○	○	○
12. Kimya çevremizdeki doğal olayların daha iyi anlaşılmasında önemlidir.	○	○	○	○	○
13. Dersler içerisinde Kimya dersi sevimsiz gelir.	○	○	○	○	○
14. Kimya konularıyla ilgili tartışmalara katılmak bana cazip gelmez.	○	○	○	○	○
15. Çalışma zamanımın önemli bir kısmı Kimya dersine ayırmak isterim.	○	○	○	○	○

APPENDIX – F

TABLE OF MISCONCEPTIONS AND CORRESPONDING ITEMS AND OPTIONS

Misconceptions	Items
The identity of the anode and cathode depends on the physical placement of the half-cells	5, 7
Electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit.	1a, 1c, 2b, 2d, 3a, 3c, 4b, 4d, 6c, 6d, 6e, 6f, 10d
Anions in the salt bridge and the electrolyte transfer electrons from the cathode to the anode.	6c, 6d, 6e, 6f, 8a, 9a, 9b, 15a, 15d, 15e
Cations in the salt bridge and the electrolyte accept electrons and transfer them from the cathode to the anode	6c, 6d, 6e, 6f, 8a, 9a, 9b, 15a, 15d, 15e
Electrons can flow through aqueous solutions without assistance from the ions.	9e 10c
The anode is negatively charged and releases electrons; the cathode is positively charged and attracts electrons.	1c, 3a
The anode is positively charged because it has lost electrons; the cathode is negatively charged because it has gained electrons.	10b
In concentration cells, cell potential was not dependent on ions concentrations.	11d
In concentration cells, the direction of the current is from more concentrated cell to less concentrated cell.	11e
In electrolytic cells, the direction of the applied voltage has	13c, 13e

no effect on the reaction or the site of the anode and cathode.	
No reaction will occur if inert electrodes are used.	12b, 14
In electrolytic cells with identical electrodes connected to the battery, the same reactions will occur at both electrodes.	13d
In electrolytic cells, water is unreactive toward oxidation and reduction.	12c
The calculated cell potentials in electrolytic cells can be positive.	13a, 14
Inert electrodes can be oxidized or reduced	12d
When two or more oxidation or reduction half-reactions are possible, there is no way to determine which reaction will occur.	13b

CURRICULUM VITAE

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MS	Gazi University Secondary Science and Mathematics Education	2003
BS	Bogazici University Secondary Science and Mathematics Education	1998
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FOREIGN LANGUAGES

Advanced English, Fluent German

PUBLICATIONS

Books

1. Köseoğlu, F., Atasoy, B., Kavak, N., Akkuş, H., Budak, E., Tümay, T., Kadayıfçı, E., & Taşdelen, U. (2004). *Yapılandırıcı Öğrenme Ortamı İçin Bir Fen Ders Kitabı Nasıl Olmalı.* Asil Yayın-Dağıtım, Ankara.

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1. Köseoğlu, F. & Taşdelen U (2004, Ağustos). *Learner-Friendly Textbooks: Chemistry Texts Supporting Constructivist Learning Models*. Paper presented at 18th International Conference on Chemical Education (18th ICCE), Istanbul, Turkey.

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1. "Türk Eğitim Derneği Akreditasyon Sistemi". Nisan-Eylül 2004.

2. “Bilimin Doğası Öğretimi: Bilim Felsefesi Ve Bilim Tarihine Dayanarak Bilimsel Argüman Oluşturma Ve Akıl Yürütme Öğretimine Yönelik Bir Öğretmen Mesleki Gelişim Paketinin Hazırlanması” (TUBITAK No: 108K086). October 2008 - ? (continues)