USING THE SCIENCE WRITING HEURISTIC APPROACH TO PROMOTE STUDENT UNDERSTANDING IN CHEMICAL CHANGES AND MIXTURES

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ABSTRACT

USING THE SCIENCE WRITING HEURISTIC APPROACH TO PROMOTE STUDENT UNDERSTANDING IN CHEMICAL CHANGES AND MIXTURES

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The purpose of the present study was to investigate the effect of Science Writing Heuristic (SWH) approach on 9th grade students' understanding of chemistry concepts and chemistry achievement in chemical changes and mixtures units. Four 9th grade classes taught by the two chemistry teachers from a public high school were selected for the study. Each teacher's one intact class was assigned as the experimental group and the other class was assigned as the control group. Students in the experimental group were instructed by the SWH approach, while those in control groups were instructed with traditionally designed chemistry instruction. Tests measuring students' conceptual understanding and achievement in the units of chemical changes and mixtures were administered as pre-test and post-test to students in both groups, and a test measuring students' attitudes toward chemistry was administered to students in both groups at the beginning of the instruction. At the end of the instruction, semi-structured interviews were conducted with 13 students from experimental group and 8 students from control group. The quantitative data were analyzed by using Multivariate Analysis of Covariance

(MANCOVA). The results revealed that the SWH approach was superior to the traditional approach on students' understanding of the concepts in the units of chemical changes and mixtures. In addition, interview results indicated that students in experimental group demonstrated better scientific understanding of chemical change and mixture concepts compared to those in control group. The interview results also showed that students in experimental group developed positive attitudes toward chemistry and SWH approach.

Keywords: Science writing heuristic approach, chemistry education, 9th grade students

ÖZ

ARGÜMANTASYON TABANLI BİLİM ÖĞRENME YAKLAŞIMININ ÖĞRENCİLERİN KİMYASAL DEĞİŞİM VE KARIŞIM KAVRAMLARINI ANLAMALARINI SAĞLAMADA KULLANILMASI

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Bu çalışmanın amacı Argümantasyon Tabanlı Bilim Öğrenme (ATBÖ) yaklaşımının 9. sınıf öğrencilerin kimyasal değişim ve karışımlar ünitelerindeki kimya kavramlarını anlama düzeylerine ve kimya başarılarına etkisini geleneksel kimya öğretim yöntemine kıyasla incelemektir. Bir genel lisede iki öğretmenin girdiği dört sınıf araştırmanın örneklemini oluşturmaktadır. Her öğretmenin bir sınıfı rastgele deney grubu olarak diğeri ise kontrol grubu olarak atanmıştır. Deney gruplarındaki öğrencilere ATBÖ yaklaşımı kullanılarak kimyasal değişim ve karışımlar konuları öğretilirken kontrol grubu öğrencilerine aynı konular geleneksel kimya öğretim yaklaşımı kullanılarak öğretilmiştir. Araştırmanın başlangıcında hem deney grubu hem de kontrol grubu öğrencilerine kimyasal değişim ve karışımlar konularında kavramsal anlamalarını ölçen bir kavram testi ve yine bu konulardaki başarılarını ölçen bir başarı testi uygulanmıştır. Bu testler aynı zamanda araştırma sonunda her iki gruptaki öğrencilere son-test olarak verilmiştir. Öğrencilerin kimyaya yönelik tutumlarını ölçen test bütün gruplara öğretimin başında uygulanmıştır. Araştırmanın bitiminde deney grubundan 13, kontrol grubundan da 8 öğrenci ile yarıyapılandırılmış görüşmeler yapılmıştır. Araştırmadan elde edilen nicel veriler Çok Değişkenli Kovaryans Analiz (MANCOVA) yöntemi kullanılarak analiz edilmiştir. Sonuçta, geleneksel yönteme kıyasla, ATBÖ yaklaşımının 9. sınıf öğrencilerin kimyasal değişim ve karışım kavramlarını anlama düzeylerinde daha etkili olduğu bulunmuştur. Ayrıca, görüşmeden elde edilen sonuçlara göre deney grubundaki öğrencilerin kontrol grubundakilere kıyasla kimyasal değişim ve karışım kavramlarını anlamalarının daha iyi olduğu tespit edilmiştir. Görüşme sonuçları, deney grubundaki öğrencilerin hem kimya dersine hem de ATBÖ yaklaşımına yönelik olumlu tutumlar geliştirdiklerini de göstermiştir.

Anahtar kelimeler: Argümantasyon tabanlı bilim öğrenme yaklaşımı, kimya eğitimi, 9. sınıf öğrencileri

To My Family

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LIST OF ABBREVIATIONS

ABBREVIATIONS

SWH	: Science Writing Heuristic
RTOP	: Reformed Teaching Observation Protocol
SWT	: Summary Writing Test
ITBSS	: Iowa Tests of Basic Skills Science
TIMSS	: Third International Mathematics and Science Study
OSS	: University Student Selection Examination
PASW	: Predictive Analytics Software
Pre-CCMAT	: Students' Pre-test scores on the Chemical Change and Mixture Achievement Test
Pre-CCMCT	: Students' Pre-test scores on the Chemical Change and Mixture Concept Test
Pre-ASTC	: Students' Pre-test scores on the Attitude Scale toward Chemistry
Post-CCMAT	: Students' Post-test scores on the Chemical Change and Mixture Achievement Test
Post-CCMCT	: Students' Post-test scores on the Chemical Change and Mixture Concept Test
ANOVA	: Analysis of Variance
ANCOVA	: Analysis of Covariance
MANOVA	: Multivariate Analysis of Variance
MANCOVA	: Multivariate Analysis of Covariance
LAL	: Low-achievement level
MAL	: Medium-Achievement Level
HAL	: High-Achievement Level
SES	: Socio-Economic Status
CG	: Control Group

EG	: Experimental Group
SD	: Standard Deviation
Sig.	: Significance
df	: Degrees of freedom
NA	: No answer
M	: Misconception
PC	: Partially Correct
C	: Correct

CHAPTER 1

INTRODUCTION

The ultimate goal of science teaching in today's modern age is the development of students' scientific literacy. Many definitions of scientific literacy have been made because of its complex and dynamic nature. Scientific literacy can be defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (National Research Council, 1996, p. 22) or "the capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD, 2003, p. 133). Realizing the importance of scientific literacy for future citizens, many efforts have been made for improving scientific literacy. There has been made substantial changes in curricula of many different countries including Turkey. The revision of the curriculum development process started in 2004 and encompassed all the learning domains at elementary and high school levels. Scientific literacy is defined in Turkish Science and Technology Curriculum as "the combination of scientific knowledge, attitudes, values, capabilities and understandings necessary for life-long learning, maintenance of curiosity, and development of inquiry, problem-solving, critical thinking and decision-making skills of the individuals" (Ministry of National Education, 2004, p. 3).

In Turkey, the revision of the curriculum development was done along with the ideas of constructivism to achieve the goals of scientific literacy. Constructivism is a learning theory, which is used widely in science education community. In constructivism, learning is defined as the active construction of meaning and it involves a change in the learner's conceptions. For this reason, learners are not viewed as passive recipients of knowledge; rather they are seen as responsible for their own learning. Because knowledge is constructed individually, knowledge is not objective, there are multiple realities. Students' construction of the meaning is also influenced by the social context. Classroom environment acts as a complex social context for learning. Students negotiate meaning through the interaction with their peers and teachers. As students engage in discussions about the concepts and share their understandings, they resolve the conflicts between the new and prior conceptions. By this way, new ideas can be integrated to the existing cognitive structure (Driver, 1988).

According to constructivist view, the characteristics of individuals influence their learning as much as the teacher and school (Yager, 1991). This idea highlights the importance of students' prior knowledge for their subsequent learning. Students' prior conceptions originate from previous classes and personal experiences acquired from observation, television, internet and social settings. These conceptions may facilitate or hinder their further learning. When students' prior conceptions are not congruent with the scientifically accepted conceptions, then they are usually referred as misconceptions (Nakhleh, 1992). These kinds of ideas are also labeled as alternative conceptions (Hewson & Hewson, 1983), children's ideas (Osborne & Wittrock, 1983), preconceptions, intuitions, alternative frameworks, and naive theories (Driver, 1988).

One common goal of research in science education is to identify students' misconceptions and develop teaching strategies for the elimination of the specified misconceptions. The strategies based on conceptual change approach are widely used for the purpose of the remediation of students' misconceptions. According to conceptual change approach developed by Posner, Strike, Hewson, and Gertzog (1982), learning is the interaction between prior knowledge and new information. The process of learning depends on the degree of the integration of prior knowledge with the new information. If individuals know little about the subject matter, new information is easily embedded in their cognitive structure (assimilation). In contrast, if a person has stronger beliefs and knowledge, there are two possibilities. If these stronger ideas are consistent with the new information, then new conceptions are easily integrated to the existing knowledge but if these stronger ideas are conflicting with the subject matter, then a set of conceptual change conditions are required for the acquisition of new knowledge (accommodation). Posner et al. (1982) focused on the more radical change, accommodation, and suggested four conditions, which must be met for this type of change to occur: (a) there must be dissatisfaction with currently held concept, (b) the new concept must be intelligible, (c) the new concept must be plausible, and (d) the new concept must be fruitful. Pintrich, Marx, and Boyle (1993) put forward an alternative view to the model of conceptual change proposed by Posner et al. (1982) by considering the importance of affective and contextual factors in explaining student learning and conceptual change. According to Pintrich et al. (1993), supporting the conditions of conceptual change is necessary but not adequate for conceptual change to occur. Students' affective characteristics and classroom contextual factors also have a role in conceptual change.

Various instructional methods can be used for the elimination of misconceptions. The strategies involve the use of conceptual change approach are very effective in that they help students change their misconceptions and acquire scientific conceptions (Niaz, 2002). To promote understanding of scientific concepts or elimination of misconceptions, there are various strategies, such as cooperative learning (e.g., Bilgin & Geban, 2006), analogies (e.g., Çalık, Ayas, & Coll, 2009), refutational texts (e.g., Hynd, McWhorter, Phares, & Suttles, 1994), conceptual change texts (e.g., Önder & Geban, 2009), combination of conceptual change texts with analogy (e.g., Pabuçcu & Geban, 2006), combination of conceptual change texts with concept mapping (e.g., Uzuntiryaki & Geban, 2005), combination of analogies with hands-on activities (e.g., Çetin, Kaya, & Geban, 2009), learning cycle (Ceylan & Geban, 2009), and common knowledge construction model (Ebenezer, Chacko, Kaya, Koya, & Ebenezer, 2010). Apart from these strategies, the Science Writing Heuristic (SWH) approach can be used in order to promote the students' acquisition of the scientific concepts (Keys, Hand, Prain & Collins, 1999).

The SWH approach is grounded on the constructivist philosophy because it encourages students to use guided inquiry laboratory activities and collaborative group work to actively negotiate and construct knowledge. SWH is not just a tool used for writing the laboratory reports but rather an argument-based inquiry because it successfully integrates inquiry activities, collaborative group work, meaning making via argumentation and writing-to-learn strategies. SWH consists of a teacher template and a student template. Teacher template includes a series of activities, which can be used for the design of the learning environment based on the SWH approach. The activities provided in teacher template are: a) exploration of prior learning, b) engagement in pre-laboratory activities, c) doing the laboratory activity, d) negotiation – interpretation of the data and observations individually, e) negotiation – sharing individual interpretations in the group and developing group interpretation of data and observations, f) negotiation – comparison of the interpretation developed based on data and observations with the textbook and experts, like teacher, g) negotiation – writing SWH laboratory report individually, and h) discussion of the concepts mentioned in the classroom. The negotiation activities are the central part of the SWH because learning occurs through the negotiation of ideas. Students negotiate meaning from experimental data and observations through collaboration within and between groups. Moreover, student template involves the structure of argumentation known as question, claim and evidence. Students can use this template in both writing their laboratory reports or participating in the classroom or laboratory activities. Reflective writing scaffolds the integration of new ideas with prior learning. Students focus on how their ideas changed through negotiation and reflective writing which helps students to confront with misconceptions and construct scientifically accepted conceptions (Burke, Greenbowe & Hand, 2005; Hand, Norton-Meier, Staker, & Bintz, 2009). The SWH approach focuses on the development of scientific thinking and reasoning, as well as metacognition, where learners are able to monitor their own learning (Greenbowe, Hand, & Rudd II, 2008).

In education, it is very important to take into account both cognitive and affective factors. Attitude is one of the important affective constructs influencing student learning. The relation between attitudes of students toward subjects and achievement in science has been investigated by many researchers (e.g., Papanastasiou & Zembylas, 2004). Several of them found that there is a positive low relationship between attitude and achievement in science (e.g., Salta & Tzougraki, 2000). Students' attitudes toward science can be improved by using effective science instruction (Uzuntiryaki, 2003).

Students' misconceptions and learning difficulties constitue a major barrier for their learning in various chemistry topics (Garnett, Garnett, & Hackling, 1995). Some studies have shown that students struggled with learning chemical changes and mixtures (Ayas & Demirbas, 1997; Eilks, Moellering, & Valanides, 2007) and they held some misconceptions in the concepts of chemical changes (Ahtee & Varjola, 1998; Andersson, 1986; Barker & Millar, 1999; Hesse & Anderson, 1992; Johnson, 2000a; Reynolds & Brosnan, 2000; Solsona, Izquierdo, & de Jong, 2003) and mixtures (Coştu, Ünal, & Ayas, 2007; Çalık, Ayas, & Coll, 2007; Stains & Talanquer, 2007; Valanides, 2000).

As it was indicated above, SWH approach can be effective on students' acquisition of chemistry concepts by promoting the conceptual change. Therefore, the present study aimed to investigate the effect of SWH approach on 9th grade students' conceptual understanding and chemistry achievement in chemical changes and mixtures units. In addition, 9th grade students' conceptions about chemical changes and mixtures and their ideas about SWH approach were examined. Students' attitudes toward chemistry were also investigated in this study.

1.1 The Main Problem and Sub-Problems

1.1.1 The Main Problem

What is the effect of Science Writing Heuristic (SWH) approach on 9th grade students' understanding of chemistry concepts and their achievement in the units of chemical changes and mixtures at public high schools in Ankara, when compared to traditional chemistry instruction?

1.1.2 The Sub-Problems

Sub-Problem 1

Is there a significant population mean difference between the groups exposed to the SWH approach and traditionally designed chemistry instruction with respect to students' understanding of chemical change and mixture concepts?

Sub-Problem 2

Is there a significant population mean difference among low-, medium-, and high-achieving students with respect to their understanding of chemical change and mixture concepts?

Sub-Problem 3

Is there a significant interaction effect between treatment and achievement level with respect to students' understanding of chemical change and mixture concepts?

Sub-Problem 4

What are the 9^{th} grade students' conceptions about chemical changes and mixtures?

Sub-Problem 5

Is there a significant population mean difference between the groups exposed to the SWH approach and traditionally designed chemistry instruction with respect to students' achievement in chemical changes and mixtures?

Sub-Problem 6

Is there a significant population mean difference among low-, medium-, and high-achieving students with respect to their achievement in chemical changes and mixtures?

Sub-Problem 7

Is there a significant interaction effect between treatment and achievement level with respect to students' achievement in chemical changes and mixtures?

Sub-Problem 8

What are the 9^{th} grade students' ideas about the SWH approach?

1.1.3 Hypotheses

The problems stated above were tested with the following hypotheses, which are stated in null form.

Null Hypothesis 1

There is no significant mean difference between the groups exposed to SWH approach and traditionally designed chemistry instruction with respect to students' understanding of chemical change and mixture concepts.

Null Hypothesis 2

There is no significant mean difference among low-, medium-, and high-achieving students with respect to their understanding of chemical change and mixture concepts.

Null Hypothesis 3

There is no significant interaction effect between treatment and achievement level with respect to students' understanding of chemical change and mixture concepts.

Null Hypothesis 4

There is no significant mean difference between the groups exposed to the SWH approach and traditionally designed chemistry instruction with respect to their achievement in chemical changes and mixtures.

Null Hypothesis 5

There is no significant mean difference among low-, medium-, and high-achieving students with respect to their achievement in chemical changes and mixtures.

Null Hypothesis 6

There is no significant interaction effect between treatment and achievement level with respect to students' achievement in chemical changes and mixtures.

1.2 Definition of Important Terms

The constitutive and operational definitions of important terms were given in this section.

Misconception: A concept (or an idea), which is different from the views of scientists (Nakhleh, 1992).

Constructivism: A theory of learning that emphasizes the active role of the learner in the construction of knowledge (Driver & Bell, 1986).

Conceptual change: A process that involves a shift in the cognitive structure of an individual (Posner et al., 1982).

Science writing heuristic approach: An argument-based inquiry approach results in acquisition of scientific conceptions, nature of science, metacognitive skills and improved attitudes toward science (Keys et al., 1999).

Traditional instruction: An instruction in which students are passive and taught by means of lecture.

Attitude toward chemistry: The degree to which a student likes or dislikes chemistry (Oliver & Simpson, 1988).

Chemical change: A phenomenon in which one or two substances are transformed into other substances, which are completely different from the initial substances (Silberberg, 2007).

Mixture: A group of two or more substances that can be separated by physical means into its components (Silberberg, 2007).

1.3 Significance of the Study

There are many variables accounting for the student achievement in science. Bloom (cited in Mitchell & Simpson, 1982) asserted that 50% of the student achievement can be accounted by cognitive characteristics of the students, 25% of it can be attributed to affective characteristics, and another 25% of it can be predicted by the quality of instruction. Therefore, instructional strategy, learning and attitudes were identified as the most important variables for research in science education (Abraham, Renner, Grant, & Westbrook, 1982). The quality of science education can be improved by creating stimulating, interesting, and supportive learning environments in which students may question, develop positive attitudes toward science and scientific conceptions (Talton & Simpson, 1987). Implementation of inquiry-based approaches is a way of improving the quality of instruction. In inquiry-based classrooms, linking new information to previous knowledge, reading, writing, and oral discourse in which students are encouraged to construct explanations and arguments are necessary components for the development of scientific conceptions and promotion of scientific literacy (Krajcik & Sutherland, 2010). SWH is an argument-based inquiry approach found to be effective on student acquisition of scientific conceptions, nature of science, argumentation, metacognitive skills and improved attitudes toward science (Keys et al., 1999). The effectiveness of the SWH approach is related with the implementation level. Students' construction of scientific conceptions can be enhanced when teachers implement the SWH approach properly (Burke, Hand, Poock, & Greenbowe, 2005; Poock, Burke, Greenbowe, & Hand, 2007).

In effectively implemented SWH classes, students pose their own questions, design their own experimentation, construct claims and evidences, and reflect on their thoughts. The structure of question-claim-evidence constitutes the argumentation. Argumentation is an integral part of the SWH and there is a great emphasis on the study of argumentation in science education. Using the argumentation facilitates the construction of knowledge and improvement of attitudes toward science. There is a need to persuade students to accept the scientific conceptions because a scientifically literate citizen demonstrates scientific views about the phenomena occurring around them. Classroom talk including claim and evidence is a tool for persuasion. In addition, students may attain positive attitudes toward science with the help of persuasion because attitude is associated with the beliefs that can change by persuasion (Keys et al., 1999; Simpson, Koballa, Oliver, & Crawley, 1994).

SWH is also an alternative format for writing science laboratory reports and a teaching technique used by the teacher to help format the flow of laboratory activities. When students write their laboratory reports with respect to SWH, they write questions, procedure, data and observations, knowledge claims, evidence, and reflections instead of writing five traditional parts, namely, purpose, methods, observations, results, and discussion (Greenbowe et al., 2008). Using alternative laboratory approaches is an important issue for the development of students' chemistry concepts; because students learn little if traditional laboratory experiments are used.

As mentioned above, using the SWH approach in science classes enhances students' understanding of science concepts (Keys et al., 1999). Therefore, the present study aims to investigate the effect of SWH approach on 9^{th} grade students' understanding of concepts, and their achievement in the units of chemical changes and mixtures. Chemical change and mixture are two chemistry concepts that have many applications in everyday context. One of the important aims of chemistry education is to improve students' understanding of the everyday life phenomena, and make them apply and use scientific concepts to describe the events occurring in daily life. From this aspect, confronting students with their scientifically incorrect explanations and making them acquire scientific conceptions is an important issue needed to be taken into consideration. Students' scientific acquisition of chemical change and mixture conceptions can facilitate understanding of further chemistry concepts, like 'chemical reactions and energy' and 'solutions' (Stavridou & Solomonidou, 1998).

The results of this study will provide useful information related to the implementation of SWH approach in high school chemistry. This study is expected to contribute to Turkish Chemistry Education by introducing the SWH approach to chemistry education. There is not much study about the implementation of SWH approach in chemistry education, and there are few studies using the SWH approach in other domains of science in Turkey (Erkol, Gunel, Kısoglu, Buyukkasap, & Hand, 2008; Erkol, Kışoğlu, & Büyükkasap, 2010; Günel, Kabataş-Memiş, & Büyükkasap, 2010; Kabatas, Gunel, Büyükkasap, Uzoğlu, & Hand, 2008).

CHAPTER 2

LITERATURE REVIEW

Students often hold personal explanations for natural phenomena that are far from current scientific explanations, and they are commonly known as misconceptions (Nakhleh, 1992). Since prior learning is an active agent for student learning, science educators have been focused on changing these misconceptions with scientifically accepted ideas. In traditional science teaching, it is difficult for the learners to change their misconceptions (Jones & Beeth, 1995). Conceptual change oriented instruction based on constructivism helps students to overcome these misconceptions (Davis, 2001). Students have also misunderstandings and learning difficulties in various chemistry topics. On this ground, this chapter presents a review of pertinent literature that provides the necessary background to guide this study. The literature review is broken down into the following basic categories: misconceptions, misconceptions in chemical change and mixture, constructivism and conceptual change, Science Writing Heuristic (SWH) and attitude.

2.1 Misconceptions

It has been widely accepted that students come to the classes with ideas, interpretations, and concepts that may facilitate or hinder their further learning (Chandran, Treagust, & Tobin, 1987; Lawson, 1983; Reynolds & Walberg, 1992; Uzuntiryaki & Geban, 2005). Some of these common-sense ideas are personal, stable, and not congruent with the scientifically accepted conceptions (Driver, Guesne &, Tiberghien, 1985; Krause, Kelly, Corkins, Tasooji, & Purzer, 2009). These kinds of ideas are often referred to as misconceptions (Nakhleh, 1992), alternative conceptions (Driver & Easly, 1987) or children's ideas (Osborne & Wittrock, 1983). Dykstra, Boyle, and Monarch (1992) found using the term 'misconception' inappropriate for referring to students' those kinds of conceptions because they claimed that such conceptions cannot be wrong. They preferred to use the term 'alternative conception' and expressed its meaning as:

1. The mistaken answer students give when confronted with a particular situation.
2. The ideas about particular situation students have which invoke the mistaken answer.
3. The fundamental beliefs students have about how the world works, which they apply to a variety of different situations.

The origin and characteristics of these misconceptions needs to be considered in order to deal with them for the improvement of students' scientific conceptions. Students' misconceptions can be classified into two general categories based on their origin: Null impediment and substantive impediment. Null impediment means students' lack of necessary information for learning new concepts. Students' missing information could be in the form of not having prior knowledge or failing to recognize the relationship between new and old concepts. Substantive impediment means scientifically incorrect conceptions resulted from personal experiences, earlier classes, and misinterpretation of the new conception to make them fit into their existing knowledge (Krause et al., 2009).

These kinds of students' conceptions are often observed in chemistry as well as in the other science disciplines. There are some potential sources that may lead to difficulties in grasping chemistry concepts. First, everyday life may cause misconceptions. For example, confusion in the use of 'energy' term which has a specific meaning in chemistry but different meanings in everyday life probably may lead students to have the misconception, e.g., bond making requires input of energy and bond breaking releases energy (Boo, 1998). The second source of students' misconception is the instructional methods employed by the teacher (Fisher, 1985). The teacher may cause students develop alternative conceptions. For this reason, they should be very careful in using the correct language when they are talking about the chemical phenomena. For example, a teacher can explain his/her understanding of the water molecule by stating that water consists of hydrogen and oxygen. The student who does not have adequate prior knowledge may misinterpret water as a mixture of hydrogen and oxygen (Andersson, 1986). The third one is the textbooks used in the chemistry classes. De Posada (1999) showed that nearly half of the textbooks virtually defined the metallic bonding model and the relationship among models and experimental facts could not be understood by students. The theoretical models employed by textbooks in their explanations were metaphorical in nature and they were open to misinterpretations. The last source of students' misconceptions is related with the abstract nature of chemistry (Gabel, 1999). Many phenomena discussed in the chemistry could be explained from a microscopic point of view. From this aspect, the knowledge about particulate nature of matter has a constructive role in the development of the chemistry concepts (Ardac & Akaygun, 2004; Garnett et al., 1995; Johnson, 2005).

There is a need to identify and promote effective ways to correct students' misconceptions to ensure that important topics in chemistry can be clearly understood. The first step in addressing students' alternative conceptions is to identify them, which can be done in a variety of ways, such as pre-class discussions, interviews, paper and pencil tests, concept maps, word association tests, or combinations of these methods. Using combinations of oral and written tests give more reliable results (Krause et al., 2009; Schmidt, 1997).

Paper and pencil tests could be in the form of multiple-choice test; two-tier, three-tier and four-tier multiple-choice test; open-ended questions; and free writing. In multiple-choice tests, there is one correct answer and three or four distracters that reflect students' probable misconceptions reported in related literature and/or during interview sessions (Bilgin & Geban, 2006; Canpolat, Pınarbaşı, Bayrakçeken & Geban, 2006; Özmen, 2007; Pınarbaşı, Canpolat, Bayrakçeken & Geban, 2006; Taştan, Yalçınkaya & Boz, 2008; Uzuntiryaki & Geban, 2005). In two-tier multiple-choice tests, first tier of each item consists of a question having two, three or four choices, and the second tier of each item consists of possible reasons for the answer given in the first tier. In a two-tier test item, the first tier measures the content knowledge; and the second tier measures the explanatory knowledge. The second tier could be in open-ended or multiple-choice format (Özmen, Demircioğlu, & Demircioğlu, 2009; Pabuçcu & Geban, 2006; Tan, Taber, Goh, & Chia, 2006). Three-tier and four-tier multiple-choice test items are enhanced versions of two-tier multiple-choice tests. A three-tier test item is constructed by adding a third tier measuring the strength of conceptual understanding to a two-tier item. A four-tier multiple-choice test item is obtained by adding an additional tier measuring the level of confidence of students for their answers given to each tier of a two-tier test item (Caleon & Subramaniam, 2010a, 2010b).

In the questionnaires including open-ended test items, for each item, first students were asked to write their answer, and then they were asked to write their explanation about the reason of their written response. Each question may include relevant figures and pictures (Ayas, Özmen, & Çalık, 2010; Azizoğlu, Alkan, & Geban, 2006). Students' writings may also serve as an evidence for conceptual change (Fellows, 1994a). Liu and Ebenezer (2002) used writing to elicit students' conceptions about solutions at the beginning of the instruction. Students were asked to write the concepts in their mind that were related to solutions. Then, they were asked to write one or more paragraphs explaining the linkage among those concepts. There are also some studies using the combination of the types of paper-pencil test, such as both two-tier and open-ended test item (Coştu, Ayas, Niaz, Ünal, & Çalik, 2007) and multiple-choice, two-tier and open-ended test items (Coştu, Ayas, & Niaz, 2010).

Gussarsky and Gorodetsky (1990) used word associations to map the conceptions of 12th grade high school students regarding equilibrium and chemical equilibrium concepts. 309 high school students in Israel participated in this study. There were three groups: Group C, serving as a control group, did not receive knowledge concerning chemical equilibrium; Group A and Group B were studying chemical equilibrium. The students were provided with a sheet of paper, on which a key concept was printed, to write down their word associations. The associations from the collected sheets were classified into categories. The results pointed to a strong associative differentiation between the equilibrium and chemical equilibrium concepts at the pre-instruction stage. The post-instruction free word associations indicated that the clear distinction between the two concepts had disappeared.

Schmidt (1997) used the combination of written tests and discussion to investigate misconceptions in chemistry. From 4300 to 7500 students of senior high schools, from all parts of Germany, took part in this study. Multiple choice test items were administered to the students. Apart from choosing the answer, students were asked to explain why they had selected that answer. Group discussions were held to gain more information about students' reasons for choosing their answers. It emerged that students held misconceptions related to isomerism, redox, neutralization and conjugate acid-base pairs.

Interviews are very useful in determining misconceptions but very time consuming. Thomas and Schwenz (1998) conducted clinical interviews with 16 volunteer students currently enrolled in the thermodynamics semester of college physical chemistry to identify their alternative conceptions about equilibrium and thermodynamics. Then, these conceptions were compared with those expressed by experts in textbooks. This study revealed that in many cases student understanding of basic concepts is limited, distorted, wrong, or missing entirely and they probably affect the quality of student learning in physical chemistry classes. The results make it clear that students in an advanced undergraduate class for chemistry majors still have difficulties with basic chemistry concepts that have been covered prior to physical chemistry (e.g., high school chemistry). This finding shows that standard instruction is not effective in modifying students' conceptions.

Using combinations of oral and written tests in identifying students' alternative conceptions give more reliable results (Schmidt, 1997). In two studies conducted by Cakmakci, Leach, and Donnelly (2006) and Cakmakci (2010), open-ended questions and individual interviews were used to elicit students' alternative conceptions in rate of reaction. Similarly, Çalık et al. (2009) used open-ended test items and individual interviews for the purpose of identifying 9^{th} grade students' scientific conceptions and misconceptions in solution.

2.1.1 Misconceptions in Chemical Changes and Mixtures

Determination of students understanding of chemistry concepts is an important issue in science education. Studies have revealed that students often hold misconceptions within the domain of chemistry, such as phase equilibrium (Azizoğlu et al., 2006), chemical equilibrium (Bilgin & Geban, 2006; Canpolat et al., 2006; Gussarsky & Gorodetsky, 1990; Huddle & Pillay, 1996; Özmen, 2007; Quilez-Pardo & Solaz-Portoles, 1995; Thomas & Schwenz, 1998; Voska & Heikkinen, 2000), thermodynamics (Kesidou & Duit, 1993; Thomas & Schwenz, 1998), stoichiometry (Huddle & Pillay, 1996), particulate nature of matter (Ayas et al., 2010; Beerenwinkel, Parchmann, & Gräsel, in press; Haidar & Abraham, 1991; Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Özmen, in press; Renström, Andersson, & Marton, 1990), mole concept (Staver & Lumpe, 1995), chemical bonding (Boo, 1998; Özmen et al., 2009; Pabuçcu & Geban, 2006), electrochemistry (Sanger & Greenbowe, 1999; Yürük, 2007), general and organic chemistry (Zoller, 1990), acid-base (Cakir, Uzuntiryaki & Geban, 2002), solution concepts (Çalık et al., 2009; Uzuntiryaki & Geban, 2005), state of matter and solubility (Ceylan & Geban, 2009), solubility equilibrium (Önder & Geban, 2006; Raviolo, 2001), rate of reaction concepts (Cakmakci, 2010; Cakmakci et al., 2006; Çalik, Kolomuç, & Karagölge, 2010), boiling concept (Coştu et al., 2007), evaporation (Coştu et al., 2010), ionisation energy (Tan et al., 2006), energy in chemical reactions (Ceylan & Geban, 2010; Taştan et al., 2008), and gases (Çetin et al., 2009).

Chemical change and mixture are two important chemistry topics at 9^{th} grade chemistry curriculum. In chemical changes unit, the concepts of chemical property, chemical change and types of chemical reactions; and in mixtures unit, classification of mixtures and separation of mixtures are covered in Turkish high school curriculum (Ministry of National Education, 2007). The concept of chemical change constitutes a base in the chemistry curriculum for the high schools. The concept of chemical change has macroscopic and microscopic domains needs to be considered for students' learning and teachers' instruction. The macroscopic domain is related with the substances and their properties, scientific processes and phenomena. From a macroscopic point of view, chemical reactions can be considered as disappearance of starting substances and appearance of new substances. On the other hand, microscopic domain is related with the particles of matter. Chemical reactions can be thought as the process of rearrangement of the atoms, in a microscopic point of view. In classifying a phenomenon as physical or chemical, students need to argue whether substances become different substances or are conserved during a transformation of matter (Solsona et al., 2003; Stavridou & Solomonidou, 1998). Many chemical and physical changes occur in daily life in addition to the science laboratory. Students' interpretation of those phenomena as physical or chemical is a sign of students' learning. Several studies revealed that students had a difficulty in distinguishing chemical change from the physical change (Ahtee & Varjola, 1998; Eilks et al., 2007; Hesse & Anderson, 1992; Stavridou & Solomonidou, 1998) because students understanding of the term 'chemical change' was not as a transformation of one or two substances into other substances, rather it was as events with some observable indicators, like color change, gas release, explosion, etc. However, those changes could be in both physical and chemical change. In addition, some students' personal criteria for the identification of chemical changes were not scientifically satisfactory. For example, some students identified a phenomenon as chemical when there were two products at the initial state, like water and sugar. Some of them thought that a chemical reaction result in a new product but their understanding of the new product was not scientifically correct. They interpreted the new product as a thing different from the initial product. For example, if salt is dissolved in water, those students interpreted the salty water as a new product, so the change as chemical. Moreover, students' correct identifications of chemical phenomena increased with their age and school level. As the students' age increased, they could correctly discriminate between physical and chemical changes (Stavridou & Solomonidou, 1998). A number of international and national studies probed students' thinking about the chemical changes (Ahtee & Varjola, 1998; Andersson, 1986; Ardac & Akaygun, 2004; Barker & Millar, 1999; Hesse & Anderson, 1992; Johnson, 2000a; Reynolds & Brosnan, 2000; Solsona et al., 2003).

Andersson (1986) classified students' explanations about the chemical change into five categories: a) it's just like that - there is no explanation of the students, e.g., rust is formed, b) displacement – new substances can appear very easily through the displacement, e.g., rust is in the air all the time, it breeds when any metal is damp, c) modification – new substance is viewed as the same substance as before, in a modified form, e.g., copper pipes are colored dark by the heat, d) transmutation – initial substance is transformed into new substance, e.g., the steel wool that has burnt has changed into carbon, and carbon weighs more), and e) chemical interaction – new substance is explained through the rearrangement of the atoms in a chemical reaction, e.g., iron reacted with the oxygen molecule.

Hesse and Anderson (1992) mentioned that teaching and learning about chemical change is not an easy process. They tried to document the complexity of the process by conducting a study with high school students. After the regular instruction of the chemical change, students were asked to explain the chemical change (rusting of an iron nail, the oxidation of copper metal, and the burning of a wood splint) written on the instrument. Then, students from different achievement levels were interviewed for the further exploration of the concepts. The questions on the both written instrument and interview schedule aimed to uncover students' chemical knowledge, conservation reasoning, and explanatory preferences. The data obtained from the interviews were analyzed in this study. It was found that there were some gaps in majority of the students' chemical knowledge, conservation reasoning, and explanatory preferences. The students could not explain the chemical phenomena with the interaction of atoms and molecules. Instead, they preferred everyday materials or energy in lieu of the reactants or products. For example, some believed that iron and cold are the reactants in rusting of an iron nail. In addition, students had a difficulty in explaining the conservation of mass in chemical change. For example, some students ignored the role of the gaseous reactants or products in chemical reactions. Moreover, some students preferred everyday analogies in their explanations rather than scientific information. Some superficial explanations were 'rusting is a breakdown of the iron', and 'the rust eats the nail like acid eats up metal or like a fungus eats the host'. There were some students confusing chemical and physical changes. For example, rusting of an iron nail was treated as a physical change.

Ahtee and Varjola (1998) examined Finnish students' conceptual understanding in chemical reactions. The students under investigation were at different grade levels. The students were given two questions and asked to explain them in their own words. The students' written responses were analyzed by the researchers. The results revealed that students' understanding concerning chemical reactions were not satisfactory at all grade levels. Students' sound understanding of the concepts increased from compulsory, to secondary and university level. Among the 7^{th} and 8^{th} grade students, some of them gave dissolving and change of state as examples of chemical reaction. The most general example of chemical reaction given by them was burning. The students at secondary and university levels wrote chemical equations but could not explain the meaning of the equation properly. Some students could not discriminate between the terms physical and chemical change. Their examples of chemical change were melting of ice, dissolving of salt, fermentation of berry juice, and rusting of iron. Most of the students were in a difficulty of using the term substance. Some of them used substance interchangeably with element (e.g., substances form bonding) or atom (e.g., substance change outer electrons). Moreover, there were some students restricting the chemical reaction as two substances combines and forms a third substance.

Barker and Millar (1999) found that a significant number of students retained misconceptions related to the conservation of matter in both closed and open systems even after the context-based chemistry teaching. The students were asked three questions, Phosphorus, Precipitation and Solution, which probed students' ideas about the conservation of matter in closed systems. In the Phosphorus question, students were asked to predict what would happen to the mass of a sealed flask including a piece of phosphorus and water after the sun was focused on the phosphorus, which caught fire. It was recognized that students confused density and mass. They thought that mass changes suggesting that gas weighs less than solid. Some other students thought that mass decreases suggesting that phosphorus is used up. Related to the Precipitation question, the students were asked to predict whether the mass of two solutions would change if they were mixed together to form a precipitate. Many students showed misunderstandings by confusing the mass and density. They thought that mass increases suggesting that solid weighs more than a liquid or mass decreases suggesting that gas is produced. In Solution question, students were asked to predict the mass of solution formed when 20 g sodium chloride dissolves in water. Many students interpreted dissolving of salt in water as a chemical change involving gas production. The authors thought that students might have confused sodium chloride with sodium metal because some students thought that mass decreases suggesting that salt reacts with water by giving off a lot of gas. About conservation of mass in open systems, the students were asked to estimate the mass of exhaust gas produced when a car of mass 1000 kg with 50 kg petrol is driven until the tank is empty. Many students simply applied the law of conservation of mass to this situation. These students might not have considered the existence of a chemical reaction in this situation. Some of them ignored the role of oxygen in the burning process.

Similar to Barker and Millar (1999), Ramsden (1997) compared the effect of context-based approach with the traditional approach on students' understanding of the key chemistry ideas: elements, compounds and mixtures; conservation of mass in chemical reactions; chemical change; and the periodic table. The findings revealed little difference between context-based approach and traditional approach in promoting students' understanding of these concepts. Conservation of mass in chemical reactions and some aspects of chemical change were poorly understood among the students.

About the conservation of mass in precipitation reactions, some students incorrectly thought that mass increased because a precipitate was a solid, which weighed more than a liquid. Some of them believed that a gas is formed in a precipitation reaction and formation of gas makes the mass decrease. These misconceptions were also detected in the study of Barker and Millar (1999). Related to the aspects of chemical change, students incorrectly thought that gas was involved in either the tablet or the water, but only given off when the tablet was placed into the water.

Johnson (2000a) investigated the development of students' conceptions of chemical change and concluded that students were more challenged with interpreting the decomposition than the composition as a chemical change. In addition, he revealed that students had a difficulty in interpreting the mass change when copper turns into copper oxide. Some students thought that some of the copper was lost, and some did not take account the mass of the oxygen. Like Barker and Millar (1999), Johnson (2000a) showed that some students had difficulty in grasping the idea that gases have weight. In Johnson's (2000a) study, it was also shown that it was difficult for the students to interpret the burning candle phenomenon and many of them held misconceptions in their explanations. For example, based on the post-test results, 40% of the students thought that both wax and oxygen are included in the process but they could not make link to the new substances occurring in the process.

In addition, Johnson (2000b, 2002) focused on the idea of chemical change in two consecutive papers. In the first paper, Johnson (2000b), emphasized on the development of the concept of the substance identity for the recognition of a chemical change. The results revealed that students could not explain the presented phenomena with substance identity as desired. The students could not internalize the idea of a change of substance. For example, some students thought that although the names of rust and iron were different, they were the same thing because they came from each other. Some believed that a lump of copper includes two substances, malachite and charcoal. These students viewed a product of a chemical change as a mixture of the reactants rather than a substance in its own right. For this reason, they had a difficulty in understanding the ‘decomposition’ as a chemical change, although they could easily grasp the idea of ‘composition’ as a chemical change.

In his further study, Johnson (2002) examined students’ explanations of chemical change in relation to the ideas of elements, compounds and the bonding between atoms. Some students had a difficulty in understanding how a gas could mix with a solid or liquid. They could not grasp the idea of interaction between the substances to form new substances. A large number of students failed to explain the phenomena in a lighted candle. They could not interpret the amount of wax after some of being alight in an expected manner. Some of the students believed that the amount of wax stays the same while some believed that the amount of was decreases due to the evaporation. Some of them thought that the wax does not have a role in producing the flame, instead the wick burns. Furthermore, there were some students holding the belief that water and/or carbon dioxide came from the wax, and wax is a compound of hydrogen and carbon. These misconceptions suggested that burning candle was a challenging example of chemical change for the students. In this study, it was supported that the development in students’ understanding of the chemical change was related with their understanding of the particulate nature of matter. Similarly, Andersson (1986) also advocated that scientific understanding of the particulate nature of matter is essential in the development of the chemistry concepts. Further, Valanides (2000) asserted that understanding of the particulate nature of matter is very important in the acquisition of the concepts of everyday phenomena, like dissolution of substances.

The phenomenon of burning candle was also investigated by Reynolds and Brosnan (2000). They developed a computer program, which produced explanations of four everyday changes, candle burning, ice melting, sugar dissolving in water, and an iron nail rusting. Some of these explanations were correct while some were incorrect. The students were asked to decide which explanation made sense, which did not make sense and which might make sense, by clicking on the appropriate button on the computer screen. Follow-up questions were asked to students in order to analyze their choices in an in-depth way. The findings revealed that students demonstrated limited knowledge or misconceptions in their explanations, e.g., the candle just melts because of the heat; when a candle burns, the air changes into something new because it reacts with the wick; when a candle burns, heat is not released because it would be a transfer of energy; something dry on the outside of the iron nail; and sugar and water molecules rearrange as ions in dissolving.

There are some studies comparing two interventions on students' understanding of chemical change. For example, Ardac and Akaygun (2004) examined the effect of multimedia-based instruction over traditional instruction on 8^{th} grade students' understanding of chemical change. They used visual representation of chemical phenomena at macroscopic, symbolic, and molecular levels during the instruction. The authors analyzed students' drawings, which were produced before and after the instruction in order to check their understanding at molecular level. The number of scientifically correct molecular representations was higher in experimental group than in control group at the end of the instruction.

Different from the studies mentioned above, Palmer and Treagust (1996) examined chemistry/science textbooks and concluded that all textbooks more or less mentioned about physical and chemical change. In addition, they mentioned about the problems related to the understanding of the concepts of physical and chemical changes. The first problem is "the concept has no single satisfactory definition" (p. 130). Four criteria were presented in order to distinguish between physical and chemical changes. According to the first criterion, no substance is destroyed or formed in a physical change but substances changed into new substances in a chemical change. This criterion is unsatisfactory because students may hold common-sense beliefs about the meaning of new substance. For instance, when water turns into ice, some students may have in a difficulty of understanding whether ice is a new substance or not. In the second criterion, weight does not change in physical changes but in chemical changes the weight changes. This criterion is generally incorrect, it may only be correct when one or more products of chemical change is a gas that is not included in the weighing. In fact, the Lavoisier's Law of Conservation of Mass applies to all physical and chemical changes. The third criterion is about the concept of reversibility. That means reversibility is easy in physical changes, but not in chemical changes. This criterion is widely used by the students and teachers, but there are exceptions and for this reason, this criterion may not apply to some situations. For example, dissolution of salt in water is considered in some textbooks as physical change but in some textbooks, this phenomenon is named as chemical change. If the dissolution of salt in water is named as chemical change, then the reversibility of this change is easier. The last criterion is related with the energy change. In physical changes, no energy is produced although energy may be changed from one form to another but in chemical changes energy in the form of heat or light may be produced or required. This criterion is not always true because there may be some exceptions in physical changes producing or requiring more heat energy than chemical reactions. Similar to Palmer and Treagust (1996), Gensler and Redlich (1970), and Johnson (2000a) argued that reversibility is an unsatisfactory criterion in distinguishing physical changes from the chemical ones because all the physical changes and most of the chemical changes are reversible.

Mixture is a fundamental concept of chemistry, taught from primary school to high school. An understanding of this concept is central for the acquisition of the chemistry concepts, like solution chemistry. Some international and national studies were carried out related to the mixtures and solutions (Coştu et al., 2007; Çalık et al, 2007; Stains & Talanquer, 2007; Valanides, 2000). In a study conducted by Coştu et al. (2007), seventh grade students' misconceptions about the mixtures and chemical compunds were determined. Then, a hands-on activity for the remediation of those misconceptions was designed. In their study, the following misconceptions of students about the mixtures were detected by using the open-ended questionnaire (p. 39):

- All mixtures are substances that do not have the same properties throughout the sample. Alternatively, all mixtures are heterogeneous.
- Mixtures are pure substances.
- Mixtures are homogeneous.
- Mixtures are combination of the two or more substances that are not pure.

- Mixtures are always combination of two different elements.
- The properties of the components in a mixture are not retained.
- Mixtures always comprise of two substances.
- The components of a mixture cannot be physically separated.
- The components of a mixture combine in exact proportion.
- The components of mixtures can be separated but compounds cannot.
- Pure compounds are homogeneous mixtures.
- Compounds are heterogeneous.

Related to the solutions, Valanides (2000) investigated student teachers understanding of the macroscopic and microscopic properties, and changes related to the dissolution of a solid (salt or sugar) in water. The effects of filtering and heating on these solutions were also examined in this study. As a result, student teachers depicted limited understanding of the particulate nature of matter in explaining the phenomena and they had a difficulty in relating macroscopic changes with the microscopic ones. They also had partial understanding of the physical and chemical changes. For example, they believed that sugar sinks to the bottom of the container and stays there because sugar molecules are heavier than water molecules. Another misconception detected in this study was that salt (or sugar) melted or dissolved. There were some students indicating that salt (or sugar) dissolves if it is stirred and without stirring it would not dissolve, despite of the enough wait time; and when stirring is stopped, the salt (or sugar) would reappear at the bottom. A commonly held belief was the formation of a new substance during the dissolution. Some students claimed that salt (or sugar) can be separated from the water by using a filter paper. The idea that volume of the solution increases as the volume of the added salt (or sugar) increases was held by some students. About the effect of heating, some students thought that when salt (or sugar) in water solution is heated, the water vapors could contain some vapors of salt (or sugar), and the solid remaining at the bottom of the container would be less.

Like Valanides (2000), Çalık et al. (2007) analyzed pre-service science teachers' (PSTs) conceptions about the dissolution of salt and sugar in water. After identification of PSTs' prior conceptions, conceptual change texts were developed for the remediation of those misconceptions. It was found that some of the misconceptions of PSTs retained even after the instruction. Some of the students thought that dissolution of ionic solids in water was a physical change but they held some incorrect explanations, such as phase change occurs, when NaCl dissolves it decomposes into Na and Cl elements, H_2 releases when KCl dissolves in water, and it reacts with water but does not lose properties. Some of them believed that dissolution of ionic salts in water was a chemical change and they asserted that a new compound forms, like KOH. It was recognized that some of the participants confused melting and dissolution in their explanations. Related to the effect of surface area of solute (salt or sugar) on the dissolution process, PSTs held some misconceptions. Some common misconceptions were 'the volume of crushed salt is less than the uncrushed salt', 'the particles of powdered sugar are smaller than the cube and granulated sugar', and 'the granulated sugar does not dissolve as rapidly because its atoms exist as a whole'.

Similar to Coştu et al. (2007), Stains and Talanquer (2007) analyzed students' classifications of elements, compounds and mixtures through the questionnaires and interviews based on the particulate representations of matter. The results revealed that students demonstrated some classification errors resulted from strong mental relationship between atom and element, and molecule and compound. The students strongly associated molecules and compounds, and defined compounds as a thing that has bonds. These students misinterpreted molecular elements as compounds. In addition, students' failure in differentiating between compound and mixture caused the classification errors. This misconception was also emphasized in the study of Coştu et al. (2007).

Students' understanding of solution concepts was also examined by Uzuntiryaki and Geban (2005) through the comparison of conceptual change and traditional approaches. 8th grade students' misconceptions in solutions were analyzed by using a multiple-choice concept test. The common student misconceptions detected in this study were, a new chemical species is formed when salt and water are mixed, sugar breaks into ions, sugar molecules do not keep their identity in sugar solution, sugar solution conducts electricity, salty water boils at a constant temperature, air is not a solution, the weight of the sugar solution is greater (or less) than the total weight of sugar and water. Generally, these misconceptions were most common in control group, less common in the experimental group.

Similar to Uzuntiryaki and Geban (2005), Pınarbaşı et al. (2006) analyzed students' conceptions in solutions by comparing the effects of conceptual change and traditional approaches. The sample consisted of 87 undergraduate students from two classes of an instructor enrolled in introductory chemistry course. In one class, students worked with refutational texts while in the other class students worked with traditional texts. The results revealed that text-based conceptual change approach helped students change their alternative conceptions with the scientific ones. Students in both groups held some misconceptions in different proportions even after the instruction. The most prevalent ones were, "volume of a solution equals the sum of the volume of solute and solvent", "dissolved particles in a solution lose weight or have no weight", and "with increasing temperature, dissolution rate increases for an endothermic dissolution but vice versa for an exothermic dissolution" (p. 328). The misconception 'a solution weighs less than the sum of its components' was also detected by Mulford and Robinson (2002), and Uzuntiryaki and Geban (2005).

There were some studies investigating students' ideas about both chemical changes and mixtures. For example, Ayas and Demirbas (1997) determined 9th grade, 10th grade and 11th grade students' conceptions of elements, compounds, mixtures, physical and chemical changes. It was concluded that many students failed to use of particulate nature of matter in their explanations at all grade levels. Most of the students could not apply their chemical knowledge into novel situations. In addition, a higher number of students had a difficulty in classifying the substances as element, compound, or mixture. Moreover, some students could not comprehend that air is a mixture of gases (Uzuntiryaki & Geban, 2005), and water and sugar are compounds. The reason why students could not grasp the gaseous or solid solutions could be that a solution is always made by dissolving a solid in a liquid (Ebenezer, 1992).

Like Ayas and Demirbas (1997), Sanger (2000) examined students' classification of the five given particulate drawings as pure substances, heterogeneous mixtures or homogeneous mixtures based on their responses to the interview questions. The students were assigned to experimental (62 students) and control (65 students) groups. The students in the experimental group were exposed to a 50-minute lesson to teach them the definitions of pure substances, homogeneous and heterogeneous mixtures both in macroscopic and microscopic point of views, while the control group students received traditional instruction at the macroscopic level. The findings revealed that students in the experimental group classified homogeneous and heterogeneous mixtures better than those in control group did. However, some students in the experimental group classified pure substances as homogeneous substances even after instruction. On the other hand, most of the students in the control group defined homogeneous and heterogeneous mixtures in a macroscopic point of view. For this reason, they classified the pure compounds as mixtures because they contain two or more different atoms, and classified all the mixtures as heterogeneous because there are two different chemicals in the drawing.

Abraham, Williamson, and Westbrook (1994) analyzed high school and college students' understandings of five chemistry concepts. Chemical change and dissolution of a solid in water were two of the concepts investigated deeply for the determination of students' misconceptions. In order to measure students' understanding about the chemical change, students were asked questions about the burning candle. They were asked to indicate the type of change when a candle burns, and give evidence for their answer. 73.3% of the students held misconceptions about the chemical changes. The most common misconception was "burning of a candle was a physical change because the candle had undergone a phase change or was the same substance" (p. 157). These students explained the black film on the glass rod by referring to oxygen from the air, gas from the flame or burning of the rod. Another misconception was "black material on the rod came from the combustion of the wick" (p. 157). These students thought that wick was burning, not the wax. There were some students explaining the phenomenon by using the rod. Some were thinking that candle burning was a chemical change because rod was burning while some were thinking that burning candle was a physical change because rod was not changing. The two concepts, physical and chemical changes, were confused by many students, and their evidences were not indicating a sound understanding, rather they were indicating rote learning. For example, some thought that burning candle was a chemical change because "it was only a phase change", or a physical change because "it is irreversible" (p. 160). About the dissolution concept, the students also held some misconceptions. The most prevalent misconception was "sugar particles floated or sank to the bottom of the beaker instead of evenly mixing" (p. 160). Other misconceptions were "sugar changes chemically into a new substance", "sugar breaks down into its ions or elements", "sugar undergoes a phase change, melts or evaporates" and "water absorbed the sugar similar to the action of a sponge" (p. 160). The first two of the four misconceptions mentioned in the previous sentence were also detected by Uzuntiryaki and Geban (2005).

The students' explanations about the dissolution and combustion were examined by Eilks et al. (2007). The authors also investigated students' understanding of the differences between physical and chemical changes. The results indicated that students could not discriminate between the macroscopic and sub-microscopic levels in explaining the given phenomena. For this reason, students held some incorrect and superficial explanations. Many students restricted chemical reactions into synthesis reactions. These students believed that two starting substances forms one product. This weak understanding was also elicited by Ahtee and Varjola (1998). Another misunderstanding detected in this study was baking cake is a physical change. This study also uncovered the misconception 'chemical reactions are always not reversible'. This wrong belief was also demonstrated in the studies of Gabel (1999), Gensler and Redlich (1970), Johnson (2000a), and Palmer and Treagust (1996). Related to the dissolution, the students classified it as a chemical change (Abraham et al., 1994; Ahtee

& Varjola, 1998; Barker & Millar, 1999) and they confused the dissolving with the melting (Abraham et al., 1994; Çalık et al., 2007; Valanides, 2000).

Like Palmer and Treagust (1996), Ebenezer and Gaskell (1995) discussed some factors influencing students' scientific understanding of the concepts about dissolving. Generally, it has been accepted that dissolution of salt or sugar in water is a physical change because the components can be easily separated by physical means. However, dissolution of salt in water is also viewed as a chemical change because salty water demonstrates different properties from salt and sugar in terms of electrical conductivity. For this reason, students may have a difficulty in understanding the dissolution of salt in water. It is not always possible to classify a phenomenon just as physical or chemical. The students need to interpret the phenomenon like dissolution of salt in water considering the different contexts because if we think that salt solution is easily separated by physical means, then it is a physical change, but if we think that salt solution conducts electricity while salt and sugar not, then it can be interpreted as a chemical process. Another reason of the difficulty that students faced when interpreting the dissolution of a solid in water raises from the abstractness of the phenomenon because students are tend to explain observable phenomena. Another problem of solution chemistry is about the language of chemistry. Some of the chemistry language is also used in our everyday life. For example, melting and particle are widely used in everyday context. In everyday life, particle can be used for the granules of sugar or salt, but in chemistry, it is used for atoms or molecules. In everyday life, when we put a piece of sugar in tea, it is said that sugar melted. However, in chemistry language it is dissolved. Another example is that in everyday life many people say that ice dissolves, however in chemistry language ice melts. The students should be aware of the distinctions between the everyday usage and chemical usage of the terms.

2.2 Constructivism and Conceptual Change

In recent years, active learning has gained importance among the educators. Therefore, they rejected the belief "knowledge can be transferred intact from the mind of the teacher to the mind of the learner", and asserted that teaching and learning are different; teachers can teach well, without having the students learn. This new learning model is 'constructivism' and can be summarized in a single statement as "knowledge is constructed in the mind of the learner". It attempts to answer the primary question of epistemology, "How do we come to know what we know?" (Bodner, 1986, p. 873). In constructivism, social negotiation is an integral part of learning. Students construct their own concepts both individually and with others. They try to understand the perspectives of other students in social environment. However, discussion is not the only way of negotiating meaning and constructing knowledge, students can negotiate meaning and construct knowledge through reading and writing texts (Driscoll, 1994; Keys et al., 1999).

Driver and Bell (1986) stated the following principles that emphasize the constructivist view of learning:

1. Learning outcomes depend on not only the learning environment but also what the learner already knows.
2. Learning involves the construction of meanings – construction of the meaning is influenced by the prior knowledge and the meanings constructed by the learners may not be the intended ones.
3. The construction of a meaning is a continuous and active process.
4. Once meanings are constructed, they can be accepted or rejected by the learners.
5. Learners are responsible for their own learning.
6. Some meanings are shared due to common features in the ideas, which children tend to use.

The prior understandings of the students emphasized in constructivism influence their learning performances including the observations they make, the interpretations they give and the design of the experiments they perform. Generally, these ideas influence students' further learning. To solve this problem, several researchers developed alternative learning models (Posner et al., 1982). Conceptual change is an approach to the application of constructivist ideas to science instruction (Hewson & Thorley, 1989). Constructivism emphasizes general process of learning, and conceptual change approach emphasizes the specific conditions which must be done for the modification of existing conceptions by new ones (Weaver, 1998). Conceptual change approach depends on Piaget's ideas of assimilation, accommodation, and equilibration that are critical to cognitive development. If a child uses existing concepts to understand new experiences, assimilation occurs. When students' existing concepts are inadequate to understand new experiences, then accommodation occurs. Equilibration is a balance between assimilation and accommodation and it determines how children move from one stage of development into the next (Driscoll, 1994). Based on Piaget's key ideas, Posner et al. (1982) proposed the conceptual change model.

Posner et al. (1982) developed Conceptual Change Model that attempted to explain "the substantive dimensions of the process by which people's central, organizing concepts change from one set of concepts to another set, incompatible with the first" (p. 211). The conceptual change model has two major components: the conditions that need to be satisfied in order to replace a central concept by another, and the person's conceptual ecology, in which an individual's current concepts are found, influences the selection of new concepts (Hewson & Thorley, 1989).

Posner et al. (1982) proposed two types of conceptual change: assimilation and accommodation. If students' existing conceptions are compatible enough to deal with new phenomena, this expected change is called assimilation, and if students' existing conceptions are inadequate to explain new phenomena, this more radical change is called accommodation. They focused on this second type of conceptual change and suggested four conditions that must be achieved for this type of change to occur:

1. There must be dissatisfaction with existing conceptions. Individuals do not make radical changes in their concepts until they realize that their current concepts are inadequate to explain new phenomena. The most common instructional strategy to create dissatisfaction with prior conceptions is using anomalous data.
2. A new conception must be intelligible. Hewson and Thorley (1989) attempted to determine whether a new concept is intelligible or not to the learner by suggesting these questions: "Does the learner know what it means? Do the pieces of the conception fit together for the learner? Is the learner able to find a way of representing the conception? Can the learner begin to explore the possibilities inherent in?" (p.542). Instructional strategies such as using analogies and metaphors increase the intelligibility of new concepts.
3. A new conception must appear initially plausible. Plausibility refers to the individual's belief about the truth of the new concept. It is not possible for a new concept to appear plausible without being intelligible. A new concept should be consistent with the current concepts of the learner and have the capacity to solve the current problems.
4. A new concept must be fruitful. A new concept should have the potential to suggest new possibilities, directions, or ideas (Hewson & Thorley, 1989).

Hewson (1996) explained the word 'change' in three different ways. First, it can mean the extinction of the former conception. However, it is not wise to accept the first explanation for change because the extinction of the ideas in the human brain is impossible. Second, it can mean an increase or decrease in the amount of something. Third, it can mean something is gaining status while something else loses status. According to Hewson and Thorley (1989), the extent to which a conception is intelligible, plausible, and fruitful is termed the status of a person's conception. The conceptual change model is about raising or lowering the status of conceptions. The more conditions are met, the more status of the conceptions is raised. Intelligibility is the first step of raising status. Without intelligibility, it is impossible for a conception to have status to a person and become either plausible or fruitful. If a new concept is intelligible, and does not contradict with existing concepts, it is also plausible and fruitful to the learner, and then its status will have risen and can be incorporated with existing concepts. On the contrary, if the new concept is intelligible, and contradicts with existing concepts, it will not be plausible to the learner. The acceptance of the new concept is hindered by the existing concepts. For the acceptance of that concept, the status of the existing concept has to be lowered so that the new conception's status can rise.

Conceptual change can be in the form of relational conceptual change, which is defined as "a process of adding new ideas and learning to distinguish appropriate contexts for their use" (Ebenezer & Gaskell, 1995, p. 2). This definition is similar to the Hewson's (1996) second definition of conceptual change mentioned above which views conceptual change as raising or lowering the status of a concept. Changing the status of a concept depends on the context. Students may hold different conceptions for explaining the same phenomenon observed in everyday life. For example, students often use the conception of 'sugar melts in tea' in their daily life. They are satisfied for using this conception because it works well in their everyday life. However, this conception does not work in chemistry language, and it is considered as a misconception. Through the well-structured chemistry instruction, these students may be taught the scientific conception as sugar dissolves in tea. The students learnt the scientific conception does not mean that they deleted the everyday conception from their mind. The everyday conception and scientific conception for the same phenomenon exist together in the conceptual ecology. Depending on the context, the status of these conceptions change, e.g., the status of 'sugar dissolves in tea' is high but the status of 'sugar melts in tea' is low in the language of chemistry, while the opposite works in everyday life. It is important for the students distinguish the concepts for the same phenomenon in appropriate contexts (Ebenezer & Gaskell, 1995; Hewson, 1996; Hewson & Thorley, 1989).

2.2.1 The Strategies Used in Conceptual Change

Changing students' misconceptions is a rather difficult task because they are resistant to change through regular instruction (Driver & Easly, 1978; Fisher, 1985; Hynd et al., 1994). Various instructional methods can be used for the elimination of misconceptions. The best way to handle misconceptions is to use instructional strategies based on conceptual change approach (Niaz, 2002). The teaching strategies based on conceptual change approach were used in different science disciplines including physics (Chambers & Andre, 1997; Hynd et al., 1994), chemistry (Ceylan & Geban, 2009, 2010; Coştu et al., 2007, 2010; Çalık, et al., 2009; Çalik et al., 2010; Çetin et al., 2009; Önder & Geban, 2006; Özmen, 2007; Özmen et al., 2009; Özmen, in press; Pabuçcu & Geban, 2006; Taştan et al., 2008; Uzuntiryaki & Geban, 2005; Yürük, 2007) and biology (Çakir, Geban, & Yürük, 2002; Özkan, Tekkaya, & Geban, 2004; Sungur, Tekkaya & Geban; 2001) at different grade levels including elementary, secondary and university levels, and led to improvement in students' achievement (Bilgin & Geban, 2006; Ebenezer et al., 2010; Sungur et al., 2001), conceptual understanding (Beerenwinkel et al., in press; Chambers & Andre, 1997; Sungur et al, 2001; Uzuntiryaki & Geban, 2005) and attitudes toward the subject matter (Ceylan & Geban, 2010; Uzuntiryaki & Geban, 2005). However, in some studies conceptual change approach was not effective on students' attitudes toward the school subject compared to traditional approach (Çakir et al., 2002; Pınarbaşı et al., 2006; Taştan et al., 2008).

Conceptual change texts are widely used in order to promote conceptual change in learning various topics (Chambers & Andre, 1997; Çakır et al., 2002; Önder & Geban, 2006; Özkan et al., 2004; Özmen, 2007; Taştan et al., 2008; Yürük, 2007). For example, Chambers and Andre (1997) investigated the effect of conceptual change text on learning fundamental direct current concepts, and the relationships between gender, interest, and experience in electricity. A total of 206 male and female college students participated as volunteers in the study. It was found that conceptual change text led to better conceptual understanding of electrical concepts than traditional didactic test. In addition, prior knowledge, interest, and experience mediated gender differences in learning about electricity, that is, using conceptual change text was effective for both men and women.

Conceptual change texts were also used in chemistry domain by Beerenwinkel et al. (in press). They compared the effects of conceptual change texts with the traditional texts on students' conceptual understanding and awareness of misconceptions in particle model of matter. A total of 214 students from 7th and 8th graders assigned to either experimental or control groups participated in this study. In the experimental groups, students read the conceptual change texts in learning particle model of matter while in the control group students read the traditional texts from their textbooks. A closed-ended test was used a pre- and post-test. The results showed that conceptual change texts caused a better construction of scientific knowledge in particle model of matter compared to traditional texts because conceptual change texts explicitly dealt with students' misconceptions and contrasted them with the scientific ones. In addition, it was found that in both groups, students having low prior knowledge benefited more from reading the texts in learning the subject matter. Moreover, it was suggested that conceptual change texts increased students' awareness in distinguishing between the misconceptions and scientific conceptions. Finally, it was recommended to use different teaching strategies in addition to conceptual change texts for long-lasting effects of conceptual change. There are several studies combining conceptual change texts with other teaching strategies, like concept mapping (Sungur et al., 2001; Uzuntiryaki & Geban, 2005) analogies (Pabuçcu & Geban, 2006), and animations (Özmen, in press; Özmen et al., 2009).

Sungur et al. (2001) conducted a study in which they used concept mapping strategy to promote meaningful learning. They investigated the effect of conceptual change text accompanied by concept mapping instruction on 10th grade students' understanding of the human circulatory system. Interview technique was used for the identification of misconceptions in the related topic. The experimental group consisted of 26 students who received conceptual change text accompanied by concept mapping instruction and the control group consisted of 23 students who received traditional instruction. The effects of science process skills and prior knowledge in biology on the dependent variable were also investigated in this study. The results of Multiple Regression Correlation analysis indicated that the proportion of the variance on the dependent variable explained by each independent variable was statistically significant. It was found that students in the experimental group performed better than those in the control group. Item analyses were utilized to determine and compare the proportion of correct responses and misconceptions of the students in both groups. The average percentage of correct responses of the experimental group was 59.8 and that of the control group was 51.6 after the treatment.

Çalık et al. (2009) used analogies to promote students' conceptual change in solution chemistry. 44 students from two different 9th grade classes participated in this study. The data were collected with a two open-ended questions administered as a pre, post- and delayed post-test; individual interviews with 6 students; and student self-assessment after each activity. One-way ANOVA results showed that there were statistically significant mean differences between pre-test and post-test, and pre-test and delayed post-test in the favor of post-test and delayed post-test. No significant differences were detected between post-test and delayed post-test, and this finding suggested that the intervention enabled students store scientific conceptions in their long term memory. These findings were also supported by the interview and student self-assessment results. On the other hand, there were some students having some misconceptions even after the instruction. For example, some students had in a difficulty in distinguishing unsaturated, saturated, and super-saturated solutions although the main purpose of the analogy was to help students distinguish these terms.

Çalik et al. (2010) used animations with student worksheets to enhance 11th grade students' conceptual understanding in rate of reaction. 72 students from two 11th grade classes participated in this pre-test/post-test non-equivalent control group design. In the experimental group, students worked with animations and worksheets in learning rate of reaction, while students in the control group were taught by traditional instruction. A concept test was administered as a pre-, post-, and delayed post-test. Analyses of the data revealed that using animations with the student worksheets encouraged students' construction of scientific conceptions, and helped students retain that knowledge in their long-term memory. Although the students' misconceptions decreased after the instruction, there were some misconceptions still held by the students in the experimental group.

Çetin et al. (2009) examined the effects of analogies and hands-on activities on students' conceptual change in gases. The sample consisted of 74 students from two different 10^{th} grade classes of the same teacher in a high school. One class was assigned as experimental group and taught with analogies and hands-on activities in learning gases concepts, while the other class was assigned as control group and taught with traditional instruction in learning the same concepts. A concept test was administered to both groups as a pre- and post-test and the results revealed a significant difference in understanding of the scientific concepts between the groups, in favor of the experimental group.

Ceylan and Geban (2009) investigated the effect of 5E learning cycle method over traditional instruction on 10^{th} grade students understanding of the state of matter and solubility concepts. 119 students instructed by the same teacher participated in this study. There were two groups: experimental group and control group. The students in the experimental group were taught by the 5E learning cycle approach in learning state of matter and solubility concepts while those in control group were taught the same concepts by traditional chemistry instruction. A concept test including both multiple-choice and open-ended questions were administered to all students as a pre- and post-test. The analyses of the data revealed that 5E learning cycle method caused a better students' acquisition of scientific conceptions and overcome the misconceptions compared to traditional instruction.

In another study, Ceylan and Geban (2010) compared the effects of demonstrations based on conceptual change approach and traditional instruction on students' understanding of chemical reactions and energy concepts. The participants were 61 tenth grade students from two classes of a teacher. One class was assigned as experimental group and instructed with the demonstrations supplying the conditions of conceptual change, while the other class was assigned as control group and instructed with the normal regular chemistry teaching. A concept test and attitude scale was administered as a pre- and post-test. The analyses revealed that experimental group students had better acquisition of scientific conceptions than the control group students did. In addition, students in the experimental group demonstrated more positive attitude toward chemistry than those in control group, after the instruction.

Bilgin and Geban (2006) examined the effects of cooperative learning approach over traditional instruction on 10^{th} grade students' conceptual understanding and achievement in chemical equilibrium. 87 students attending to two intact classes of the same teacher participated in this study. One class was assigned as experimental group and taught with the cooperative learning approach by supporting the conditions of conceptual change while the other class was assigned as control group and instructed with the traditional instruction. A test measuring students' conceptual understanding in chemical equilibrium was administered as a pre and post-test. In addition, a test measuring students' science process skills was given to the students at the beginning of the study, and a test measuring students' achievement related to computational problems in chemical equilibrium was administered at the end of the treatment. Moreover, interviews were conducted with 12 students in both groups for further exploration of the concept held by the students after the instruction. MANCOVA results revealed that the students in the experimental group had a better conceptual understanding and achievement of computational problems in chemical equilibrium compared to the traditional group. Students in the experimental group engaged in small group discussions, which facilitated the active participation of the students, interaction between the students, and critical thinking, and further encouraged the acquisition of scientific conceptions and elimination of misconceptions. Although experimental group students performed better than those in control group on conceptual questions did, there were some students having misconception even in the experimental group after the instruction. In addition, students' science process skills contributed significantly to the variation of students' conceptual understanding and achievement in chemical equilibrium.

Similar to Bilgin and Geban (2006), Canpolat et al. (2006) examined the effect of conceptual change approach on students' understanding of chemical equilibrium, and they found that conceptual change approach was effective on students' understanding of chemical equilibrium conceptions. Unlike Bilgin and Geban (2006), Canpolat et al. (2006) studied with pre-service chemistry teachers and used conceptual change texts accompanied with an analogical model and demonstrations to promote conceptual change.

Coştu et al. (2010) developed PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) method to promote conceptual change and investigated its effectiveness on students' understanding of evaporation. 52 pre-service science teacher who were at their first year participated in this study. There was only one group in this study and all the students were administered a concept test as a pre-, post-, and delayed post-test. There were multiple-choice test items, two-tier test items and open-ended questions in the concept test. The students were taught the concept of evaporation through the PDEODE strategy. Data analyses revealed that PDEODE teaching strategy enabled students reduce the number of misconceptions related to the evaporation and encouraged them to acquire scientific conceptions. Some misconceptions were retained by some students even after the instruction. Although there were significant differences in the pre-test and post-test means scores, there were no significant differences in the means scores of post-test and delayed post-test. That means PDEODE teaching strategy helped students retain their new conceptions in their long-term memory.

Ebenezer et al. (2010) investigated the effects of Common Knowledge Construction Model (CKCM) lesson sequence, a relational conceptual change model, on 7th grade students' achievement and conceptual change in a biology unit. 68 students participated in this quasi-experimental post-test only control group design. There were two classes, which were randomly assigned as experimental and control groups. In the experimental group, students were taught the excretion topic in biology by using CCKM lesson sequence, while in the control group; students were taught the same topic using the traditional instruction. Students' science achievement was measured by a unit test while their conceptual change was measured by qualitative pre- and post-test. The students in both groups were similar with respect to many aspects like prior knowledge at the beginning of the study, but the teachers in experimental and control groups were different. However, some precautions were taken to prevent the possible effects of this threat to the internal validity of the study. The quantitative analysis revealed that students taught with CKCM performed significantly better than those taught with traditional instruction with respect to the science achievement. The analysis of the qualitative pre- and post-test showed that students held more scientific views after the intervention of CKMC. There were some indicators demonstrating the change in students' understanding, like addition and deletion of ideas, the number of students having the scientific conceptions, replacement of everyday language with the scientific concepts, and the difference in the complexity of students' correct responses.

Hynd et al. (1994) conducted a study to determine the effect of three instructional variables on conceptual change in physics. Ninth and tenth grade students who held misconceptions about the motion of objects participated in viewing a demonstration engaged in student-to-student discussion and read a refutational text about Newton's laws of motion. Students were randomly assigned to eight groups representing combinations of the three activities and given pre-test, instruction and post-test. Post-test results showed that students who read refutational text about the targeted physics principles learned, in the long term, more than students participated in demonstrations and discussions. This study confirmed that refutational text is effective and failed to explain that discussion and demonstration are effective strategies in enhancing the learning of scientific principles of physics in the long term. The lack of a stronger effect of demonstration on conceptual understanding is somewhat surprising when compared to the results of the study conducted by Ceylan and Geban (2010).

Moreover, Pintrich et al. (1993) criticized the studies not taking into consideration student affective characteristics and classroom contextual factors. How student prior knowledge facilitates or hinders learning can be explained by considering the affective and contextual factors. Students' having adequate prior knowledge does not guarantee conceptual change to occur. There may be a failure of activating prior knowledge or transferring prior knowledge into new situations. Affective characteristics and classroom contextual factors act as mediators of conceptual change. For example, if the new information is not gaining attention of the students, then these students may not be eager to learn new information. Likewise, if students' knowledge makes sense to them, then they would probably do not change their existing conceptions with the new ones. Students' control of learning beliefs facilitates the conceptual change process. If students believe that they have control on their own learning, then they will probably active in resolving the conflict between their existing knowledge and new information. In contrast, if they do not see themselves as intentional learners, they may not be eager to resolve the discrepancy.

As mentioned above, there are various strategies targeting students' understanding of scientific concepts or remediation of misconceptions. Science Writing Heuristic, an approach grounded in and derived from constructivist epistemology, can also be used for conceptual change because it promotes the elicitation of students' misconceptions, and the development of scientific conceptions through a set of argument-based inquiry activities. Students negotiate meaning and construct knowledge, reflect on their own understandings through writing, and share and compare their personal meanings with others in a social context (Keys et al., 1999).

2.3 The Science Writing Heuristic (SWH)

Science Writing Heuristic (SWH) is a tool designed for connecting conceptual understandings with laboratory investigations. SWH increases students' metacognitive knowledge regarding laboratory work. SWH likes Gowin's Vee heuristic in terms of being a kind of laboratory report writing tool. SWH differs from Gowin's Vee heuristic in that it is more than a laboratory report writing tool. SWH integrates guided inquiry laboratory activities with collaborative peer discussion and writing-to-learn strategies. The SWH consists of two parts: a teacher template and a student template (Keys et al., 1999).

Table 2.1 The science writing heuristic, Part I: A template for teacher-designed activities to promote laboratory understanding

1. Exploration of pre-instruction understanding through individual or group concept mapping.
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.
3. Participation in laboratory activity.
4. Negotiation phase I - writing personal meanings for laboratory activity (e.g., writing journals).
5. Negotiation phase II - sharing and comparing data interpretations in small groups (e.g., making a group chart).
6. Negotiation phase III - comparing science ideas to textbooks or other printed resources (e.g., writing group notes in response to focus questions).
7. Negotiation phase IV - individual reflection and writing (e.g., creating a presentation such as a poster or report for a larger audience).
8. Exploration of post instruction understanding through concept mapping.

The first part of the SWH, teacher template (Table 2.1), includes a sequence of proposed activities for teachers to make them engage students in meaningful thinking, writing and discussion about the laboratory work. Firstly, the students are involved in individual or group concept mapping to elicit prior knowledge and more specifically misconceptions about the particular topic under investigation. Second, teachers may design pre-laboratory activities such as brainstorming, asking beginning questions about the topic under investigation, or conveying the prior knowledge. Third, students involve in laboratory work. The laboratories through which authentic data and unique results obtained are preferable. Fourth, students think about the meaning of their data by themselves, for example they may write journals. Fifth, students discuss their personal meanings of the data with their peers. In this phase, students are promoted to generate knowledge claims to state their personal meanings of the data. Sixth, students may compare their understandings of the data with textbooks or other printed materials, or the teacher. At the end of the investigation, students are encouraged to write up their understandings in different formats, such as laboratory report, research poster, or newspaper article. Finally, the teacher involves the students in concept mapping activity after the laboratory investigation in order to make students reflect on their understandings of the laboratory concepts. The final phase gives the teacher an opportunity to compare students' initial and final understandings of the concepts and to understand whether conceptual change has occurred (Keys et al., 1999).

Table 2.2 The science writing heuristic, Part II: A template for student thinking

1. Beginning Ideas - What are my questions?
2. Tests - What did I do?
3. Observations - What did I see?
4. Claims - What can I claim?
5. Evidence - How do I know? Why am I making these claims?
6. Reading - How do my ideas compared with others?
7. Reflection - How have my ideas been changed?

The second part of the SWH, student template (Table 2.2), consists of a series of questions for students to be used during the laboratory activities. Student template can be used either individually or as a group. The questions in student template guide students in developing explanations about their data. The teacher can make changes in questions considering the type of the laboratory activity. Firstly, students pose questions about the laboratory task under investigation. They determine the questions they want to answer and can be answered through the laboratory investigation. Second, they engage in laboratory investigation and make observations. Third, they develop explanations and generalizations based on their data and observations, and then they make knowledge claims. Fourth, students are encouraged to show evidence for their claim. Then, students compare their personal explanations with scientifically accepted explanations. This step encourages the process of conceptual change. Finally, students reflect on whether their ideas have changed during the laboratory context (Keys et al., 1999).

Science laboratory report written in SWH format differs from the traditional laboratory format in a variety of ways (Table 2.3). Traditional laboratory reports tend to separate connections among investigation questions, methods, observations, data, evidence, claims, and hypotheses but SWH format encourages peer discussions and writing about these connections (Keys et al., 1999). In traditional laboratory format, procedures are the same for each student, data are similar, and claims match expected outcomes, results and conclusions are limited for developing scientific reasoning skills but the SWH format encourages students' participation in laboratory investigations by requiring them to pose questions, propose methods to address these questions and conduct appropriate investigations. In SWH format, students generate claims and support them with evidence, and they think about the relationships among questions, evidence and claims (Burke et al., 2005).

Table 2.3 Comparison of the SWH format to traditional format

SWH Format	*Traditional Format*
Beginning questions	Title, purpose
Test and procedure	Procedure
Observations	Data and observations
Claims	Discussion
Evidence	Equations, calculations, graphs
Reflection/ Reading	No Equivalent

The SWH laboratory environment is student centered. The students are mentally and physically very active throughout the laboratory activity. At the beginning of the activity, they pose questions regarding the experiment and design the experiment, and they form the groups. Then, they engage in laboratory investigations, they collect data and make observations. After the completion of the laboratory task, the students negotiate the meaning of those data and observations via intra- and inter-group discussions. They construct knowledge by making claims and supporting those claims with evidences based on their experimentation. Finally, they attempt to integrate the new knowledge with their existing knowledge through the reflection. The role of the teacher is more than that of a coach. The teacher provides opportunities for students to discuss beginning questions, sets up the laboratory for student-centered learning environment, allows students to form their groups, makes students organize their data, and makes students to generate knowledge claims and evidence (Burke et al., 2005).

There are many international studies investigating the effectiveness of SWH approach over traditional approach with respect to students' understanding of science concepts at different grade levels (Akkus, Gunel, & Hand, 2007; Hand, Wallace, & Yang, 2004; Hohenshell & Hand, 2006; Keys et al., 1999; Rudd II, Greenbowe, & Hand, 2002; Rudd II, Greenbowe, & Hand, 2007; Rudd II, Greenbowe, Hand, & Legg, 2001; Schroeder & Greenbowe, 2008).

Keys et al. (1999) examined the influence of SWH activities on students' meaning making, conceptual change, and reasoning. In addition, students' writings and understandings of nature of science were also investigated in this study. A science teacher's two classes of 8th grade students participated in this study. The data were collected from small group discourse, student written reports, questionnaires, and interviews. As a result, students written reports illustrated the presence of student science learning, metacognitive thinking, and reflection on their self-understanding. Students reasoned about the meaning of data, and they interpreted the data to support their claims. Some of the reflections on self-understanding indicated conceptual change about the science concepts. The questionnaire and interview results showed that students' understanding of nature of science improved over time during the instruction based on SWH approach. Mainly, students held more scientific views about the collaboration and argumentation in science, the nature of evidence, and the nature of scientists' work after the instruction.

There are some studies comparing the SWH laboratory report format with the standard report format. Rudd II et al. (2007) conducted a study with undergraduate students attending to general chemistry course. Two teaching assistants had two laboratory sections. In one of the sections of each teaching assistant, students prepared laboratory reports in SWH format, while in the other section students prepared laboratory report in traditional report format. All the students in the course had identical textbook, instructor, and assignments. The findings revealed that students engaged in SWH laboratory report format demonstrated better understanding of the chemical equilibrium concepts than those engaged in standard laboratory report format. In addition, it was found that SWH sections were more effective than traditional sections in eliminating students' misconceptions and learning difficulties in chemical equilibrium.

Rudd II et al. (2001) investigated the effect of type of laboratory report format (SWH vs. traditional) on undergraduate students understanding of physical equilibrium concepts in a general chemistry course. There were 80 students in five laboratory sections taught by two teaching assistants. One of the teaching assistant had two SWH laboratory sections and one traditional laboratory section, while the other had one SWH and one traditional laboratory section. The findings revealed that using the SWH student template as the laboratory report format in place of the standard format increased students' performance on the physical equilibrium. In addition, students demonstrated positive attitudes toward using the SWH laboratory report format. Most of the students preferred SWH laboratory report format to the traditional one, and felt that they learnt more by using the SWH template. In another study, Rudd II et al. (2002) compared students using SWH format and those using traditional format to complete their laboratory reports with respect to their performance in an introductory college chemistry course and concluded that SWH approach engaged students with their laboratory work and developed their conceptual understanding via writing and discussion. In addition, based on the survey and interview results, students believed that SWH format encouraged them connect laboratory experiences with the associated chemistry concepts. They felt that their chemistry understanding and motivation to learn chemistry increased through the instruction.

Schroeder and Greenbowe (2008) investigated the performance and perceptions of undergraduate students in organic chemistry course offered during the summer term. In the lecture portion of this course, POGIL (Process Oriented Guided Inquiry Learning) was used while in the laboratory section of this course SWH approach was used. The performance of the students was compared with the performance of the traditional group who attended the same course during the spring semester in the same year. A survey was given to the participants both at the beginning and at the end of the instruction. The results revealed that students' performance on nucleophilic substitution reaction mechanism improved compared to those in traditional group. In addition, survey results indicated that student perceptions regarding this course changed through the instruction. Most of the students believed that this course was easier than they had expected to be it.

Students' conceptual understanding in science becomes deeper when teachers, instructors, or teaching assistants effectively implement the SWH approach. If the instructors provide opportunities for students to share their ideas and negotiate the meaning of their experiences within group and whole class, their students could better develop science concept and argument (Burke et al., 2005; Poock et al., 2007; Nam, Choi, & Hand, in press). There are also some studies investigating the impact of implementation level of SWH on students' success.

Omar and Hand (2004) investigated the practices of 16 teachers using the SWH approach at different grade levels within a professional development program. Classroom observations, questionnaires, interviews, baseline test, and unit pre- and post-tests were used for the collection of data. As a result, three teacher implementation levels (low-medium-high) were defined based on classroom management, dialogical interaction, questioning skills, and content knowledge. Students' conceptual understanding in science improved as the teacher defined the big ideas properly, engaged the students in dialogical interactions, and asked open-ended questions in the classroom. In addition, students involved in high implementation level of SWH performed statistically better than those in low-implementation level did.

Burke et al. (2005) trained novice chemistry teaching assistants through a series of sessions. For this purpose, two laboratory activities were designed to put the teaching assistants in the role of student and to model for them their role as teaching assistant. By this way, teaching assistants could learn about the SWH approach directly experiencing learning process in line with the SWH approach. At the end of the training sessions, they discussed the differences between traditional and student-centered learning environment by focusing on the roles of the instructor and traditional versus SWH laboratory report formats.

Poock et al. (2007) compared the effectiveness of teaching assistants' degree of successful implementation of the SWH in undergraduate chemistry laboratory course in terms of student achievement in chemistry. 78 students attending to an undergraduate chemistry course for two semesters, and their teaching assistants participated in this study. The results revealed that the degree of teaching assistants'' implementation of SWH affected students' performance in chemistry. As the degree of implementation of SWH increased, students' success in chemistry increased. In addition, SWH approach was found very effective on students who have limited prior knowledge regarding the topic under investigation. Students who entered the course with a low-level of previous chemistry knowledge and who were taught with the SWH approach demonstrated better performance in chemistry course compared to students in previous years, with similar previous knowledge and who were not taught with SWH approach.

Cavagnetto, Norton-Meier, and Hand (2006) conducted a case study in order to deeply analyze two grade five teachers' implementation level of SWH approach in relation to student achievement. These two teachers were in the first year of a professional development program, which aimed at increasing their pedagogical and content knowledge and embedded language activities in SWH classrooms. Teacher level of implementation was analyzed through the observations, video analyses, and field notes. The analyses of the data indicated that these two teachers were at different levels of implementation. One of the teachers was at low-level implementation, whilst the other was at high-level implementation. A relationship was detected between teachers' implementation level and student achievement in science. The authors concluded that the students who had an opportunity of greater voice in the classroom also had an opportunity to negotiate the meaning of the science concepts, which resulted in greater performance in science.

Akkus et al. (2007) compared the effectiveness of the SWH approach to traditional approach on students' performance on post-test items with respect to students' achievement level and teachers' implementation of the approach. Seven teachers teaching different subjects and 592 students from different grade levels participated in this study. Each teacher had one experimental and one control groups. In the experimental group, SWH approach was followed while in the control group traditional approach was followed. Before the instruction, all the teachers participated in a workshop related to the implementation of SWH approach. Teacher observational data was used to determine the quality of teacher implementation level while statistical analyses were used for the comparison of student performances across the groups. The teachers were rated according to their implementation levels of SWH and traditional approaches. The findings revealed that quality of the implementation affected students' performance and high-quality implementation of the SWH approach closed the achievement gap within science classrooms. In addition it was demonstrated that implementation of SWH approach was useful for low-achieving students. As the implementation of SWH became higher, the benefit of low-achieving students gradually increased because student voice increased as the implementation level increased which contributed to the student construction of scientific knowledge and arguments.

The implementation of SWH approach was also investigated in Korea by Nam et al. (in press) at 8th grade science classrooms. They compared the SWH and control classes with respect to student voice, science argument, teacher role, and questioning using the modified Reformed Teaching Observation Protocol (RTOP). In addition, students' achievement on the Summary Writing Test (SWT) was also compared across the groups. There were three teachers implementing the SWH approach. Each of the two teachers had two SWH classes and two control classes, and one teacher had two SWH classes and one control class. Significant differences were detected between experimental and control groups with respect to the total RTOP scores, and SWT scores. There were also significant differences between the teachers' implementation levels. Higher level of SWH implementation led to higher student performance in science.

The implementation level of SWH could be increased by increasing the quality of the elements of SWH approach, like questioning, dialogical interaction, and argument structures. Martin and Hand (2009) designed a longitudinal single case study to analyze an experienced fifth grade teacher's implementation of SWH approach. The teacher was involved in a professional development project and her class sessions were videotaped for further analyses. The videotapes were analyzed based on the Reformed Teacher Observation Protocol (RTOP). The analyses of the data showed that the teacher moved from a traditional approach to a more student-centered approach through shifting her questioning patterns, which was not easily achieved. The teacher changed her questioning style by decreasing the amount of yes/no or factual recall questions, and increasing the high-level questions. As the high-level questions increased so did the student voice. By the way, an increase in student voice resulted in an increase in student use of elements of argument, like claim, evidence, and rebuttal.

Writing is an integral part of the SWH approach because writing makes students negotiate meaning for verbal symbols, which further enhances the construction of scientific knowledge (Hand et al., 2004). There are some studies integrating various writing-to-learn strategies within SWH classrooms and investigating the role of writing on students' conceptual understanding in science and metacognition.

Hand et al. (2004) compared the SWH and traditional classes with respect to students' conceptual understanding. In addition, the authors investigated the contribution of using a second task of writing a textbook explanation in SWH classes to students' conceptual understanding. Students' metacognition was also investigated in this study. There were three groups in this quasi-experimental study: a control group (one class), a treatment group (two classes) exposed to SWH approach, and a treatment group (two classes) exposed to SWH approach and writing a textbook explanation (SWH + textbook) for their peers. 93 seventh grade students attending to five class sessions of a biology teacher participated in this study. The findings indicated that SWH and SWH + textbook group outperformed control group students on the multiple-choice items of the test. However, only the SWH + textbook group performed better than the other two groups on essay type questions. Based on the analyses of interview transcripts, three assertions were done: First, students thought that SWH activities, which are formulating their own question, participating in peer group discussions, making connections between concepts and writing contributed to their conceptual understanding in science. Second, students demonstrated a sound understanding about the nature of a knowledge claim, the relation between question and claim, and claim and evidence. Third, students claimed that textbook writing increased their conceptual understanding and metacognition because they recognized their own knowledge gaps, and translated technical knowledge into everyday knowledge during writing.

Hohenshell and Hand (2006) demonstrated the benefits of integrating writing-to-learn strategies within SWH implementation. For this purpose, they compared the students engaged in SWH laboratory report writing and traditional report writing. In addition, they compared the SWH classes writing to the teacher and to their peers. 91 students from 9^{th} and 10^{th} graders attending to a biology course participated in this study. In total, there were three groups: control group (writing traditional in format + summary writing to the teacher), SWH group (writing in SWH format + summary writing to the teacher), and peer review group (writing in SWH format + summary writing to peers). All the groups engaged in identical laboratory except the writing type and audience. The data were collected through a pre-test and two post-tests. First post-test was administered just after the instruction, and the second post-test was administered after the summary writing task. These tests included both recall and conceptual questions. Open-ended surveys and semi-structured interviews were conducted to identify students' perceptions about the writing activities. The results revealed that there were no significant differences between the students completing laboratory report in SWH format and in traditional format. After the completion of the summary report writing, significant differences were observed among the groups. There was a significant difference between SWH and control group on conceptual questions, although no significant differences were detected on recall questions. In addition, in SWH classes, the students who wrote to their peers scored higher than those wrote to their teacher. Moreover, survey and interview results indicated that students in SWH and peer review groups were more aware of their own learning during writing compared to the control group.

Grimberg and Hand (2009) analyzed student written texts with respect to their understanding of science. Totally 11 codes emerged from the student written texts through the qualitative analyses. Students' reasoning processes were observations, measurements, comparisons, analogies, clarifications using questions or statements, claims, cause/effect relations, inductions, deductions, experimental designs, and argumentation. Further, these codes were categorized into three general themes: perception, conception, and abstraction. In addition, students were classified as low-achieving or high-achieving based on their previous achievement scores. All the students were engaged in three different inquiry activities based on SWH approach. The nature of the beginning questions was different across the three laboratory activities, namely, decision-making, descriptive/speculative, and integration. The results revealed that reasoning processes of the students were not dependent on their achievement level, but on the nature of inquiry. High-level reasoning processes were mostly used in decision-making inquiry, and less used in integration activity. Low-level reasoning processes were largely used in descriptive/speculative inquiry, and less used in decision-making inquiry activity. This study supported the notion that SWH approach encourages the development of students' scientific argumentation strategies and closes the achievement gap between low- and high-achieving students. Through the involvement in SWH classroom, all the students had an opportunity to negotiate the meaning of the ideas via intra- and inter-group discussions, and construct knowledge by developing the scientific arguments. For this reason, the authors concluded that SWH approach facilitated both high-achieving and low-achieving students' use of reasoning processes, and consequently their science understanding in the same way.

Hand and Choi (2010) examined undergraduate students' writings in organic chemistry laboratory classes using the SWH approach. 111 students engaged in SWH laboratory sessions related to organic chemistry and completed laboratory reports for their laboratory investigations. These laboratory reports were collected and analyzed with respect to use of multi-modal representations in constructing arguments. The findings indicated that students used multiple modes of representation in the evidence part of their laboratory report in order to support their claims. The students who embedded multi-modal representations with the text in the evidence part could construct high quality arguments, and a high quality argument resulted in higher performance in organic chemistry laboratory.

Choi, Notebaert, Diaz, and Hand (2010) investigated the impact of writing component of SWH approach on 5th, 7th and 10th grade students' construction of quality arguments. They also tried to find out the components of arguments (questions, claims, questions-claims relationship, evidence, claims-evidence relationship, and reflection) predicting the quality of arguments. 296 writing samples were collected and analyzed in this study. Stepwise multiple regression analyses revealed that the relationship between claims and evidences was the most critical element predicting the quality of arguments. In addition, it was shown that SWH approach was useful in the promoting students' construction of quality arguments.

Some researchers focused on some elements of the SWH approach like beginning question and student talk. For example, Cavagnetto, Hand, and Norton-Meier (in press) examined the impact of small group and whole-class strategies for determining the inquiry question on student achievement and teacher perception. Two grade five teachers participated in this study. In one of the classes of each teacher, students in each group negotiated their own inquiry question with the teacher, and in the other class students as a whole negotiated a single inquiry question with the teacher. The other elements of the SWH were similar across all the groups. The teachers' classrooms were observed throughout the study, and semi-structured interviews were conducted with the teachers. Students' achievement scores were determined by using unit tests and Iowa Tests of Basic Skills Science (ITBSS). The results showed that there were no significant differences between the students in both groups with respect to their science achievement in unit tests and ITBSS. In addition, there were no differences in teacher implementation of small group and whole-class strategies. The teachers perceived that using small group strategy was beneficial for their students while managing the whole class strategy was easier than the other was.

Cavagnetto, Hand, and Norton-Meier (2010) analyzed student talk in small groups during the construction of claims and evidences. Small group discussions in a fifth grade science classroom using the SWH approach were audiotaped for data collection. The audio recordings were then transcribed and coded with respect to on-task or off-task talk, generative or representational talk, components of argument in generative talk, and the functions of language used in group talk. The analyses of the transcripts revealed four general patterns: First, students were involved in the construction of claims and evidences in SWH classes largely. Second, both generative and representational talk contributed to the students' development of claims and evidences. Third, student talk mainly composed of claims and data as components of argument. The rebuttals and counter-claims indicating a high-level argument were less frequent in the student talk. Finally, the function of the language used in group talk was mostly informative in nature, that is, students shared the information among themselves. The authors concluded that representational talk stimulated the generative talk because while students were talking about representing the argument in written format, they engaged in a deeper level of reflection on the argument, which further facilitated the generation of further arguments.

Students' perceptions about the implementation of SWH approach were also investigated by the researchers. For example, Gunel, Omar, and Hand (2003) attempted to demonstrate students' perceptions about the SWH process and the effect of SWH approach on different student achievement levels. 156 students at 7th grade attending to the biology course participated in this quasi-experimental study. These students were involved either in experimental group or control group. All the students were engaged in three laboratory activities. Students in experimental group wrote laboratory reports in SWH format, while those in control group wrote their laboratory report in traditional format. Then, all the students were engaged in a summary writing process in which they were asked to write what they learnt during the instruction of the related topic. 25 multiple-choice questions and three conceptual questions were used as a pre-test and post-test. A survey was administered at the end of the study to elicit students' perceptions about the treatment. The findings showed that students in the SWH group performed better than those in control group on the conceptual questions did. Among the achievement levels, low-achieving students benefited from SWH approach more than high-achieving and middle-achieving students did. In addition, survey results revealed that students in SWH groups expressed that they were learning when they were writing. Students also felt that investigating their own questions were also helpful for their learning.

There are also some national studies investigating the effectiveness of SWH approach over traditional approach at elementary and college levels (Erkol et al., 2008, 2010; Günel et al., 2010; Kabatas et al., 2008). Kabatas et al. (2008) investigated the impact of SWH approach on 6th grade students' science achievement and attitudes toward science in electricity unit. 108 students at 6th grade taught by the same teacher involved in this quasi-experimental study. One class was randomly assigned as control group while the others were assigned as experimental groups. In the experimental group, SWH approach was used while in the control group traditional instruction was used in teaching the electricity concepts. A baseline test, a unit test and semi-structured interviews were used for the collection of data. Unit test was administered as a pre-test, post-test and retention test. The findings revealed that students who were exposed to SWH approach performed significantly better on conceptual questions than those exposed to traditional approach. In addition, students in the experimental groups held more positive attitudes toward science than those in control group. They stated that they learnt more by using the SWH approach, and enjoyed investigating their own questions for the laboratory activities.

Erkol et al. (2008) examined the effect of SWH approach on undergraduate students' physics achievement and attitudes toward laboratory in introductory physics laboratory course in electricity unit. Four laboratory sections of a teaching assistant with 80 freshman students participated in this study. Two laboratory sections were treated as experimental group while the other two were treated as control group. In the experimental group, students engaged in laboratory activities following the SWH approach and wrote their laboratory reports in SWH format, while in the control group students engaged in traditional laboratory activities, and wrote their laboratory report in traditional format. A unit test and attitude scale was administered to the students at the beginning and at the end of the instruction. Semi-structured interviews were also conducted with some students in both groups at the end of the treatment. The results showed that SWH approach increased students' physics achievement in electricity unit, their conceptual understanding, and attitudes toward physics laboratory. The interviewed students preferred to have laboratory classes based on SWH approach and indicated that they learnt better through SWH approach. In addition, they believed that writing in SWH format encouraged them think about the concepts deeply.

Similarly, Erkol et al. (2010) explored the effects of SWH approach on undergraduate students' conceptual understanding and attitudes toward the laboratory in the mechanics unit. This study involved 42 undergraduate physics education in students instructed by a teaching assistant in two laboratory sections of the introductory physics laboratory course. In one of the laboratory sections, SWH approach was followed while in the other traditional approach was followed. Pre-test, post-test and attitude scale were used to collect the data. The results revealed that students in SWH group significantly outperformed those in traditional group on the post-test scores. In addition, students felt that SWH approach enhanced their conceptual understanding. Moreover, they thought that writing laboratory report in SWH format was helpful for their learning.

Günel et al. (2010) investigated the effects of SWH approach on students' science achievement and attitudes toward science. 108 students attending to three different 6th grade classes of a science teacher participated in this quasi-experimental study. One class was randomly assigned as control group, and the other two classes were assigned as experimental groups. In the experimental groups, SWH approach was followed in teaching the heat unit while in the control groups, traditional instruction was followed in teaching the same unit. In the experimental groups, students wrote reports following the laboratory activities, but only in one of the experimental groups, the students were asked to prepare self-evaluation reports following the laboratory activities. A unit test including both multiple-choice and conceptual questions were administered to all students both at the beginning as a pre-test and at the end of the instruction as a post-test and retention test. Semi-structured interviews were also conducted with some students in both groups. Statistically significant differences were detected between experimental and control groups based on their post-test and retention test scores in favor of the experimental group. In addition, the experimental group engaged in self-evaluation report writing task performed better than the other experimental group on the conceptual questions. Moreover, students in the experimental groups demonstrated more favorable attitudes toward science than those in control group.

The results indicated that using SWH approach in science laboratory was advantageous for students compared to those students exposed to more traditional laboratory activities. SWH approach is an inquiry-based laboratory approach and it is inductive in nature. Discussion and writing portions of the SWH approach led students in treatment groups to score significantly better on conceptual questions in comparison to control groups. Moreover, SWH was found effective on developing students' metacognition, understanding of nature of science and conceptual change (Keys et al., 1999). There are also some national studies but the number and scope of these studies are very limited compared to the international studies. Therefore, this study aims to investigate the effect of SWH approach on 9th grade students' understanding of chemistry concepts in mixtures and chemical changes unit, and their chemistry achievement.

2.4 Attitude

Cognitive and affective variables are closely linked in learning and instruction (Duit & Treagust, 2003). In the literature, it was demonstrated that cognitive variables influence student achievement in science (Chandran et al., 1987). Prior knowledge is a well-known cognitive characteristics influencing student achievement in science (Chandran et al, 1987; Gooding, Swift, Schell, Swift, & McCroskery, 1990; Lawson, 1983; Reynolds, & Walberg, 1992). There are are also some studies investigating the role of affective characteristics, such as attitudes, values, beliefs, opinions, interests and motivation, in relation to student achievement in science (Germann, 1988; Gooding et al., 1990; Hough & Piper, 1982; Kan & Akbaş, 2006; Mitchell & Simpson, 1982; Oliver & Simpson, 1988; Singh, Granville, & Dika, 2002; Talton & Simpson, 1987) and conceptual change (Pintrich et al., 1993). Briefly, students' learning outcomes in science is accounted by their values, beliefs, motivation, and attitudes as well as their previous knowledge regarding the subject matter (Simpson et al., 1994).

Nowadays, science educators are aware of the fact that affective variables, especially attitudes toward subject matter, are as important as cognitive variables in influencing students' achievement (Koballa, 1988). Attitude can be defined as "a predisposition to respond positively or negatively to things, people, places, events, or ideas" (Simpson et al., 1994, p. 212). Attitude is divided into two areas: science attitudes and attitudes toward subject matter. These concepts are two different constructs needs to be taken into consideration. 'Science attitudes' means "behaviors associated with critical thinking and typically meant to characterize the thinking processes of scientists" (p. 115), while 'attitudes toward subject matter' means "our favorable or unfavorable feelings" toward the subject matter (Koballa, 1988, p. 117). Shrigley, Koballa, and Simpson (1988) clarified the distinction between attitude toward a subject matter and scientific attitudes with respect to the evaluation criterion. Scientific attitudes are seldom evaluative while attitude toward science is evaluative indicating like or dislike toward a subject matter. The other characteristics of attitude toward science are: attitudes are not observable, attitudes are correlated with the related behavior, the social influence act as a mediator between attitude and behavior, attitudes are learnt by directly or indirectly, and attitudes are about an object or subject matter. Furthermore, attitude is related with the beliefs, opinions, and values. Attitude is often confused with these terms although there are differences in the meanings of these concepts. Beliefs and opinions are more cognitive than the attitudes. A value is broader than the attitude. A person may have a value and many attitudes related to that value. A value can be defined as a "long-range moral or ethical imperatives, an end rather than a means" (Shrigley et al., p. 672). Both attitude and value have the evaluative quality. However, the major difference between these two concepts is the abstractness of the ideas, that is, value encompasses ideas that are more abstract while attitude does not (Simpson et al., 1994).

Attitude toward science is an important predictor of student achievement in science, and it explains a significant proportion of the variance in science achievement (Gooding et al., 1990; Oliver & Simpson, 1988). Hough and Piper (1982) found a significant relationship between students' attitudes toward science and their science achievement ($r = .45$). Mitchell and Simpson (1982) detected a significant correlation between student achievement and attitude in biology. Germann (1988) found significant but low correlations between attitude and achievement. Students with more positive attitudes participate in learning activities than students with a less positive attitude. A high relationship between the learning environment and attitudes toward science was detected by Talton and Simpson (1987). Students' feelings about the activities within the classroom, and the interaction between the students are all essential factors contributing to how students feel about science. The relationship between the learning environment and science achievement and between attitudes toward science and science achievement were weaker than the relationship between learning environment and attitudes toward science. Students' feelings about the learning environment and chemistry contributed to their conceptual understanding in chemistry.

Papanastasiou and Zembylas (2004) conducted a study to investigate the relationship between attitude and achievement in science for senior high school students in Australia, Cyprus, and USA. The data were obtained from the Third International Mathematics and Science Study (TIMSS) database. The relationships were examined through the use of structural equation modeling software, AMOS. The results for Australia showed that the students who had high science achievement also had positive attitudes toward science. However, there was no significant influence of attitudes on achievement in science. For Cyprus, it was found that students' attitudes influenced their achievement in science, but their science achievement did not influence their attitudes. The findings for USA indicated that students' attitudes toward science significantly and positively influenced their science achievement. However, students who had high science achievement had negative attitudes toward science.

Kan and Akbaş (2006) identified students' attitudes toward chemistry and then determined the relationship between students' attitudes toward chemistry and their achievement in chemistry. The data were obtained from 819 high school students at 9^{th}, 10^{th}, and 11^{th} grade, and analyzed through the descriptive statistics and correlation analyses. The analyses revealed that students' attitudes toward chemistry was slightly positive, and there were differences in the chemistry attitudes across the grade levels, 10^{th} grade students' attitudes toward chemistry was the highest. Moreover, attitude toward chemistry was the significant predictor of chemistry achievement, and explained about 10% of the variation in chemistry achievement.

The attitude toward science is a significant source of variation in science achievement. Therefore, changing attitudes results in improved achievement in science (Oliver & Simpson, 1988). Students had better instructional methods and a better learning environment had significantly better attitudes than those did not have (Germann, 1988). Hands-on laboratory instruction affects students' attitudes toward science and achievement in science positively. For this reason, an instruction including laboratory experiences could be a viable and effective mean in promoting students' acquisition of scientific conceptions and positive attitudes toward science (Freedman, 1997).

Some studies dealing with the effectiveness of instruction on chemistry achievement focused on students' attitudes toward science. For example, Uzuntiryaki (2003) examined the effects of instruction based on constructivist approach on ninth grade students' attitudes toward chemistry. The results revealed that constructivist approach produced significantly higher positive attitudes toward chemistry than the traditional chemistry instruction. In another study, Uzuntiryaki (2005) investigated the effect of conceptual change approach on 8^{th} grade students' attitudes toward science, and demonstrated that conceptual change approach led students to develop more positive attitudes toward science in comparison to traditional approach. Similar to Uzuntiryaki (2003, 2005), Ceylan and Geban (2010) supported the improvement of students' attitudes toward chemistry through a conceptual change approach. However, there were some studies could not detect an improvement in students' attitudes through the implementation of conceptual change approach (Çakir et al., 2002; Pınarbaşı et al., 2006; Taştan et al., 2008). Some of the studies using SWH approach investigated its effect on students' attitudes toward science (Gunel et al., 2003; Günel et al., 2010; Kabatas et al., 2008), students' attitudes toward laboratory report format (Rudd II et al., 2001) and attitudes toward laboratory instruction (Erkol et al., 2008, 2010). All of these SWH studies demonstrated positive influences of SWH approach on students' attitudes toward science or any other object.

In conclusion, the size of the relationships between attitudes toward science and science achievement were varying across studies. Several of them found that there was a positive low correlation between attitude and achievement (e.g., Salta & Tzougraki, 2004). Because of such a relationship exists between attitude and achievement, it could be a potential confounding variable in an experimental research design. For this reason, it is worth to investigate students' attitudes toward chemistry at the beginning of the instruction in order to enhance the internal validity of the particular study.

2.5 Summary of the Findings of the Reviewed Studies

1. Students come to the class with ideas, interpretations, and concepts that may impede their subsequent learning (Uzuntiryaki & Geban, 2005). These kinds of ideas are often referred to as misconceptions (Nakhleh, 1992).
2. Students have misconceptions in chemical changes (Ahtee & Varjola, 1998; Andersson, 1986; Barker & Millar, 1999; Hesse & Anderson, 1992; Johnson, 2000a; Reynolds & Brosnan, 2000; Solsona, et al., 2003) and mixtures (Coştu et al., 2007; Çalık et al., 2007; Stains & Talanquer, 2007; Valanides, 2000).
3. Instructional strategies employed by the teacher, abstract nature of the chemistry, textbooks, and everyday life are the major sources of misconceptions (Garnett et al., 1995).
4. Changing students' misconceptions is a rather difficult task because they are resistant to change through regular instruction (Driver & Easly, 1978; Fisher, 1985; Hynd et al., 1994).
5. Instructional strategies based on conceptual change are effective on students' understanding of scientific concepts or remediation of misconceptions (Chambers & Andre, 1997; Hynd et al., 1994).
6. The strategies involve the use of conceptual change approach are very effective in conceptual change (Niaz, 2002). There are various strategies targeting students' understanding of scientific concepts or remediation of misconceptions: cooperative learning (e.g., Bilgin & Geban, 2006), analogies (e.g., Çalık et al., 2009), refutational texts (e.g., Hynd et al., 1994), conceptual change texts (e.g., Önder & Geban, 2006), combination of conceptual change texts with analogy (e.g., Pabuçcu & Geban, 2007), combination of conceptual change texts with

concept mapping (e.g., Uzuntiryaki & Geban, 2005), combination of analogies with hands-on activities (e.g., Çetin et al., 2009), learning cycle (e.g., Ceylan & Geban, 2009), and common knowledge construction model (e.g., Ebenezer et al., 2010).

7. Affective characteristics and classroom contextual factors influence conceptual change (Pintrich et al., 1993).
8. SWH is an argument-based inquiry approach leading to acquisition of scientific conceptions, nature of science, metacognitive skills and improved attitudes toward science (Keys et al., 1999).
9. There are many international studies investigating the effectiveness of SWH approach over traditional approach with respect to students' understanding of science concepts at different grade levels (Akkus et al., 2007; Hand et al., 2004; Hohenshell & Hand, 2006; Keys et al., 1999; Rudd II et al., 2001, 2002, 2007; Schroeder & Greenbowe, 2008).
10. If the instructors implement the SWH approach effectively, their students could better develop science concept and argument (Burke et al., 2005; Poock et al., 2007; Nam et al., in press).
11. There were some studies investigating the student performance in SWH and traditional classes in relation to achievement level (Akkus et al., 2007).
12. Writing is an integral part of the SWH approach because writing makes students negotiate meaning for verbal symbols, which further enhances the construction of scientific knowledge (Hand et al., 2004).
13. Students' perceptions about the implementation of SWH approach were also investigated by the researchers (Gunel et al., 2003).
14. There were also some national studies investigating the effectiveness of SWH approach over traditional approach at elementary and college levels (Erkol et al, 2008, 2010; Günel et al., 2010; Kabatas et al., 2008).
15. There is a positive low correlation between attitude and achievement (Salta & Tzougraki, 2004).

In the light of summary obtained from the literature review, it can be said that using the SWH approach led to better understanding of scientific concepts, and attitudes toward science. In addition, the misconceptions of the students about chemical changes and mixtures, and the relation between attitude and achievement were also emphasized in the literature review. The literature indicated that there are few studies regarding the implementation of SWH approach at high school chemistry level, and students had a difficulty in understanding the chemical change and mixture concepts. For this reason, the effects of SWH approach on 9^{th} grade students' understanding of chemical change and mixtures concept was investigated in the present study.

CHAPTER 3

METHOD

In the previous chapters, problems and hypotheses of the study were presented, the related literature was reviewed, and the essence of the study was justified. In this chapter, population and sample, description of variables, instruments, procedure, analyses of the data, and assumptions and limitations of the study are explained briefly.

3.1 Population and Sample

The target population of the study consists of all 9^{th} grade public high school students in Ankara district. Since it is not easy to meet this target population, accessible population was determined as all 9^{th} grade students in Çankaya district. The results of this study were generalized to this population. In Çankaya district, there were 17 public high schools and these high schools included approximately 3400-4250 ninth grade students who were taught chemistry. The sample of this study was determined by selecting a public high school from the accessible population. A public high school having a well-equipped science laboratory was selected conveniently. From that high school, four intact classes of two different teachers were participated in this study by taking into consideration the willingness of chemistry teachers. The sample of this study consisted of 122 ninth grade students from a public high school. Each teacher's one intact class was assigned as the experimental group and the other class was assigned as the control group. There were 62 students (33 males and 29 females) in the experimental groups while there were 60 students (30 males and 30 females) in the control groups. Students' ages ranged from 15 to 17 years old. Students were from middle-class families.

Experimental groups were taught by the instruction based on SWH approach and the control groups were taught by traditionally designed chemistry instruction. In order to facilitate the proper instruction of SWH approach in the experimental groups, the teacher was given training sessions prior to the study. The teacher and the researcher discussed instructional plans before the instruction.

3.2 Variables

There were two dependent variables and six independent variables in this study.

3.2.1 Dependent Variables

The dependent variables of this study were students' understanding of chemistry concepts measured by Chemical Change and Mixture Concept Test (CCMCT), and chemistry achievement measured by Chemical Change and Mixture Achievement Test (CCMAT). These variables were interval and continuous.

3.2.2 Independent Variables

The independent variables of this study were type of instruction (SWH approach and traditional instruction), achievement level, attitudes toward chemistry, socio-economic status (SES), gender, and age. Attitude toward chemistry was considered as continuous variable and was measured on interval scale. Instruction type or treatment and achievement level were considered as categorical variables and were measured on nominal scale. Among these variables, types of instruction and achievement level were group membership, and attitude toward chemistry, SES, age and gender was used in order to understand the group difference at the beginning of the instruction.

Socio-economic status (SES) of the students is one of the variables contributing to student learning. The variable SES is associated with family income, parents' education level, average income of a school district where students live, or some of these variables. A significant relationship was detected between SES and science achievement by Fleming and Malone (1983). For this reason, students' socio-economic status was also examined before the treatment. Because SES is a kind of construct, it can be measured by a set of variables. In this study, SES was computed by combining the variables mother education level, father education level and the number of books held at home (Pallant, 2005). The data associated with SES was obtained through the administration of the Student Background Questionnaire (see Appendix A).

Students' chemistry mean scores in previous semester were used to determine achievement levels. The mean of the students' previous chemistry scores was 47.6, while the standard deviation was 24.6. The students who scored a half standard deviation (-.5 to .5) around the mean were in medium-achievement level, the students who scored a half standard deviation below the mean were in low-achievement level (-.5 and down), and similarly the students who scored a half standard deviation above the mean were in high-achievement level (.5 and up) (Akkus et al., 2007).

3.3 Instruments

Chemical Change and Mixture Concept Test (CCMCT), and Chemical Change and Mixture Achievement Test (CCMAT) were used as instruments.

3.3.1 Chemical Change and Mixture Concept Test (CCMCT)

This instrument was used to identify students' misconceptions in chemical changes and mixtures. CCMCT was a two-tier test developed by the researchers. Some of the questions were developed taking into consideration the related literature (Andersson, 1986; BouJaoude, 1992; Coştu et al., 2007; Çalık, 2005; Çalık et al., 2007; Eilks et al., 2007; Papgeorgiou & Sakka, 2000) and some revisions were made on those test items. In the first tier, a multiple-choice question was asked and in the second tier, the reason of preferring that choice was asked. In the development of the first-tier, possible misconceptions were included in the alternatives of each item. Common misconceptions addressed by the CCMCT were shown in Table 3.1. Totally, there were 40 items in CCMCT: 20 questions from unit1 (chemical changes) and 20 questions from unit2 (mixtures). The questions in the first tier, that is, multiple-choice questions, were scored 2 if it is right, 0 if it is wrong. The questions in the second tier, that is, open-ended questions, were scored 2 if it is correct, 1 if it is partially correct, and 0 if it is wrong or misconception. Therefore, the maximum score that a student can get from this test was 80, while the minimum was 0. Pilot study was conducted to evaluate reliability aspects of this test. There were 98 high school students (51 females, 47 males) in the pilot study. Cronbach alpha reliability of the pilot scores of the test was computed as .80. For validity issue, three experts in chemistry education examined this test and evaluated whether the items in the test were well enough to identify students' misconceptions. These experts' recommendation was used to revise the test. The opinions of these experts were used as content related evidence for validity issue. A Turkish language teacher examined the test with respect to its grammatical aspects and understandability, and a chemistry teacher examined this test for understandability. The opinions of Turkish language teacher and chemistry teacher were used as an evidence for face validity. This test was administered to all students both before and after the treatment (see Appendix B).

Table 3.1 Common misconceptions probed by CCMCT

- Physical changes are reversible while chemical changes are not (Abraham et al., 1994; Eilks, et al., 2007; Gabel, 1999; Gensler & Redlich, 1970; Johnson, 2000a; Palmer and Treagust, 1996; van Driel, deVos, van der Loop, & Dekkers, 1998).
- Change of state is a chemical change (Ahtee & Varjola, 1998; Briggs & Holding, 1985; Kind, 2004).
- A nail's weight does not change after rusting (BouJaoude, 1992; Hesse & Anderson, 1992; Horton, 2007).
- A nail's weight decreases after rusting (BouJaoude, 1992; Mulford & Robinson, 2002).
- A nail's weight increases after rusting by due to adding something like water, rust, oxygen, oxygen and water, without a reaction (Andersson, cited in Kind, 2004).
- Rust eats away the material (BouJaoude, 1992; Hesse & Anderson, 1992).
- Iron and rust are the same (Hesse & Anderson, 1992; Johnson, 2000b).
- Coldness causes a nail to rust (Hesse & Anderson, 1992; Horton, 2007).
- Iron turns into other elements after rusting (Andersson, 1986).
- Rusting of an iron nail is a physical change (Hesse & Anderson, 1992).
- Mass decreases in combustion (Barker & Millar, 1999; Johnson, 2000a)
- A candle burning is the same as wax melting (BouJaoude, 1992; Reynolds & Brosnan, 2000).
- When a candle burns, only the wick burns (Abraham et al., 1994; Johnson, 2002; Reynolds & Brosnan, 2000).
- The initial substance vanishes in a chemical reaction (van Driel et al., 1998).
- Things dissolve by mixing them in water or solutions are in liquid state (Ebenezer, 1992; Horton, 2007; Papageorgiou & Sakka, 2000; Silberberg, 2007).
- Things dissolve by stirring (Valanides, 2000).
- Melting and dissolving is the same thing (Çalık et al., 2007; Eilks et al., 2007; Valanides, 2000).
- Weight decreases in dissolving (Horton, 2007; Mulford & Robinson, 2002; Pınarbaşı et al., 2006; Uzuntiryaki & Geban, 2005).

Table 3.1 Common misconceptions probed by CCMCT (continued)

• Dissolution of salt in water is a chemical reaction because a completely different substance is formed (Ahtee & Varjola, 1998; Barker & Millar, 1999; Çalık et al.,2007).
• Sugar dissolving in water is a chemical change (Abraham et al., 1994; Ahtee & Varjola, 1998; Uzuntiryaki & Geban, 2005).
• All mixtures are heterogeneous (Coştu et al., 2007; Sanger, 2000).
• Confusion between pure substances and mixtures (Driver, Squires, Rushworth, & Robinson, 1994; Ryan, 1990; Sanger, 2000).
• Failure to discriminate between elements, compounds and mixtures (Briggs & Holding, 1985; Coştu et al., 2007; Papageorgiou, 2002; Papageorgiou & Sakka, 2000; Stains & Talanquer, 2007).
• The identities of the components in a mixture are not retained (Coştu et al., 2007; Uzuntiryaki & Geban, 2005).
• Mixtures always consist of two substances (Coştu et al., 2007).

3.3.2 Chemical Change and Mixture Achievement Test (CCMAT)

This instrument was used to assess students' chemistry achievement in two consecutive chemistry units on chemical changes and mixtures. The researchers developed this instrument by taking into account the high school chemistry curriculum. In question development process, the researcher benefited from the textbooks, University Student Selection Examination (OSS), some international studies like TIMSS (1999, 2003) and the literature (Mulford, 1996). In test construction process, first, the objectives of the units on chemical changes and mixtures were stated (see Appendix C). This test consisted of 22 multiple-choice questions: 9 questions from unit1 (chemical changes) and 13 questions from unit2 (mixtures). Reason for preferring multiple-choice items is that it is easy and quick to administrate and it enables the researcher to score objectively. Each test item consisted of five alternatives: one correct answer and four distracters. Items in the test were related to physical change, chemical change, types of chemical reactions, classification of mixtures, solutions, solubility, factors affecting solubility, and separation of mixtures. This test was examined by two professors, one assistant professor and three research assistants in chemistry education to establish content validity, and by two chemistry teachers and two Turkish language teachers for the appropriateness of language and student level. Originally, there were 40 items in the test. After the revision of the test, it included 22 items. A pilot test was conducted to evaluate reliability aspects of this test scores. There were 381 high school students (52% females, 48% males) in the pilot study, and the Cronbach reliability coefficient was computed as .75. In the scoring process, each correct response was scored as 1, and each incorrect response was scored as 0. Therefore, total maximum score that a student can get from this test was 22, while the minimum was 0. This test was given to both groups as a pre-test to assess whether there was a group difference prior to the instruction and as a post-test to compare the students' chemistry achievement between experimental and control groups at the end of the instruction. This test was administered in groups by the teachers in regular class hours and took 35 minutes (see Appendix D).

3.3.3 Attitude Scale toward Chemistry (ASTC)

This test was developed by Geban, Ertepınar, Yılmaz, Altın and Şahbaz (1994) to measure students' attitudes toward chemistry as a school subje"ct. This scale consisted of 15 items in 5-point likert type scale: fully agree, agree undecided, disagree, and fully disagree. The reliability was found to be .83. This test was given to students in both groups before the treatment (see Appendix E). It covers both positive and negative statements. Total possible ASTC scores range is from 15 to 75. While lower scores show negative attitudes toward chemistry, higher scores show positive attitudes toward chemistry. This is a standard test; therefore, there is no need to collect evidence for validity.

3.3.4 Semi-Structured Interviews

Semi-structured interviews were used for the purpose of understanding students' ideas about the usage of SWH approach and their conceptual understanding in the units of chemical changes and mixtures. Interviews were administered to volunteer students individually. The interview schedule was constructed by the researchers. In line with the recommendations of the professors and colleagues, the revisions were done. A tape recorder was used during interview process in order to record the data. Interview protocol included two parts: Part A and Part B. Part A portion of the interview schedule was administered to the volunteer students in both experimental (13 students) and control groups (8 students). In Part A, there were conceptual questions (8 questions) regarding chemical changes and mixtures. The purpose of this interviewing process was to elicit students' misconceptions in the units of chemical changes and mixtures, and by this way to support the misconceptions obtained from the post-CCMCT. Part B portion of the protocol were only administered to the students in the experimental group (13 students) because the questions in the Part B portion of the protocol were related to the implementation of SWH approach. In Part B, the students were asked 14 questions, and generally, the questions were related to the difference between traditional and SWH approaches, changes in teacher, question-claim-evidence, and writing. General questions were also included in the protocol. Part A portion of the interview schedule lasted about 30 minutes while Part B portion of it lasted about 25 minutes (see Appendix F).

3.3.5 The Classroom Observations

The main aim of classroom observation was to observe the implementation of treatment in the experimental and control group for the treatment verification. In the experimental group, implementation of SWH approach and in the control group implementation of traditional approach was observed carefully. In addition, the roles of the teacher and students, the classroom activities and the interactions among students, and between teacher and students were observed. During each observation, naturalistic approach was followed and field notes were taken about the implementation process. Also an observation checklist that consisted of 17 items with 3 point likert type scale (yes - 2 / partially - 1/ no - 0) was used during the observation (see Appendix G).

3.4 Procedure

In this study, a quasi-experimental design was used to investigate the effect of SWH instruction on students' understanding of chemical change and mixture concepts, and their chemistry achievement. The study started with a detailed review of literature. The keywords, misconception, constructivism, conceptual change, science writing heuristic, attitude toward science, science education, and chemistry education were determined at the beginning of the study. Then, Educational Resources Information Center (ERIC), Dissertation Abstracts International, Social Science Citation Index (SSCI), Science Direct, and Internet (Google scholar) were searched. The MS and PhD thesis which were done both in abroad and Turkey, and the books were also examined. In addition, previous studies that were done in Turkey were searched from YÖK, Hacettepe University Journal of Education, and Education and Science. The materials obtained from the literature review were read, examined in detail, and results of the studies were compared with each other. Next, the measurement tools were developed by the researchers. Two measurement tools were developed by the researchers; and one measurement tool was taken from literature. The instruments developed by the researchers were tested in pilot study. Results of the pilot study were analyzed and evaluated by the researchers and a specialist in chemistry education with respect to reliability and validity issues. Necessary changes were done with respect to this revision before final study.

This study was carried out over a ten-week period. A quasi-experimental design was used in this study because it is unlikely to obtain administrative approval to randomly select and remove a selected few students from different classrooms for any study in a high school. A public high school in Çankaya district was selected as defined in sampling part. Research design of the study can be seen in Table 3.2. During the study, the topics related to chemical changes and mixtures were covered as a part of regular classroom curriculum in chemistry course. The instruction was two 45-minute sessions per week. Four intact classes of two different teachers in a public high school were participated in this study. Each teacher's one intact class was assigned as the experimental group and the other class was assigned as the control group. Totally, there were four groups in this study: two of them were experimental groups and two of them were control groups. The control groups were instructed by using traditional approach, while the experimental groups were instructed by using SWH approach. Just before the study begins, pre-tests, CCMCT, CCMAT, and ASTC were administered to both experimental and control groups to understand whether there was a significant difference between experimental and control groups with respect to measures of these instruments before the treatment. The treatment period started after pre-tests were given. To examine the effect of treatment, the same tests, CCMCT and CCMAT, were given to students in both groups as a post-test.

Table 3.2 Research design of the study

Groups	Pre-test	Treatment	Post-test
Experimental group	CCMCT, CCMAT, ASTC	Instruction based on SWH	CCMCT, CCMAT
Control group	CCMCT, CCMAT, ASTC	Instruction based on Traditional Approach	CCMCT, CCMAT

In this study, the teachers had no experience of implementing the SWH approach prior to the study. In fact, at the time of the investigation, there was a change in the 9th grade chemistry curriculum from teacher-centered into more student-centered approach (Ministry of National Education, 2007). The teachers were introduced the new curriculum and they were said that they were required to use student-centered approach in their chemistry classes but they had a difficulty in comprehending how can be student-centered. For this reason, this study was very encouraging for them. They were eager to learn the SWH approach. Before the study, the researcher had several meetings with the teacher at school in order to train them about the implementation of SWH. The teachers were given SWH information notes (see Appendix H) in the first meeting and introduced the SWH approach. In the second meeting, the teachers read the given materials, and the researcher and the teachers discussed about the implementation of SWH. The teachers were very anxious about the implementation at the beginning because this approach was a student-centered approach and the teachers were required to shift from teacher-centered into student-centered teaching, which was not an easy process. The researcher had regular meetings with the teachers in every week until the study begins. During the treatment, the researcher met with the teachers before the class session about the procedure needs to be followed in the class. The researcher participated in all class sessions with the teacher and observed the class by taking field notes and filling out the observation checklist. After each class session, the researcher met with the teachers and discussed about the implementation of SWH approach. During the discussion, the researcher made suggestions to the teacher for the proper implementation in the following weeks. During the implementation period, the researcher repeated the same procedure mentioned above for each teachers' class. The researcher also warned the teachers to teach the control group students as in the same way they thought before and not to do things specified for the experimental groups.

The laboratory was just repaired at the time of the investigation and it was very appropriate for having classes. However, the teachers were not using laboratory although the students and the administrators in that school were very eager to use it.

There were many chemicals and equipment in chemistry laboratory but most of them were still in the boxes. The researcher spent much time for the arrangement of chemicals and the equipment in the laboratory. The researcher labeled all of them to make easy for the students usage. Most of the chemistry classes of the experimental groups were done in the laboratory. In order to make the treatment less novel, the control group students were also taken to the laboratory because students in different classes were talking to each other and they were talking about what they did in the chemistry classes or other classes.

In the first week, students in the experimental groups were taken to the laboratory and they were told that the chemistry classes will be done in the laboratory in most of the weeks. It was the first time for the students coming to the laboratory and they did not have much information about the laboratory safety rules and the basic materials used in the chemistry laboratory. For this reason, in the first laboratory class hour, the students were informed about the laboratory safety rules, and the basic materials like beaker, tube, etc. Because the students' safety is very important in the chemistry laboratory, they were especially warned about the toxic materials. The teachers asked students to form their own groups. There were 32 students in one of the experimental groups and 30 students in the other experimental group. There were five benches at the chemistry laboratory and for this reason students formed five groups in each of the experimental group for the classroom activities. The students were given a handout about the SWH approach (see Appendix I). Then, the students were introduced SWH approach via the mystery activity (Burke et al., 2005, p. 39) (see Appendix J). Each group was given a handout about the mystery activity. The students were asked to read it individually and write a question, a claim, and evidences about the mystery death activity. Then, the students shared their questions, claims, and evidences in order to construct a group question, claim, and evidence. After the completion of this task, a student from each group wrote their group's question, claim, and evidences on the white board and then each group explained their written arguments to the entire class. After each group presented, students in the rest of the class asked them questions or refuted something they claimed or argued. After all these processes were completed, the teacher summarized what they did from the beginning to the end. The teacher engaged students in a discussion about questions, claims, and evidences in order to make students aware of the meaning of those words. This activity was not related to chemistry, for this reason, it attracted students' attention very much. Actually, the aim of this activity was to make students conceptualize the process of argumentation, which is a structure of question, claim, and evidence. At the end of the class session, the teacher asked students whether they want to have chemistry class as in this class. All the students agreed on having the classes like in that class. Then the teacher engaged students in a discussion about the following week's chemistry topic, which was chemical change. Firstly, the teacher attempted to elicit students' prior understanding about chemical changes through discussion because students were taught this concept in their prior school period. This discussion lasted about 10 minutes. The teacher focused on the big idea they are going to structure the chemistry class on it. Then the teacher asked students to write down what they want to learn about this big idea until the following week's chemistry class and share those within their group, and then prepare a beginning question for the next class. In the following week, student came to the class with their beginning questions and wrote them on the white board. Each group presented their questions to the class. During the presentation, each group also mentioned about the procedure that they are going to follow. The teacher and the rest of the class evaluated the quality of the question in terms of the relation to the big idea and appropriateness for the laboratory investigation. The procedure was also discussed in the classroom. This took about 20 minutes of the class session. After some revisions on some group's questions and procedures, each group engaged in the laboratory investigations in order to find out an answer to their questions. Each group recorded the data and observations during the experimentation process. Then, they wrote claims and evidences based on their data and observations, and then they supported their claims with the evidences. After the completion of these processes, each group wrote their questions, claims and evidences on the white board and presented them to the class. During the presentation, the teacher and the rest of the class asked some questions, which started a discussion environment in the class. There were some students refuting the arguments of the presenter group. Like this group, the other four groups presented their arguments and a discussion environment occurred most of the time. At the end of the class session, the teacher summarized what they did in the class, and tried to connect the ideas presented in the class with the big idea by creating a discussion environment with the students. Then, the teacher, asked students write a laboratory report based on SWH approach (see Appendix K) and bring them in the next week. In the SWH laboratory report format, the titles were beginning questions, test, data and observations, claims, evidences, reading, and reflections. The teacher explained how could be written those parts of the report. The students attended to seven more class sessions about the chemical changes and mixtures and they involved in extra four laboratory sessions, about chemical changes (chemical changes and types of chemical reactions) and mixtures (classification of mixtures, and separation of mixtures). For each laboratory session, the students followed the same approach. Some sessions lasted in two hours but some of them lasted more than two hours (see Appendix L for sample SWH lesson, and Appendix M for sample student laboratory reports).

On the other hand, in the control groups, teacher-centered instruction was used as traditional approach. The teacher used lecture and discussion methods and solved problems to teach chemical change and mixture concepts without considering students' misconceptions. Students were required to read the related topic from the textbook used in chemistry course prior to that lesson. The teacher explained each concept and asked questions to the students to promote discussion. Toward the end of the lesson, the teacher distributed worksheets that include mathematical and conceptual questions to be answered related to the topic. Enough time was given students to respond the questions. By this way, they were expected to reinforce the concepts taught by the teacher. At the end, worksheets were scored and corrected, and then students investigated the corrections on their worksheets. In some class hours, students were engaged in traditional laboratory activities. Students read the procedures of the laboratory experiment prior to the lesson. The teacher explained the procedures of the experiment. Then, students conducted the experiments without making knowledge claims and evidence. At the end of the laboratory activity, students recorded data and observations and they were asked to write a laboratory report in traditional format, including purpose, procedure, observations and data, results, and discussion. The teacher designed the experiment, asked questions and helped students during the activity.

At the end of the instruction, students in experimental and control groups were given post-tests to compare the effects of SWH and traditional approach on their chemistry achievement and conceptual understanding.

3.5 Analyses of Data

Quantitative data were collected by using Chemical Change and Mixture Concept Test (CCMCT), Chemical Change and Mixture Achievement Test (CCMAT), and Attitude Scale toward Chemistry (ASTC). Data list, consisting gender, types of instruction, answers of each subjects to each question and subjects' total scores in each test, were prepared by using SPSS in which columns show variables and rows show the students participating in the study. The statistical analyses were done by using PASW (Predictive Analytics Software) Statistics 18.

Missing data analyses were done before the descriptive statistics and inferential statistics. There were not any missing data in the pre-ASTC. There were missing data in pre-CCMAT, pre-CCMCT, post-CCMAT and post-CCMCT. The percentages of missing values were 4% of the total number in pre-CCMAT and pre-CCMCT, and 2.5% of the total number in post-CCMAT and post-CCMCT. The students who were missing in both post-CCMAT and post-CCMCT were excluded from the data set. Since the other missing values do not exceed 5% of the total number, they were replaced with the mean during the statistical analyses.

The quantitative data obtained in this study were analyzed in two parts. In the first part, descriptive statistics and in the second part, inferential statistics were used. In order the test the hypotheses, statistical analyses were done by using PASW Statistics 18. In this analysis, there were two dependent variables, two independent variables, and covariates. Inclusion of these two dependent variables in the same analysis is only possible using statistical technique named multivariate analysis of covariance (MANCOVA). This statistical technique can both equate groups on more independent variables and control Type 1 error. This technique permits a more powerful test of differences among means by reducing the error variance (Pallant, 2005). It is justified to use MANCOVA because the dependent variables in this study were correlated moderately ($r = .50$). The level of significance (α) was set to the .05 because it is mostly used value in educational studies. In other words, the probability of rejecting the true null hypothesis (probability of making Type 1 error) was set to .05 prior to the hypotheses testing. The power of this study was set to .80. Therefore, the probability of failing to reject the false null hypothesis (probability of making Type 2 error) was found .20. Since it was very difficult to obtain a large effect size in educational studies, effect size was preset as medium.

The qualitative data were collected mainly through the semi-structured interviews and classroom observation. Students written responses on the second tier items of the CCMCT were also coded qualitatively. In the interviews, a tape recorder was used while in the classroom observation, detailed notes were taken, and a checklist was filled out. For the analyses of the interview data, first the audio recordings were transcribed in verbatim by the researcher. The data were organized in order to understand the data and then they were coded by the researcher. The codes which were close to each other collected together. By this way, the codes were categorized into general themes. Then, the interview data were interpreted based on the codes and categories by presenting direct quotations from the interview data (Marshall & Rossman, 2006). The researcher coded the interview transcripts several times and then these codes were examined by two experts in science education. The feedback given by those experts were taken into consideration by the researcher. The field notes taken during the classroom observation were also organized as in the interview data. The field notes were interpreted based on the categories determined in advance by the researcher in relation with the data obtained from the classroom observation checklist. These interpretations were also checked by two experts in science education. Moreover, students written responses on the second tier of the CCMCT were also coded by the researcher based on the predetermined criteria as wrong response, specific misconception, partially correct response and correct response. Then, two experts in science education examined these codes. The revisions were made in accordance with the feedback given by those experts.

3.6 Assumptions of the Study

1. Students in the experimental group were not interacting with the students in the control group.
2. The tests were administered under standard conditions.
3. The students answered the items of the tests honestly and seriously.
4. The teacher was not biased during the treatment.

3.7 Limitations of the Study

1. The study was limited to the units of chemical changes and mixtures.
2. This study was conducted with 122 students indicating a small proportion of the accessible population.
3. The assumption of the independent observations for the statistical analyses may not be met properly because of the administration of the tests and treatments in groups at the same time.
4. The generalizability of this study was limited due to the convenience sampling.
5. Multiple-choice tests were used to evaluate students' chemistry achievement.
6. Only the researcher observed the lessons.

CHAPTER 4

RESULTS

The results were divided into five sections. In the first section, statistical analyses of the pre-test scores on the CCMAT, CCMCT, and ASTC were presented; in the second section, statistical analyses of post-test scores were displayed; in the third section, students responses to the interview questions were presented; in the fourth section, students' ideas about the SWH approach were given, and in the last section, classroom observation results were shared.

4.1 Statistical Analyses of Pre-test Scores

Prior to the treatment, MANOVA was conducted to determine whether there was a statistically mean difference between control and experimental groups with respect to conceptual understanding and chemistry achievement in the units of chemical changes and mixtures. Univariate ANOVA was run to investigate whether there was a statistically significant mean difference between experimental and control groups with respect to students' attitudes toward chemistry. Statistical analyses were performed at .05 significance level using PASW Statistics 18.

4.1.1 Statistical Analysis of Pre-CCMAT and Pre-CCMCT Scores

Descriptive statistics for the dependent variables across the experimental and control groups, and achievement levels were displayed in Table 4.1. In this table, CG refers to control group, EG refers to experimental group, LAL refers to low-achievement level, MAL refers to medium-achievement level, and HAL refers to high-achievement level. As seen from this table, the experimental and control group students mean scores on pre-CCMAT and pre-CCMCT was closer to each other. However, the mean scores of high-achieving students were higher than that of middle-achieving students, and middle-achieving students' mean scores were higher than that of low-achieving students on pre-CCMAT and pre-CCMCT prior to the treatment.

Table 4.1 Descriptive statistics with respect to pre-CCMAT and pre-CCMCT scores across experimental (N=60) and control groups (N=60), and across low- (N=55), medium- (N=25), and high-achievement levels (N=40)

	Mean		SD		Skewness		Kurtosis	
	pre-CCMAT	pre-CCMCT	pre-CCMAT	pre-CCMCT	pre-CCMAT	pre-CCMCT	pre-CCMAT	pre-CCMCT
CG	7.733	27.71	3.695	8.548	-.188	.114	-1.191	-.400
EG	9.183	28.71	2.789	10.712	-.418	.154	.437	-.352
LAL	7.62	23.21	2.984	6.983	-.421	.474	-.597	-.349
MAL	8.24	28.21	3.62	10.340	-.102	.178	-1.004	.902
HAL	9.75	35.09	3.303	8.235	-1.053	-.743	.853	2.344

Before interpreting the MANOVA outputs, independence of observations, multivariate normality and homogeneity of the variance-covariance matrices assumptions were checked. It was assumed that the students took the tests independent from each other without any interaction during the administration of the tests. The teachers were warned about controlling the independence of the students during test taking process. For multivariate normality assumption, skewness and kurtosis values for the dependent variables were checked. Skewness and kurtosis values displayed in Table 4.1 can be considered as tolerable values for univariate normality, which may be a sign of multivariate normality. Homogeneity of variance-covariance matrices was checked through Box's test and Levene's test. Box's Test result showed that the covariance matrices of the dependent variables were equal across groups, F (15, 26759) = 1.589,

p = .068. Results of Levene's test in shown in Table 4.2 revealed that each dependent variable has the same variance across groups.

Table 4.2 Levene's test of equality of error variances

	F	df1	df2	p
pre-CCMAT	1.898	5	114	.100
pre-CCMCT	.802	5	114	.550

Having met the assumptions of MANOVA, the results were interpreted. Results were displayed in Table 4.3.

Table 4.3 MANOVA results with respect to collective dependent variables

Source	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Sig. (p)
Group	.945	3.319	2	113	.040
Ach. Level	.696	11.224	4	226	.000
Group*Ach. Level	.989	.308	4	226	.872

The findings indicated that there was a significant mean difference between experimental and control groups with respect to collective dependent variables. In addition, there was a significant mean difference across students' achievement levels in collective dependent variables. In order to find out whether the significant differences were on both dependent variables or just one, further univariate ANOVA results were interpreted. The univariate results with respect to achievement level and group were presented in Table 4.4.

Table 4.4 Univariate ANOVA results with respect to achievement levels

Source	Dependent Variable	df1	df2	*F*	Sig. (*p*)
Group	pre-CCMAT	1	114	6.689	.011
	pre-CCMCT	1	114	.713	.400
Ach. Level	pre-CCMAT	2	114	5.259	.007
	pre-CCMCT	2	114	23.986	.000

As seen from the Table 4.4, there was a statistically significant mean difference between experimental and control groups with respect to pre-CCMAT scores, and there were significant differences among low-, medium-, and high-achievement levels with respect to both pre-CCMAT and pre-CCMCT scores. Because there are three levels of the independent variable, achievement level, it is necessary to understand where the significant differences lie. For this reason, follow-up pairwise comparisons were interpreted. Post Hoc test results were displayed in Table 4.5.

In Table 4.5, it was seen that there were significant differences between the students in low-achievement level and high-achievement level on pre-CCMAT and pre-CCMCT scores. There were also significant differences between low-achieving students and medium-achieving students, and medium-achieving and high-achieving students on pre-CCMCT scores.

In order to identify whether the significant differences observed in achievement levels were the same across experimental and control groups. The significance of the interaction effect between achievement level and group variables were interpreted. It was seen that there was no significant interaction effect between group and achievement level. That means there were significant differences between the achievement levels in both experimental and control group students.

Table 4.5 Follow-up pairwise comparisons

Dependent Variable	Ach. Level	Ach. Level	Mean Difference	Std. Error	Significance
pre-CCMAT	LAL	MAL	-.62	.766	1.000
		HAL	-2.13*	.661	.005
	MAL	LAL	.62	.766	1.000
		HAL	-1.51	.810	.195
	HAL	LAL	2.13*	.661	.005
		MAL	1.51	.810	.195
pre-CCMCT	LAL	MAL	-5.00*	1.991	.040
		HAL	-11.88*	1.715	.000
	MAL	LAL	5.00*	1.991	.040
		HAL	-6.88*	2.104	.004
	HAL	LAL	11.88*	1.715	.000
		MAL	6.88*	2.104	.004

Moreover, the correlation between SES, age, gender, and pre-CCMCT and pre-CCMAT were also computed in order to find out whether any significant relationships exist among them prior to the study. Before looking at the correlations, the descriptive statistics of these variables were presented in Table 4.6. According to this table, it was seen that males were more than females in both experimental and control groups. Generally, the students were born in 1993 and 1994 in both groups and their socio-economic level was medium in both groups.

The correlations of these variables with the pre-test scores were given in Table 4.7. According to this table, there were no significant relationship between SES, age, gender, and pre-CCMAT and pre-CCMCT. Only between pre-CCMAT and pre-CCMCT was a significant moderate relationship. Therefore, the students in the experimental and control groups were similar.

Table 4.6 Descriptive statistics with respect to SES, age, and gender across experimental (N=60) and control groups (N=60)

	Mean	SD	Skewness	Kurtosis
SES				
CG	7.88	2.762	.250	-.950
EG	7.93	2.537	.161	-.250
Total	7.91	2.641	.207	-.672
Age				
CG	1993.77	.427	-1.294	-.339
EG	1993.73	.516	-1.818	2.582
Total	1993.75	.472	-1.647	1.796
Gender				
CG	1.50	.504	,000	.608
EG	1.52	.504	-,068	-2.065
Total	1.51	.502	-.034	-2.033

Table 4.7 Correlations of gender, age, and SES with the pre-test scores

	Gender	Age	SES	Pre-CCMAT	Pre-CCMCT
Gender	-	-.133	-.003	.010	-.081
Age	-.133	-	.076	.132	.214
SES	-.003	.076	-	-.009	.176
Pre-CCMAT	.010	.132	-.009	-	.396*
Pre-CCMCT	-.081	.214	.176	.396*	-

* Correlation is significant at the 0.05 level.

4.1.2 Statistical Analysis of Pre-ASTC Scores

Descriptive statistics for the dependent variables including skewness and kurtosis across groups were presented in Table 4.8. According to this table, students in the control group had more favorable attitudes toward chemistry than those in experimental group prior to the treatment.

Table 4.8 Descriptive statistics with respect to pre-ASTC scores across experimental (N=60) and control groups (N=60)

	Mean		SD		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG
pre-ASTC	54.65	53.03	9.631	10.727	-.604	-.471	.658	1.270

Independence of observations, univariate normality and equality of variances assumptions were checked prior to the interpretation of the univariate ANOVA outputs. Although the students interacted among each other during the treatment, it was assumed that they took the tests separately and they did not interact with each other during the administration of the tests. The teachers were warned about controlling the independence of the students during test taking process. For normality assumption, skewness and kurtosis values for the individual dependent variables were checked. Equality of the variances assumption was tested with Levene's test.

Skewness and kurtosis values in Table 4.8 are the indicators of a univarite normality for the individual dependent variables across experimental and control groups. Except one value, these values are between -1.00 and +1.00, it can be concluded that dependent variables are normally distributed. Levene's tests indicated non-significant results by proposing that normality assumption was met and population variances of the dependent variables were the same across the groups. The results of the Levene's tests were shown in Table 4.9.

Table 4.9 Levene's test of equality of error variances

	F	df1	df2	p
pre-ASTC	.309	1	118	.579

Having met the assumptions of univariate ANOVAs, the results were interpreted. Results were displayed in Table 4.10.

Table 4.10 Univariate ANOVA results with respect to dependent variable

	F	df1	df2	*p*
pre-ASTC	.763	1	118	.384

The results revealed that there was no significant mean difference in students' attitudes toward chemistry between experimental and control groups prior to the treatment. Therefore, the students in both groups were similar with respect to attitudes toward chemistry.

4.2 Statistical Analyses of Post-test Scores

The hypotheses stated in Chapter 1 were tested using MANCOVA because there were significant differences between the experimental and control groups with respect to pre-CCMAT and pre-CCMCT scores at the beginning of the study. In order to partial out the unwanted effects of the pre-tests, MANCOVA was conducted. In this statistical analysis, treatment and achievement level were independent variables, post-CCMAT scores and post-CCMCT scores were the dependent variables, and pre-CCMAT and pre-CCMCT were the covariates. Statistical analyses were performed at .05 significance level using PASW Statistics 18.

Descriptive statistics for the dependent variables across the experimental and control groups, and achievement levels were displayed in Table 4.11. As seen from Table 4.11, the students in experimental group had the higher mean scores on post-CCMAT and post-CCMCT than those in control group. In addition, high-achieving students had higher mean scores than middle-achieving students, and middle-achieving students had higher mean scores than low-achieving students in post-CCMAT and post-CCMCT.

Table 4.11 Descriptive statistics with respect to post-CCMAT and post-CCMCT scores across experimental (N=60) and control groups (N=60), and across low- (N=55), medium- (N=25), and high-achievement levels (N=40)

	Mean		SD		Skewness		Kurtosis	
	post-CCMAT	post-CCMCT	post-CCMAT	post-CCMCT	post-CCMAT	post-CCMCT	post-CCMAT	post-CCMCT
CG	8.983	30.01	3.647	10.235	.109	.159	-.283	-.913
EG	13.75	36.74	2.229	11.104	-.111	.101	-.609	-.035
LAL	10.07	28.27	4.586	10.08	.016	.519	-.975	-.374
MAL	11.72	36.37	3.048	11.843	-.075	-.107	-.666	-.734
HAL	12.92	38.53	2.313	9.117	-.336	.349	-.591	1.745

Before interpreting the MANCOVA outputs, the assumptions of independence of observations, homogeneity of the variances and covariances, multivariate normality, correlation between dependent variable and covariate, correlations among covariates, and homogeneity of the regression slopes were tested. It was assumed that the students took the tests independent from each other without any interaction during the administration of the tests. The teachers were warned about controlling the independence of the students during test taking process. For univariate normality assumption, skewness and kurtosis values for the dependent variables were checked. Skewness and kurtosis values, displayed in Table 4.11, can be considered as tolerable values for univariate normality, which may be a sign of multivariate normality. Homogeneity of variance-covariance matrices was checked through Box's test and Levene's test. Box's Test result showed that the covariance matrices of the dependent variables were equal across groups, F (15, 26759) = 1.072, p = .377. Results of Levene's test shown in Table 4.12 revealed that each dependent variable has the same variance across groups.

Table 4.12 Levene's test of equality of error variances

	F	df1	df2	*p*
post-CCMAT	1.077	5	114	.377
post-CCMCT	.962	5	114	.444

The correlation between dependent variables and covariates should be significant. This assumption was checked through the calculation of correlations between them. The correlations between post-CCMAT and pre-CCMAT (p = .000), post-CCMAT and pre-CCMCT (p = .002), post- CCMCT ad pre-CCMAT (p = .001), and post-CCMCT and pre-CCMCT (p = .000) were significant.

The correlations between the covariates should not be too strong. This assumption was tested through the bivariate correlation. The correlation between pre-CCMAT and pre-CCMCT was found to be .396, indicating a medium relationship according to Cohen's (1992) criteria.

Homogeneity of the regression slopes assumption was tested by checking the significance of the interaction between the treatment and covariates. No custom interaction was found between the treatment and pre-CCMAT (Wilks' Lambda = .997, F (2, 103) = .132, p = .876), and between the treatment and pre-CCMCT (Wilks' Lambda = .979, F (2, 103) = 1.103, p = .336).

Having met the assumptions of MANCOVA, the results displayed in Table 4.13 were interpreted.

Table 4.13 MANCOVA results with respect to collective dependent variables

Source	Wilks' Lambda	Multivariate *F*	Hypothesis df	Error df	Sig. (*p*)	Effect size	Power
Pre-CCMAT	.912	5.346	2	111	.006	.088	.831
Pre-CCMCT	.943	3.372	2	111	.038	.057	.625
Group	.610	35.543	2	111	.000	.390	1.000
Ach. Level	.856	4.490	4	222	.002	.075	.938
Group*Ach. Level	.731	9.428	4	222	.000	.145	1.000

Main Effect: The findings indicated that there was a significant mean difference between experimental and control groups with respect to collective dependent variables when the effects of pre-CCMAT and pre-CCMCT mean scores were controlled. The size of the mean difference between experimental and control groups was large (Cohen, 1992). That means, 39% of the multivariate variance on the dependent variables was associated with the treatment. In addition, power, the probability of detecting a significant difference when it truly exists, was found to be 1. These findings revealed that the difference found between experimental and control groups arouse from the treatment effect and this difference had practical importance. What is more, a significant mean difference across students' achievement levels was found in collective dependent variables.

In order to determine whether the effect of treatment and achievement level were significant on each dependent variable, univariate ANCOVA results were interpreted. Table 4.14 shows the results of univariate ANCOVAs.

Table 4.14 Univariate ANCOVA results with respect to dependent variables

Source	Dependent Variable	df1	df2	F	Sig. (p)	Effect Size	Power
Pre-CCMAT	post-CCMAT	1	112	10.778	.001	.088	.902
	post-CCMCT	1	112	.650	.422	-	-
Pre-CCMCT	post-CCMAT	1	112	.558	.457	-	-
	post-CCMCT	1	112	6.804	.010	.057	.734
Group	post-CCMAT	1	112	70.972	.000	.388	1.000
	post-CCMCT	1	112	9.969	.002	.082	.879
Ach. Level	post-CCMAT	2	112	6.533	.002	.104	.902
	post-CCMCT	2	112	5.080	.008	.083	.811
Group*Ach. Level	post-CCMAT	2	112	19.899	.000	.262	1.000
	post-CCMCT	2	112	.184	.832	-	-

As seen from the table 4.14, there was a statistically significant mean difference between the experimental and control groups in the favor of experimental group with respect to post-CCMAT and post-CCMCT scores, when the effects of pre-CCMAT and pre-CCMCT mean scores were controlled.

In addition, significant differences were observed among the low-, medium-, and high-achieving students with respect to these two dependent variables, in the favor of experimental group. Further analyses of pairwise comparison were interpreted to explore the differences among the achievement levels. Post Hoc test results were displayed in Table 4.15.

Table 4.15 Follow-up pairwise comparisons

Dependent Variable	Ach. Level	Ach. Level	Mean Difference	Std. Error	Significance
post-CCMAT	LAL	MAL	-1.64*	.576	.030
		HAL	-2.85*	.579	.001
	MAL	LAL	1.64*	.576	.030
		HAL	-1.20	.623	.219
	HAL	LAL	2.85*	.579	.001
		MAL	1.20	.623	.219
post-CCMCT	LAL	MAL	-8.09*	2.332	.008
		HAL	-10.26*	2.342	.009
	MAL	LAL	8.09*	2.332	.008
		HAL	-2.16	2.522	.977
	HAL	LAL	10.26*	2.342	.009
		MAL	2.16	2.522	.977

In Table 4.15, it was seen that there were significant differences between the students in low-achievement level and medium-achievement level, low-achievement level and high-achievement level on both pre-CCMAT and pre-CCMCT scores.

Interaction Effect: In Table 4.13, it was seen that there was a significant interaction effect between group and achievement level on the collective dependent variables. In order to conceptualize whether this significant interaction effect differs with respect to individual dependent variables, further univariate ANCOVA outputs (see Table 4.14) were interpreted. The univariate ANCOVA results revealed that there was a significant interaction effect between group and achievement level with respect to post-CCMAT scores but there was no significant interaction effect between group and achievement level with respect to post-CCMCT scores. The interaction between group and achievement level was presented in Figure 4.1.

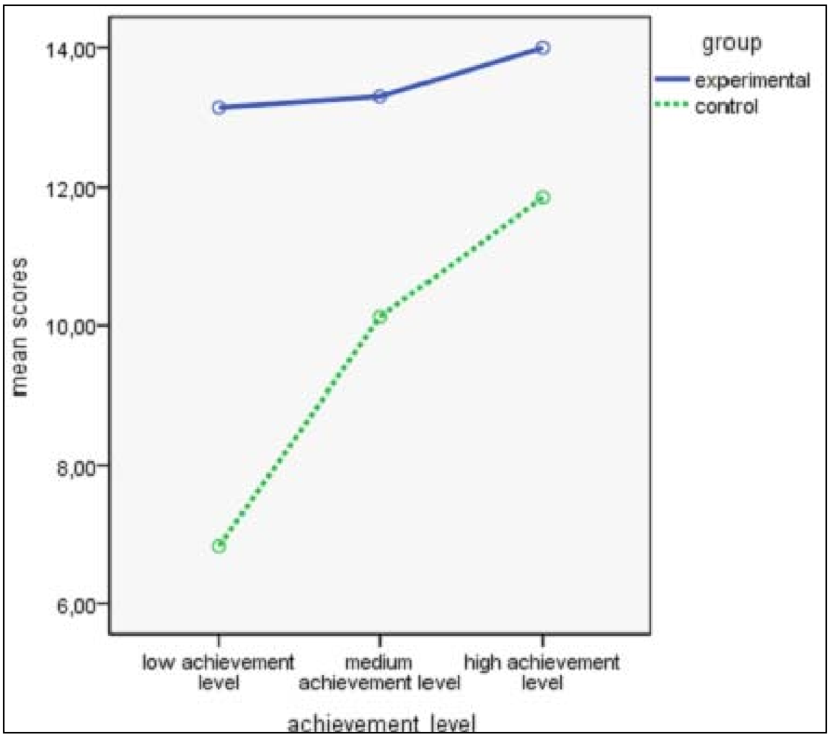

Figure 4.1 Interaction between group and achievement level with respect to post-CCMAT scores

According to Figure 4.1, low-, medium-, and high-achievers performed closer to each other on post-CCMAT in the experimental group but in the control group, there were differences among low-, medium-, and high-achievers. High-achievers scored higher than medium-achievers, and medium achievers scored higher than low-achievers in the control group. In addition, the mean difference between experimental and control group in low-achievement level was the greatest and that of in high-achievement level was the smallest. In order to determine whether these differences were significant at .05 values, three separate univariate ANOVAs were conducted. For each univariate ANOVA, the group was treated as independent variable, and students' scores on post-CCMAT was dependent variable. For each univariate ANOVA, first the assumptions were checked. It was assumed that the students took the tests independent from each other without any interaction during the administration of the tests. The teachers were warned about controlling the independence of the students during test taking process. For univariate normality assumption, skewness and kurtosis values for the dependent variables were checked. Skewness and kurtosis values displayed in Table 4.16 can be considered as tolerable values for univariate normality. Homogeneity of variances assumption was checked through Levene's test. Results of Levene's test shown in Table 4.17 revealed that each dependent variable has the same variance across groups in LAL and MAL, but not in HAL. The violation of this assumption in HAL does not constitute a major problem because the sample sizes were equal across experimental and control groups.

Table 4.16 Descriptive statistics with respect to post-CCMAT scores across experimental and control groups for each achievement level

	N		Mean		SD		Skewness		Kurtosis	
	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
LAL	27	28	13.54	6.39	2.63	2.60	-.169	-.005	-1.101	1.05
MAL	13	12	13.70	9.75	2.29	2.53	-.205	.418	-.063	.272
HAL	20	20	13.89	12.15	1.59	2.68	.028	.150	-.283	-1.13

Table 4.17 Levene's test of equality of error variances

	F	df1	df2	*p*
LAL	.203	1	53	.654
MAL	.329	1	23	.572
HAL	6.818	1	38	.013

The results of the three separate univariate ANOVAs were displayed in Table 4.18.

Table 4.18 Three separate univariate ANOVA results with respect to post-CCMAT scores

	F	df1	df2	*p*	Effect Size	Power
LAL	106.347	1	51	.000	.676	1.000
MAL	10.482	1	21	.004	.333	.870
MAL	3.982	1	36	.054	-	-

In Table 4.18, it was seen that low-achieving students in the experimental group significantly outperformed low-achieving students in the control group with respect to post-CCMAT scores. Likewise, medium-achieving students in the experimental group significantly scored higher than medium-achieving students in the control group. According to Cohen (1992), the size of these differences is large. However, the difference between high-achieving students in the experimental and control groups was not significant.

Figure 4.2 and Figure 4.3 compare low-, medium-, and high-achieving students' mean scores on pre-CCMAT and post-CCMAT across experimental and control groups, respectively. According to Figure 4.2, there were differences in the mean scores of low-, medium-, and high-achieving students on pre-CCMAT, but there were not any difference among the achievement levels on the post-CCMAT. In the experimental group, the mean differences among different achievement levels disappeared at the end of the treatment. According to Figure 4.3, there were differences in the mean scores of low-, medium-, and high-achieving students on both pre-CCMAT and post-CCMAT. In the control group, the mean differences among different achievement levels appeared even after the traditional instruction.

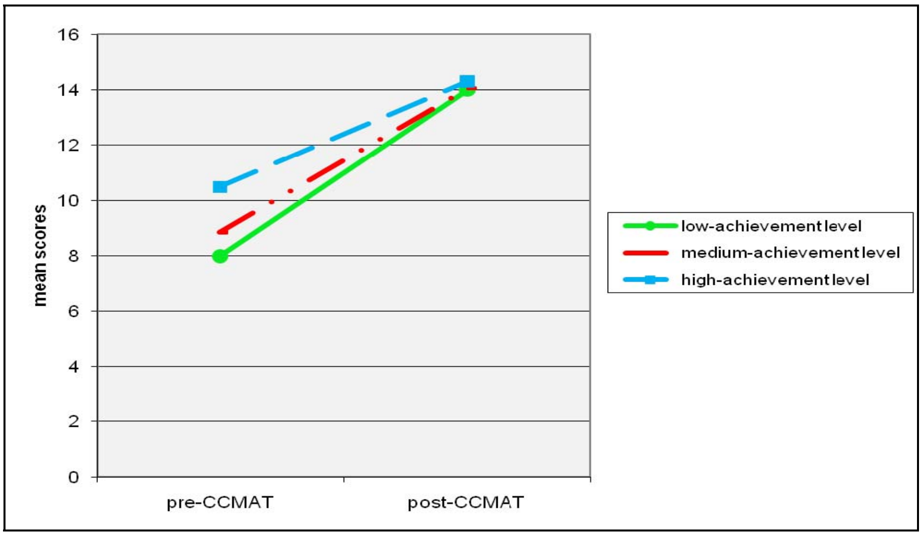

Figure 4.2 Comparison of low-, medium-, and high-achieving students' mean scores on pre-CCMAT and post-CCMAT in experimental group

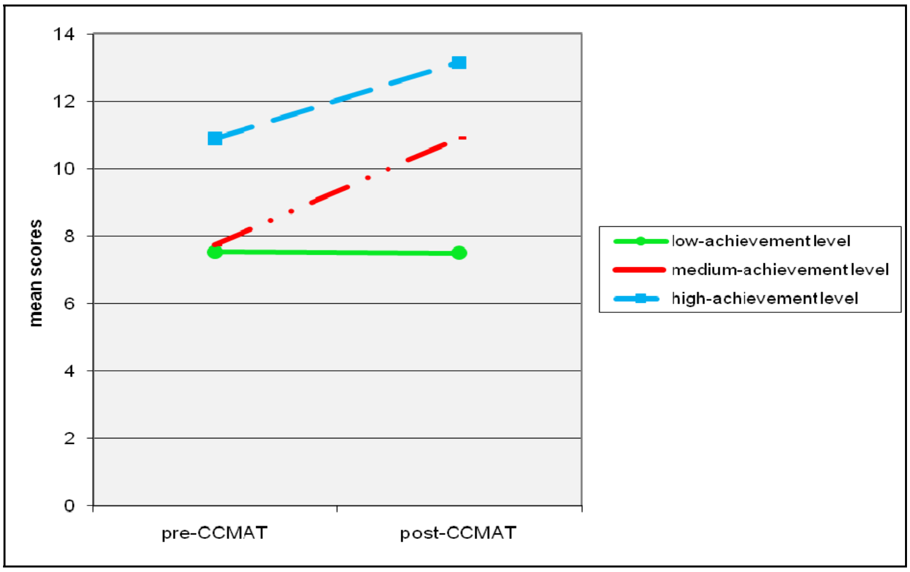

Figure 4.3 Comparison of low-, medium-, and high-achieving students' mean scores on pre-CCMAT and post-CCMAT in control group

Students' responses on post-CCMAT and post-CCMCT were also examined in this particular study. The percentages of students' correct responses on the post-CCMAT for each item were displayed in Figure 4.4, and the percentages of students' responses on the post-CCMCT were shown in Figure 4.5. According to Figure 4.4, the proportions of students' correct responses in the experimental group were greater than that of in the experimental group on post-CCMAT. Moreover, there were great differences in the proportion of students' correct responses in the items 3, 7, 9, 10, 11, 14, 15, 17, 18, 19, and 22 across the groups in the post-CCMAT.

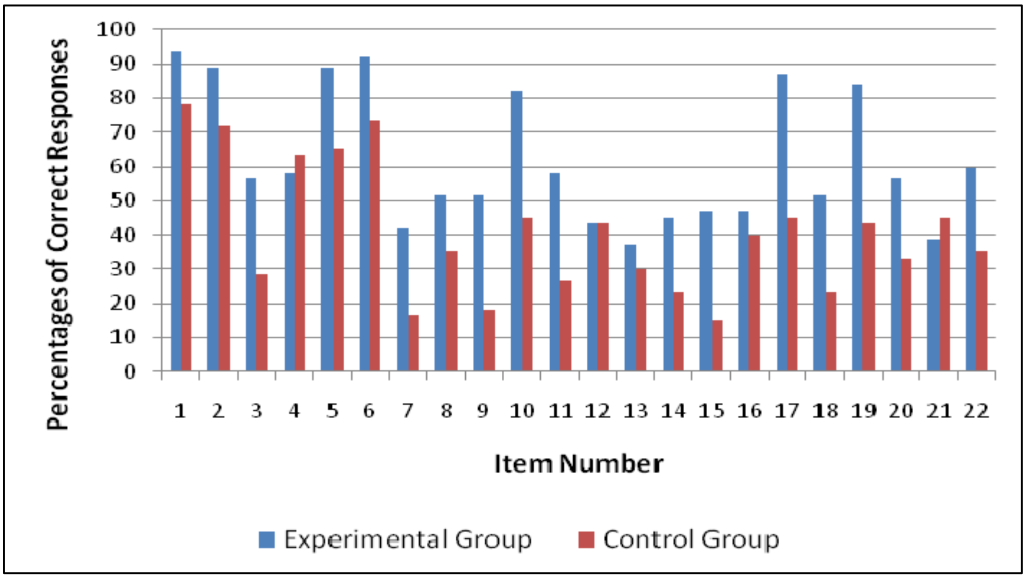

Figure 4.4 Comparison of the percentages of students' correct responses on post-CCMAT across experimental and control groups

In item 3, students were asked how the energy changes during the chemical reaction of burning petrol. After the treatment, the proportion of students answered this item correctly was 56% in the experimental group, while it was only 28% in the control group. In another item (item 7), students were given information about the usage of oxidants as a disinfectant, and then asked which matters can be used as a disinfectant. 42% of the students in the experimental group gave correct response to this item.

However, the percentage of students in the control group answering this item correctly was 17%. The 9th question was related to a chemical reaction of two salt solutions. In this question, students were asked to choose the correct explanations based on the information about the mixture of two different salt solutions. In the experimental group, the percentage of students answering this item correctly was 52%, while it was 18% in the control group.

In an item related to mixture (item 10), students were asked an example of a mixture. 82% of the students in the experimental group responded to this item correctly. However, the proportion of students answering this item correctly was 45% in the control group. Likewise, students were asked an example of a heterogeneous mixture in item 11. The percentage of students answering this question was 58% in the experimental group while it was only 27% in the control group. There was also a question about the properties of salt solution in item 14. 45% of the students in the experimental group gave correct response to this item, whereas it was only 23% in the control group. In item 15, students were given a graph about the relationship between temperature and the amount of solute in a mixture, and then students were asked to select the correct response among the alternatives related to the given graph. The percentage of students selecting the correct response was 47% in the experimental group, while it was only 15% in the control group. A question about ranking dissolution rate of different sizes of sugar particles in water was asked to students in item 17. 87% of the students in the experimental group ranked the dissolution rates of given sizes of sugar particles correctly while it was 45% in the control group. In item 18, the definition of bronze was given, and then the percentages of copper and tin by mass taken from three different samples of bronze statue were given in a table. Then students were asked to choose the correct information based on the table. 52% of the students in the experimental group selected the correct response, while it was 23% in the control group. There was an item about the solubility of gases (item 19), and the students were given a table and then asked to find out the correct alternative. The percentage of students having the correct response was 84% in the experimental group, while it was 43% in the control group. The last item (item 22) was related to the separation of mixtures. 60% of the students in the experimental group correctly separated the given mixture based on the given instruction. However, the percentage of students answering this item correctly was 35% in the control group.

In addition, the results indicated that treatment has an effect on elimination students' misconceptions in both chemical changes and mixtures units according to the post-CCMCT. For each item, the proportion of students' correct responses and misconceptions were examined. The percentages of students' correct responses for each item in post-CCMCT were given for each group in Figure 4.5. In this figure, the single items represents the first tier of a question (multiple-choice), the even items following each single item represents the second tier of that question (open-ended).

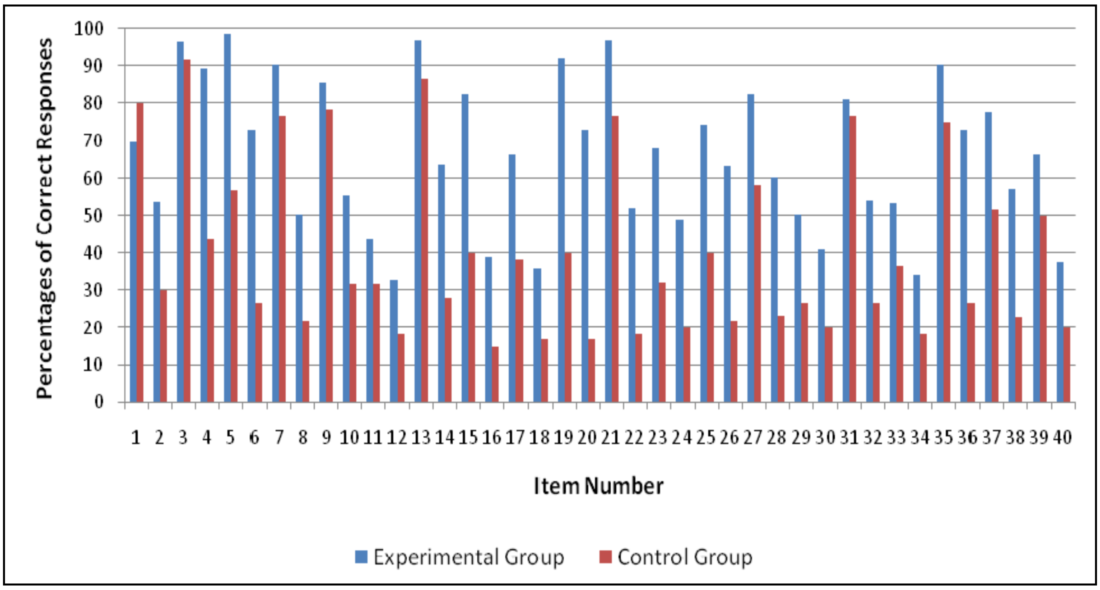

Figure 4.5 Comparison of the percentages of students' correct responses on post-CCMCT across experimental and control groups

As seen in Figure 4.5, in the first tier items, the proportion of students' correct responses were higher than their second tier items, in favor of experimental group. In the second tier items, some students in both groups had partial understanding, some had no understanding, and some held some misconceptions when they were explaining the reason of their choice to the multiple-choice questions given in the first tier items. There were differences in the proportion of misconceptions between experimental and control groups. The proportion of misconceptions held by students in control groups was higher than that of in the experimental groups in most of the items.

Related to chemical changes, the students were asked the type of change (physical or chemical?) when a candle burns and then they were asked to make an explanation regarding their choice, in item 1 and item 2, respectively. At the beginning of the treatment, 48% of students in the experimental group and 50% of those in control group thought that ‘if a candle burns, physical change occurs’. After the treatment, the percentages of students who answered this item correctly increased from 52% to 72% in the experimental group and from 50% to 75% in the control group. In the explanation part of this question, the proportion of misconceptions held by the students in the experimental group decreased from 55% to 14%. However, the proportion of misconceptions held by the students in the control group decreased from 58% to 30%. It did not decrease as much as in the experimental group. The common misconceptions observed in both groups were ‘If a candle burns, it melts and that is a physical change’, ‘If a candle burns, physical change occurs because it is reversible’, ‘If a candle burns, physical change occurs because it is an example of state change’, ‘If a candle burns, there is a physical change because the candle melts and takes another shape’, and ‘There is a physical change because candle can be reused after it burns’.

The students were asked the type of change occurring, when a teaspoon of salt is added to a glass of water and then explain their reason, in item 5 and item 6, respectively. 92% of the students in the experimental group answered this item correctly as ‘physical change’, but the percentage of students answering this item correctly was 57% in the control group. When explaining their reason, some students showed misconceptions (7% in the experimental group, 32% in the control group). They thought that ‘it is a physical change because the salt melts in water’, ‘It is a chemical change, because we cannot obtain salt again', and ''Salt dissolves in water, so that's a chemical change'.

In an item related to chemical change (item 9), the students were asked the type of change when a silver ring tarnishes. At the beginning of the treatment, 65% of the students in the experimental group and 48% of the students in the control group incorrectly thought that 'if a silver ring tarnishes, physical change occurs', but at the end of the treatment, these percentages decreased from 65% to 14% in the experimental group, and from 48% to 22% in the control group. Moreover, some students showed misconceptions when they were explaining their reason for item 9. The misconceptions held by students in the experimental (11%) and control groups (23%) were: If a silver ring tarnishes, there is a physical change because a) it occurs at the outer part of the silver ring; b) the ring is still silver even if it tarnishes, and c) we can get rid of the tarnish of the silver ring.

Like item 9, the students were asked the type of change when a nail rusts in item 13. After the treatment, 97% of the students in the experimental group and 86% of the students in the control group correctly responded to this question. At the beginning of the treatment, they were 65% and 72% in experimental and control groups, respectively. The proportions of students' correct responses to this item were closer to each other across groups. The students were also asked to explain their reason for item 13. After the treatment, some students in experimental (5%) and control groups (12%) showed misconceptions in their explanations in item 14. They thought that 'It is a chemical change because it is irreversible', 'It is a physical process because only the nail's outer part rusts', and 'It is a physical change because we can clean the rust with a sandpaper'.

Related to rusting of a nail, in item 15, the students were asked how the weight changes when a nail rusts. Before the treatment, 43% of the students in the experimental group and 38% of those in the control group answered this item correctly as 'If a nail rusts, its weight increases'. After the treatment, the percentages of students having correct response to this item increased from 43% to 82% in the experimental group but in the control group it only increased from 38% to 45%. In addition, there were differences in the proportion of alternative conceptions held by students in the experimental and control groups. 8% of students in the experimental group and 25% of them in the control group thought that ‘If a nail rusts, its weight decreases’ and they explained their reason as ‘because the nail decays’. In addition, the students (10% from experimental group and 30% from control group) who thought that ‘If a nail rusts, its weight does not change’, explained their reason with the law of conservation of mass. Even some students thought that ‘If a nail rusts, its weight increases’, they could not explain the reason scientifically. That is, they thought that ‘Rust is something that is not related to the nail and it covers the outer part of the nail, so it increases the weight of the nail’.

Item 17 was also related to rusting of a nail, and the students were asked to select the correct one from the given alternatives. After the treatment, 66% of the students in the experimental group and 38% of the students in the control group selected the correct alternative that ‘If the rust of a nail is cleaned, its weight decreases’. On the other hand, even after the treatment, some students (11% from experimental group and 22% from control group) incorrectly believed that ‘Cold causes rusting’, and some (25% from experimental group and 37% from control group) incorrectly thought that ‘The element, iron, changes into different elements during rusting’.

Related to mixtures, students were asked a question about the appearance of the mixtures in item 21. After the treatment, 97% of the students in the experimental group and 77% of those in the control group correctly responded to this question as ‘Mixtures could be homogeneous or heterogeneous’. At the beginning, these percentages were 65% and 63% in the experimental and control groups, respectively. Some students in the control group (13%) could not give examples of homogeneous and heterogeneous mixtures properly. For example, some thought that salt in water is an example of heterogeneous mixture.

In item 23, the students were given alternatives about the structure of mixtures, and then asked to select the correct one. After the treatment, the proportion of the correct alternative ‘Every mixture contains two or more substances’ held by the students were 68% and 32% in experimental and control groups, respectively. The alternative conceptions detected in both groups were: a) Every mixture contains two or more free elements (8% from experimental group and 35% from control group), b) Every mixture contains two or more compounds (3% of the students in the experimental group and 18% of those in the control group), c) Every mixture contains only two different substances (5% of the students in the experimental group and 13% of those in the control group), and d) Every mixture contains only one kind of substance (2% of the students in the experimental group and 7% of those in the control group).

In item 25, students were asked a question about the ice-water. The percentages of students who answered to this item correctly as ‘Ice-water is heterogeneous, but not a mixture’ were 74% in the experimental group, and 40% in the control group, at the end of the treatment. On the other hand, some students in both groups held these alternative conceptions: a) Ice-water is a homogeneous mixture (11% from experimental group and 25% from control group). These students thought that ice melts in water, then it becomes a homogeneous mixture; b) Ice-water is a heterogeneous mixture (15% from experimental group and 35% from control group). These students thought that it is a homogeneous mixture because ice does not dissolve in water.

In item 27, the students were asked what could be the mass of the solution when 1 g salt and 20 g water were mixed together. After the treatment, 82% of the students in the experimental group, and 58% of those in the control group correctly responded to this item as 21 g. On the other hand, many students in the control group (27%) incorrectly believed that ‘The mass is less than 21 g because the salt disappears in water’. The percentage of students in the experimental group having this misconception was only 7%.

In item 29, the students were given the following drawings (see Figure 4.6) and then asked which drawings could belong to a mixture.

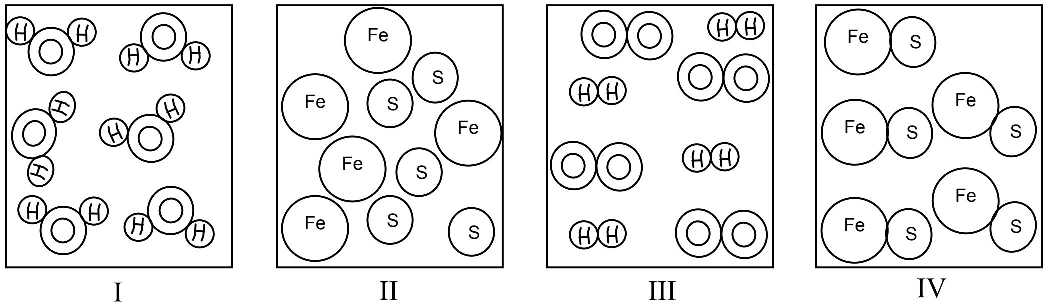

Figure 4.6 The drawings given in 29th item of the CCMCT

At the end of the treatment, the students who could identify the mixtures from the given drawings correctly as II and III were 50% in experimental group, and 27% in the control group. Before the treatment, the percentages were 27% in the experimental group, and 20% in the control group. Some students (20% from experimental group, and 22% from control group) incorrectly thought that the drawings I and IV were mixtures. Some of them explained their reason as ‘Drawings I and IV are mixtures, the other drawings are elements’; and some thought that ‘Drawings I and IV are mixtures because there should be two different elements in order to be a mixture’.

In item 37, the students were asked what happens to the sugar, when it is put into a glass of water. The common misconception observed in both groups was ‘Melting and dissolving are the same’. Students used the terms melting and dissolving interchangeably. They thought that ‘Sugar melts, dissolves and disappears in the water’. At the beginning of the treatment, the proportion of students having this misconception was 55% in the experimental group, and 53% in the control group. At the end of the treatment, the students having this misconception were 22% in experimental group and 43% in the control group.

In the last two items (item 39 and item 40), the students were asked the state of the solutions. After the treatment, the percentages of students who answered this item correctly as ‘Solutions could be in the form of solids, liquids, or gases’ were 66% in the experimental group and 50% in the control group. The alternative conceptions observed in both groups were: a) All solutions are in the form of liquid (16% from experimental group and 22% from control group). These students thought that only the liquids could be a solvent; b) Solutions could be in the form of either liquid or gases (10% from experimental group, and 11% from control group). These students thought that solids cannot be dissolved among each other; and c) Solutions could be in the form of either liquid or solid (8% from experimental group, and 17% from control group). These students thought that gases cannot be dissolved, and there is not any gases solvent.

4.3 Analyses of Students' Responses to the Interview Questions

In this study, interviews were conducted with 23 ninth grade students from both experimental and control groups. The purpose of interviews was to obtain detailed information about students' reasoning of chemical change and mixture concepts. Thirteen students from experimental group and eight students from control group were selected voluntarily. The students were a mixture of high-, medium-, and low-achievers in both groups. In the experimental group, out of thirteen students four students were from high-achievers, five students were from medium-achievers, and four students were from low-achievers. In the control group, out of eight students, two students were from high-achievers, three students were from medium achievers, and three students were from low-achievers. Interview results indicated that students in SWH groups had more scientific understanding of chemistry concepts compared to those in control groups. The interviews helped to clarify students' misconceptions observed in chemical change and mixture concept test (CCMCT). Students' responses to the interview questions were coded and then these codes were categorized into three themes: definition of the concepts, examples of the concepts, and relationship among the concepts. The distributions of the number (percentages) of the students in both groups across codes were given in Table 4.19, and each category was explained in below:

Table 4.19 The distribution of the number (percentages) of students in experimental and control groups across the codes identified from interviews (NA: No answer, M: Misconception, PC: Partially correct, C: Correct)

	Experimental Group				Control Group			
	NA	M	PC	C	NA	M	PC	C
Definition of the concepts								
- Definition of physical change	0 (0%)	0 (0%)	3 (23%)	10 (77%)	0 (0%)	0 (0%)	4 (50%)	4 (50%)
- Definition of chemical change	0 (0%)	0 (0%)	2 (15%)	11 (85%)	1 (12%)	2 (25%)	1 (12%)	4 (50%)
- Definition of mixture	0 (0%)	0 (0%)	4 (31%)	9 (69%)	1 (12%)	2 (25%)	4 (50%)	2 (25%)
- Definition of solution	0 (0%)	1 (8%)	8 (61%)	4 (31%)	0 (0%)	3 (37%)	5 (62%)	0 (0%)
Examples of the concepts								
- Examples of physical change	1 (8%)	0 (0%)	0 (0%)	12 (92%)	1 (12%)	2 (25%)	0 (0%)	5 (62%)
- Examples of chemical change	0 (0%)	0 (0%)	0 (0%)	13 (100%)	0 (0%)	0 (0%)	0 (0%)	8 (100%)
- Examples of mixtures	0 (0%)	1 (8%)	0 (0%)	12 (92%)	0 (0%)	0 (0%)	0 (0%)	8 (100%)
- Examples of solution	2 (15%)	4 (31%)	3 (23%)	4 (31%)	0 (0%)	4 (50%)	2 (25%)	2 (25%)
Relationship among the concepts								
- Physical and chemical change	0 (0%)	6 (46%)	3 (23%)	4 (31%)	0 (0%)	6 (75%)	1 (12%)	1 (12%)
- Rusting and - weight	1 (8%)	5 (38%)	3 (23%)	4 (31%)	1 (12%)	5 (62%)	1 (12%)	1 (12%)
- Mixture and solution	1 (8%)	0 (0%)	0 (0%)	12 (92%)	2 (25%)	2 (25%)	0 (0%)	3 (37%)
- Solubility and pressure	0 (0%)	1 (8%)	4 (31%)	8 (61%)	0 (0%)	1 (12%)	6 (75%)	1 (12%)
- Solubility and temperature	1 (8%)	3 (23%)	6 (46%)	3 (23%)	0 (0%)	4 (50%)	3 (37%)	1 (12%)
- Dissolving, melting and disappearance	0 (0%)	2 (15%)	3 (23%)	8 (61%)	0 (0%)	5 (62%)	1 (12%)	2 (25%)

4.3.1 Definition of the Concepts

The students in both experimental and control groups were asked the definitions of physical and chemical changes, mixture, and solution. Most of the students in the experimental group and a few students in the control group could define these terms scientifically. Some students in both groups defined these terms partially correctly. Some students in the control group and a student in the experimental group could not make any definition, and some in control group defined them incorrectly.

Related to the definition of physical change, most of the students in the experimental group (ten students) defined it correctly but some (three students) defined it partially correctly. For example, a student in the experimental group defined it correctly as "A change in the physical properties of matter without a change in its chemical properties", and a student defined it partially correctly as "A change in matter without a change in its properties". The second one is partially correct because in a physical change, the matter's physical properties changes but chemical properties do not.

On the other hand, in the control group, some students defined it correctly (four students), and some defined it partially correctly (four students). For example, a student in the control group defined it correctly as "A change in a matter without a change in its atoms". Some students defined physical change partially correctly as "A change in the shape of a matter" or "A change in the state of a matter".

About the concept of chemical change, there were correct definitions in both experimental (eleven students) and control (four students) groups. For example, a student in experimental group and a student in the control group defined this term correctly as "A change in the chemical properties of a matter". There were also some partially correct definitions in both experimental (two students) and control (one student) groups. For example, a student in the experimental group defined it as "A change from one matter to another matter", and a student in the control group defined it as "Formation of a new matter by losing its own properties". These students' definitions were partially correct, because they were not clear. Some students in the control group could not define this term (one student) and some defined it incorrectly (two students). For example, a student in the control group defined chemical change as “It is the decaying or molding of a matter without losing its properties”. This definition is incorrect because in a chemical change chemical properties of matter changes.

Related to the definition of the mixture, nine students from experimental group and two students from control group could define the mixture correctly. For example, a student in the experimental group defined it as “The process of mixing two or more than two substances without any constant proportion” and a student in the control group defined it as “The process of mixing two or more than two substances without losing their own characteristics”. Some students in the experimental (four students) and control (four students) groups defined this term partially correctly. For example, a student in experimental group defined it as “The process of mixing a few pure substances without losing their own characteristic” and a student in the control group defined it as “The process of mixing two substances”. Two students in the control group defined this term incorrectly. For example, a student stated that “The process of mixing two elements”. A student in the control group could not make any definition of mixture.

Students in both groups had a difficulty in defining the term ‘solution’. Only four students in the experimental group could define the solution correctly but none of the students in the control group could make a correct definition. For example, a student in the experimental group defined it correctly as “A homogeneous mixture of two or more substances”. On the other hand, eight students in the experimental group and five students in the control group defined solution partially correct. For example, a student in the experimental group defined it as “Dissolution of two substances in each other” and a student in the control group defined it as “A matter which forms through the combination of a solvent and a solute”. One student from experimental group and three students in control group made incorrect definitions of the solution as dissolution of a solid matter in a liquid matter.

4.3.2 Examples of the Concepts

The students in both groups were asked the examples of the concepts of 'physical change', 'chemical change', 'mixture' and solution'. Related to the physical change, students in both groups gave similar examples, like cutting paper into pieces, and state changes as melting of an ice and a candle. One student from experimental group and one student from control group could not give an example to the physical change. In the control group, two students gave 'spoiling of yoghurt' and 'burning of candle' as examples to the physical change incorrectly. In addition, most of the students in the experimental and control groups stated that burning, tarnishing, and rusting processes were examples of chemical changes. Only one student from experimental group stated that 'obtaining yoghurt from milk' and a student from control group stated that "milk souring" as examples of chemical changes different from their peers.

When students asked the examples of mixtures, most of the students in the experimental and control groups stated 'salt-water' and 'sugar-water' as examples of mixtures. A student in the experimental group wrongly stated that ice water was an example of mixture. Only one student in the experimental group stated that spray was a kind of mixture. All other examples given by the students in both groups except the example 'spray' were the mixtures in which water and solid were used. The students were also asked to give examples of solutions. Most of the examples of solutions were in the form of liquid. The most common ones were 'salt-water' and 'sugar-water'. Some students in both groups stated that alloys as an example of solid solutions, and air as an example of gaseous solutions. Some students in both groups could not give examples of solid and gaseous solutions although they stated there could be solid and gaseous solutions. Some students in the both groups believed that all solutions are in the form of liquid. For example, a student wrongly claimed, "There should be a liquid as a solvent in a solution because solids and liquids cannot be a solvent".

4.3.3 Relationship among the Concepts

The students were asked the type of change in the processes of 'burning of a candle', 'tarnishing of a silver ring', 'rusting of a nail' and 'dissolving of sugar in water' in the semi-structured interviews. These questions were also asked in CCMCT. In order to support the findings obtained from CCMCT, these questions were also asked in the interviews. Related to 'burning of a candle', all the students in the experimental group except one, stated that it was a chemical change. The students who thought that it was a chemical change justified their views by stating that "It is an irreversible process", "All burning processes are an example of chemical change", and "Its chemical properties changes". On the other hand, three students in the control group stated that it was a chemical change and out of these three students only one of them could explain the reason of their idea as "In the burning process, there is a chemical reaction with oxygen". In the control group, one student incorrectly claimed that 'burning of a candle' was a physical change. She explained her reason as "When the candle burns, it melts, and only its shape changes, its chemical formula does not change. For this reason, it is a kind of physical change". The other students held mixed views regarding the burning of candle. Primarily, they thought that the candle melts when it burns. They also thought that all type of burnings were chemical change. For example, one student in the control group stated her mixed view as "There is no chemical change in burning of a candle because only its external appearance changes, I think it is a physical change. In fact, there is a burning process. I think it could be a chemical change because burning processes are given as an example of chemical change, and also in here, there is a burning process but its appearance does not change…"

About the 'tarnishing of a silver ring', five students in the experimental group and two students in the control group incorrectly thought that it was a physical change. All of these students explained their reason with reversibility of the process. For example, a student in the experimental group incorrectly believed that "It is physical because we can make the silver ring shiny again by immersing the tarnished silver in a special liquid". The other eight students in the experimental group scientifically explained the reason. For example, a student stated, "It is a chemical change because there is a chemical reaction, the silver and air goes to the reaction, for this reason it tarnishes". On the other hand, in the control group, five students could not explain why they thought that it was a chemical change. For example, one student in the control group stated, "It is a chemical change. I do not know the reason, I remembered like that based on my memorizations".

The students were also asked the type of change in the rusting process. Almost all of the students in both groups stated that there was a chemical change in rusting of a metal nail. However, experimental group students' explanations were more scientific than control group students' explanations. Almost all of the students explained the reason scientifically correct in the experimental group. For example, a student stated that "It is a chemical change because iron in the nail reacts with oxygen and iron-oxide forms". On the other, only a few students in the control group explained the reason scientifically correct. Most of them explained the reason partially correct. For example, one of them stated, "It is a chemical change because it looks like the process of tarnishing of silver, and rusting processes are chemical". One of the students in the control group incorrectly thought, "There is only a color change in rusting of a metal nail, the metal nail does not lose its properties".

Related to rusting of a metal nail, the students were also asked whether the weight of a metal nail changes when it rusts, and when its rust on it is removed compared to its original (not rusted) status. As seen in Table 4.20, there were some students in both groups holding misconceptions about the reaction between rusting and weight. The misconceptions detected based on students' explanations were "If a metal nail rusts, its weight decreases because it loses its hardness", "If a metal nail rusts, its weight does no change because, there is not any external effect on rusting, it occurs within the structure of the matter", "If a metal nail rusts, its weight does not change because of the law of conservation of matter", "If a metal nail rusts, its weight decreases because the rust is more lighter", "If a metal nail rusts, its weight decreases because its strength decreases and the distance between the molecules increases", "If a metal nail rusts, its weight does not change because some iron metal goes away, and the rust comes in lieu of that iron, the weight of them are the same, so there is no change in weight", "If the rust of a metal nail is removed, its original weight does not change because it is a metal nail, again", and "If the rust of a metal nail is removed, its original weight does not change because when the rust is removed it returns to its original form". In addition, some students in both groups could not make scientific explanations although they stated that "If a metal nail rusts, its weight increases". Generally, the students incorrectly thought that rust is a something that they don't know, it comes from outside onto the metal nail, and this makes an extra weight to the metal nail. On the other, there were some students having scientific conceptions. For example, a student in experimental group stated her scientific views as "If a metal nail rusts, its weight increases because it reacts with oxygen and iron oxide forms. If we remove the rust, some of the iron goes away from the metal nail, so its original weight decreases".

Table 4.20 Students' conceptions about relation between rusting and weight

	Increases		Decreases		does not change		do not know	
	EG	CG	EG	CG	EG	CG	EG	CG
Does the weight of a metal nail change when it rusts?	9	5	1	2	3	1	0	0
Does the original weight of a metal nail change, when its rust on it is removed?	0	0	8	4	4	3	1	1

The students were also asked the relation between mixture and solution. Some students in experimental (one student) and control groups (two students) could not make any relation between these two concepts. Two students in the control groups held the misconceptions, "All the mixtures are not solutions because a solution always includes water in it", and "A solution is something in which melting occurs. I think, acetone is a solution because it removes polish away from the nail. Acetone dissolves the nail polish in it, but it is not a mixture". The other students correctly related solutions with mixtures by stating that all solutions are mixtures but not all mixtures are solutions.

Related to the effect of pressure on the solubility of gases in liquids, the students were asked 'How does the dissolved amount of carbon dioxide changes when the lid of the soda-water is opened?' In the experimental group, one student incorrectly thought that "Dissolved amount of carbon dioxide does not change when the lid of the soda-water is opened because the dissolved amount of the substance is constant in a certain soda-water", and one student in the control group incorrectly stated that "The liquid carbon dioxide transforms into gaseous carbon dioxide when the lid of the soda-water is opened". There were some students in both experimental (four students) and control (six students) groups who could not explain properly why they thought that the dissolved amount of carbon dioxide decreases when the lid of the soda-water is opened. The percentage of students who correctly related the decrease in the dissolved amount of carbon dioxide in soda water when its lid is opened to the pressure change was higher in experimental group (61%) than in control group (12%).

The students in both groups had a difficulty in interpreting the effect of temperature on the dissolved amount of gases in liquids. The students were asked to answer the question 'How does the dissolved amount of carbon dioxide changes when the soda-water is put into the refrigerator?' One student in experimental group could not give an answer to this question. In the experimental group, three students thought that dissolved amount of carbon dioxide do not change when the soda water is put into the refrigerator because its lid is not opened and the refrigerator's function is only keeping it cold. However, compared to experimental group (23%), the proportion of students' misconceptions was higher in the control group (50%). For example, a student in control group wrongly stated, "Dissolved amount of carbon dioxide does not change when the soda-water is put into the refrigerator because its lid is closed". A different student stated his view as "Dissolved amount of carbon dioxide does not change when the soda water is put into the refrigerator because the refrigerator keeps the dissolved amount of carbon dioxide constant". In addition, some of them claimed that dissolved amount of carbon dioxide increases when the soda water is put into the refrigerator, but they could not justify their claims. They incorrectly explained their reason by stating that "In the refrigerator, the pressure increases, for this reason, the dissolved amount of carbon dioxide in soda-water increases". Three students in experimental and a student in control group could correctly explain the effect of temperature on the solubility of carbon dioxide in water.

The students were asked what happens when a piece of sugar is put into the water, and then they were asked the type of change occurring in this phenomenon. All the students in experimental group (13 students) correctly stated that when a piece of sugar is put into the water, there is a physical change. However, three of the interviewed students in control group stated that phenomenon was a chemical change. One of them incorrectly explained her view as "A new substance (sugar-water) forms when sugar is put into the water". A student in control group was in transition between physical and chemical change when interpreting the given phenomenon. He incorrectly believed that anyone cannot get sugar again from a sugar-water. In addition, students were asked what happened to the sugar when it is put into the water. A student in experimental group and three students in control group used dissolving and melting interchangeably when interpreting what happened to the sugar when it is put into the water. For example, a student stated, "Sugar melts in water", and then the interviewer asked that "Does it melt?", then the same student stated, "It melts, that is, it dissolves". A student in experimental and two students in control group used dissolving and disappearance interchangeably when interpreting the given phenomenon, although they believed that there is sugar in the solution.

Interview results revealed that students in experimental (46%) and control (75%) groups had a difficulty in distinguishing between physical and chemical changes. In addition, some students in control group had a difficulty in defining mixture and solution. Some students in both groups had a difficulty in understanding and giving the examples of gaseous and solid solutions. Some students in both groups also had a difficulty in explaining the weight change in rusting process. There were some students could not making any relation between solubility of gases in liquids and pressure and temperature. Moreover, some students in both groups used dissolving with melting and disappearance interchangeably. Although there were some knowledge gaps and misunderstandings of the students in both groups, the proportion of those students in experimental group were less than that of in control group. To sum up, it was found that the misconceptions observed in the interviews were consistent with those detected as a result of CCMCT. That is, interview results verified the results of the CCMCT.

4.4 Students' Ideas about the SWH Approach

At the end of the treatment, 13 students from the experimental group were participated in semi-structured interviews. The purpose was to elicit their ideas about the implementation of SWH. Students' responses to the interview questions were coded and categorized into three dimensions namely, 'comparison of the SWH and traditional classes', 'changes in students', and 'general ideas'. The distributions of the number (percentages) of the students in both groups across codes were given in Table 4.21, and each dimension was explained separately in below:

Table 4.21 The distribution of the number (percentages) of students in experimental group across the codes identified from interviews

Codes	Number of students (Percentages)
Comparison of the SWH and traditional classes	
- Activities (Experiment)	13 (100%)
- Student participation	12 (92%)
- Group activities	11 (85%)
- Writing activities	9 (69%)
- Preference of approach	SWH (10 - 77%), both SWH and Traditional (3- 23%)

Table 4.21 The distribution of the number (percentages) of students in experimental group across the codes identified from interviews (continued)

Changes in students	
- Talking much	10 (77%)
- Learning better	13 (100%)
- Being responsible on their own learning	7 (54%)
- Involvement in activities to a greater extent	9 (69%)
- Getting higher grades	4 (31%)
- Willing to learn	10 (77%)
- Great interest in open-ended activities	5 (38%)
- Excitement in activities	12 (92%)
- Increased self-efficacy	11 (85%)
- Learning by doing	13 (100%)
- Better social skills	8 (61%)
General ideas	
- Suggestions	
· more SWH activities (experiments)	13 (100%)
· more discussion of the concepts	3 (23%)
· more daily life examples	3 (23%)
· consideration of University Student Selection	1 (8%)
- Problems	
· Noise	3 (23%)

4.4.1 Comparison of the SWH and Traditional Classes

All the students compared SWH classes with their previous traditional chemistry classes. Based on the students' responses, these codes were obtained: 'activities (experiments)' (100%), 'student participation' (92%), 'group activities' (85%), 'writing activities' (69%), and 'preference of approach'.

The experiments embedded in SWH classes were the main difference according to all students. Although, the school studied in this research had a well-equipped chemistry laboratory, the students were not using it in their classes. Some students stated that they did not use the laboratory and made a science experiment even when they were at primary level because of lack of the laboratory at that time. For example, one of the students stated, “In this semester, we had chemistry classes in the laboratory, but in the previous semester we had classes theoretically in the classroom”. Another student expressed his views as “It was the first time for me doing experiments in classes”.

Another thing viewed by the students different in SWH classes was the participation of the students. Generally, the students stated that in the previous semester, at first, teacher was explaining the concepts and then they were taking notes in the classroom, there were not any activity; but in this semester, they stated that they did experiments, observations, discussions, and briefly, they learnt by doing. For example, a student stated, “In the previous semester, only the teacher was talking in the classes, we were listening, and solving problems, but in this semester we participated in classes”. A different student expressed her views about students’ participation in classes as “In this semester, we talked, discussed, and did experiments. We presented our claims and evidences”.

All the students agreed upon the idea that group and whole-class discussions were helpful in their learning, and thinking. For example, a student stated, “We changed our ideas through discussion”, and another student stated, “My peers were thinking different than me, I was also taking into consideration their views, so I started to think about the things from different perspectives”. Some students stated that group activities increased their friendship, participation in classes, and social skills like working together.

Students also compared the writing activities in two semesters. They stated that writing was a part of their classes both in two semesters but the writing activities were different. They all stated that they were taking notes in the previous semester, but in this semester, they wrote laboratory reports, which increased their knowledge retention. For example, one of the students stated, “At first semester, the teacher was saying and we were writing, and I was not learning but in this semester I wrote by myself, I learnt more”. Another student stated, “In this semester, I was aware of my own learning through writing laboratory report". A different student expressed that "In the previous semester, it was boring when I was writing but in this semester it was enjoyable".

Moreover, students mentioned about the advantages of determining their own questions for their investigations. For example, one of the students stated, "We thought about what we do not know and want to know about the topic before we prepare our questions, as a group". They also mentioned about advantages of constructing claims and evidences. A student expressed his ideas as "Claims and evidences helped us to convince our peers".

After students compared SWH and traditional classes, they were asked which one they would prefer. Most of the students (77%) preferred to have SWH classes rather than traditional classes. They supported their views by providing some reasons like learning better in SWH classes, getting high grades, involvement in activities, retention of knowledge, and enjoyable. Three students (23%) preferred to have both SWH and traditional classes because they thought that if they had all chemistry classes by using SWH approach, they could not cover chemistry curriculum, which was important for their success at University Student Selection Examination.

4.4.2 Changes in Students

Students were aware of the effect of implementation of SWH approach on themselves. They stated some differences when they compared them in two semesters. Generally, the students described the perceived changes as 'learning better' (100%), 'talking much' (77%), 'being responsible on their own learning' (54%), 'involvement in activities to a greater extent' (69%), 'getting higher grades' (31%), 'willing to learn' (77%), 'great interest in open-ended activities' (38%), 'excitement in activities' (92%), 'increased self-efficacy' (85%), 'learning by doing' (100%), and 'better social skills' (61%).

All the students stated that they learnt better using SWH approach. For example, a student stated "I did not like chemistry classes in the previous semester because I was not learning, because I did not like it, I was not successful in chemistry classes; but in this semester I learnt better, realized that chemistry classes were funny, and started to like chemistry classes which resulted in higher grades in chemistry". There were some students focusing on their talk during the instruction. For example, a student stated, "In the previous semester, generally I was memorizing, and I was talking based on memorization; but this semester I could add my own knowledge when I was talking", and another student stated, "I talked more in this semester".

Some of the students stated that they were aware of the fact that their learning was under their control because they were determining their own questions for their investigations and designing the testing procedure. 69% of the students found them very active during the learning process because they stated they actively contributed to the all the classroom activities. 38% of the students showed a great interest in open-ended activities. For example, a student stated his view as "When I came to each SWH class, I was very curious about which group will investigate what question and what each group will find as a result of laboratory investigation…because we were conducting experiments that were not included in our textbooks, and we were not knowing the results of those experiments in advance…Therefore I was willing to learn". In addition, most of the students (92%) claimed that the activities provided in SWH classes were funny and there were great excitement in the activities.

Some students believed that their self-efficacy increased through the implementation of SWH. For example, a student stated, "I was not thinking that I can do an experiment by my own in the laboratory. It was an idea that was impossible for me because I was thinking that doing an experiment was not attainable goal for me but through the SWH activities, I realized that I can do experiments and I further conceptualized that if a person learns something, s/he can do it". A different student stated the increase in his self-efficacy as "At the beginning of the implementation of SWH approach, my self-efficacy was low because I was getting excited when I start to talk in front of my peers…Doing experiments increased my self-efficacy…I was an introversive person before having the SWH classes…" 61% of the students agreed upon the idea that group activities increased their social skills, like sharing their information with their peers, being open to criticism, expressing themselves properly, and having different point of view.

Moreover, all the students stated that some of their conceptions changed during the implementation. When they were asked to exemplify this situation, some could not do it. For example, a student stated, “At the beginning, I was thinking that milk is homogeneous but then I learnt that it was heterogeneous”. Another student stated, “At first, I was thinking that the color of the litmus-paper does not change in a mixture of acid and bases, but then I learn that the color of the litmus-paper does not change in a neutral solution”.

4.4.3 General Ideas

The students were asked whether they have suggestions for their improved learning of chemistry concepts and the problems encountered in the SWH classes. All the students suggested that SWH activities could be done for better learning in the following semesters. In addition, some of them thought that ‘discussion of the concepts’ and ‘giving daily life examples’ could be done more in order to support learning. However, a student made such a different suggestion, “I think it is better to have chemistry classes considering the University Student Selection Exam (OSS)”. Moreover, some students stated that they had some problems during the implementation. For example, a student stated, “We were talking in front of the classroom but some students were not listening to us, I think that was a problem”.

In summary, students stated laboratory experiments, group work, and writing style as the main differences between SWH and traditional approach. The students found them more active in chemistry classes compared to their previous semester chemistry classes. All the interviewed students enjoyed the activities done in SWH approach and claimed that they understood the chemistry concepts in SWH classes more than in traditional classes. Generally, they preferred to have chemistry classes in

SWH format. It can be concluded that SWH approach also affected students' attitudes toward chemistry positively.

4.5 Classroom Observation Results

This study was conducted over a ten-week period in a public high school. The researcher attended all the class sessions of experimental and control groups. The main aim of the classroom observation was to describe the implementations of SWH and traditional approaches in experimental and control groups, respectively. The roles of the teacher and students, the classroom activities and the interactions among students, and between teacher and students were examined in order to provide treatment verification. The researcher acted as a non-participant observer most of the time by filling out the classroom observation checklist described in Chapter 3 and taking field notes during the teachers' implementation of the SWH and traditional approaches. The researcher helped to the teacher in both groups during the laboratory activities only in distributing the chemicals and materials for the laboratory investigations. Based on the analyses of the data obtained through field notes and classroom observation checklist, the following interpretations were done for the implementations in each group.

There were two experimental and two control groups, and two teachers. Each teacher taught one experimental group and one control group. In these groups, the topics related to chemical changes and mixtures were covered as a part of regular classroom curriculum in chemistry courses. In the experimental groups, students were instructed by using SWH approach. It was the first time for the teachers implementing this approach, so they were inexperienced about SWH. The researcher met with the teachers before the class time and shared what they were going to do at that class. The teachers were not using laboratory before this investigation. They forgot the materials used in chemistry laboratory, and to do an experiment. For this reason, they hesitated to have classes in the laboratory at the beginning. Because SWH approach requires students' investigations, it was a better choice to have classes in the laboratory. The laboratory condition of that school was very good. It was also appropriate for the group work. As time went on, the teachers used to have classes at the laboratory. There were also problems in terms of the students. Students were not used to have classes in the laboratory. Some students did not use the laboratory even in their primary school period. At the beginning, they viewed going to the laboratory as a field trip, and some students made noise. As time passed, the students were also used to have classes at the laboratory, and the noise decreased in the class.

In the first SWH class session, students were asked to form their own groups. In one of the experimental classes, there were three groups with six students and two groups with seven students, and in the other experimental group, there were five groups with six students. Then an activity, not related to chemistry, was done in order to make students understand the concepts of ‘question’, ‘claim’, and ‘evidence’ because SWH was grounded on the structure of question, claim and evidence, and it was important to make students understand these concepts beforehand. This activity was related to a mystery death of a man. The students were given a scenario and they were asked to formulate question, and construct claims and evidences, as a group. This activity gained students’ attention very much. All the students participated in group work, and shared their ideas until they reached consensus on their group’s claim and evidences. After 10 minutes, each group was asked to present their claims and evidence to the other groups. The students shared their claims and evidences with the class. There were discussions among the students and between the teachers and students. The students were trying to convince others, and defending their views. At that time, the teachers guided the discussion and tried to give a chance of talk to all the students. At that time, sometimes all the students were talking at the same time and they were not listening to each other. The teachers exerted effort to make students listen to each other. This activity was very interesting for the students because it was open-ended and all the students were trying to find out one correct answer, and they were asking to the teachers the correct answer. The teachers said that there is not only one correct answer; they explained that it was important to support claim and convince others. At the end of this activity, the teachers discussed with the students about the meaning of claim and evidence. Then, the teachers asked students whether they were willing to have chemistry classes like that class session. All the students said “yes”.

Five laboratory sessions related to physical and chemical change, types of chemical reactions, classification of mixtures, and separation of mixtures were done. For each class session, the teachers started a discussion as a pre-laboratory activity. By this activity, the teachers aimed to elicit students’ prior learning. Then, students were asked to write down what they want to learn about the related topic, and formulate a question that can be answered through a laboratory investigation. After each group determined their own questions, each group was asked to write their questions to the white board. The teachers read these questions and asked students whether these questions were researchable or not. Some revisions were made on some students’ questions. Then, each group started to make a plan about their investigations. At this time, the teachers walked around the groups and talked about the procedure of each group. Then, the students took the materials that they needed by their own but the chemicals were given by the teachers and the researcher. After each group completed their materials and chemicals, they started to conduct their investigations. During the investigations, the teachers walked around the groups and helped the groups. If needed, the researcher helped to the teachers. The students were asked to take notes during the observations, and recorded the data. Upon the completion of the investigations, the students were asked to construct claims and evidences based on their data. They also asked to construct a group claim and evidences, and write them on a paper. As soon as all the groups completed these processes, each group came in front of the classroom and shared their claims and evidences with other groups. The students and the teachers asked questions about this presentation. After all the groups’ presentations, the main concepts for that class session were discussed in detail. The teachers summarized what they aimed for that class session, and what they did. The teachers encouraged students to ask questions if they did not understand something or wanted to learn something. At the end of each session, daily life applications of the concepts were also discussed.

Students filled out most of the part of the laboratory reports in the class hours. They filled out the remaining parts after the class hours, at their home and submitted them in the following week, at the class hour.

On the other hand, there were 29 students in one of the control groups and 31 students in the other control group. The students in the control groups were instructed with traditional approach. The teachers used mostly lecture and sometimes discussion methods. The teachers did not consider students prior learning, they did not ask questions for eliciting students' misunderstandings. Students were required to read the related topic from the textbook used in chemistry course prior to that lesson, but most of them were coming to the class without reading those parts, and some of them were not bringing their textbooks to the class. During the transmission of knowledge, the teachers frequently used the white board to write the chemical formulas, chemical equations, and drew some figures. Then the teachers made students to take notes. Because, the chemistry teachers were preparing their materials for the classes together, their notes and the problems solved in these control groups were the same. The students at the same grade level in that school were also taking the same exams in chemistry course. At the end of the class sessions, algorithmic problems were solved in the control groups. They also wrote the problems on the white board and waited students to make them solve the problems. There were a few students in both of the control groups considering teachers' directions, and participating in classes actively. Most of the students were talking among each other when teacher turned back in order to write something on the white board. The teachers were exerting much effort in order to make them silent.

Some of them were not using notebook and were not taking any notes or writing the problems. These students were copying their friends' notebooks for the exam. The teachers were stating that they would be responsible for the notes taken and problems solved in the classrooms in their exams. They were also stating that the problems that were similar to those problems would be asked in their exams. For this reason, some of the students were trying to understand the problems even when they did not take notes. The teachers were also emphasizing on the participation of students. According to the teachers, participation of students mean, sitting silently in the classroom, taking notes, and trying to solve problems because they were always emphasizing on these criteria in the classroom. In addition, teachers were stating that their participation would affect their oral exam scores. In order to get higher grades, some students were hanging their hands when the teacher asked who wanted to come to the white board to solve the problem. Of these students, some were coming to the white board even they did not understand the topic. The teachers were helping to those students while they were solving problems.

In addition to lecture and discussion methods, sometimes the teachers used laboratory in their instruction. All the students did the same experiments in their textbooks. Students read the procedures of the laboratory experiment prior to the class hour and then the teachers explained the procedures of the experiment before doing the experiment. Then, students as a group conducted the experiments with the help of the teachers. During the laboratory activity, students recorded data and observations. After the completion of the experiment, the teachers asked questions to their students about the experiment, and a discussion environment occurred between the teacher and students. At the end of the class hour, students were asked to write a laboratory report, including purpose, procedure, observations and data, results, and discussion in their notebooks.

Concisely, the observations in two groups revealed that SWH approach was more effective than traditional approach in terms of gaining students' interest in the chemistry topics, and active participation in classes.

4.6 Summary of the Results

Pre-test results revealed that there was a statistically significant mean difference between experimental and control groups with respect to pre-CCMAT and pre-CCMAT scores, in favor of the experimental group. In addition, there were significant differences between low-achieving and high-achieving students on pre-CCMAT and pre-CCMCT scores. There were also significant differences between low-achieving students and medium-achieving students, and medium-achieving and high-achieving students on pre-CCMCT scores. Moreover, there were no significant differences between the groups with respect to their attitudes toward chemistry, and no significant relationships between SES, age, gender, and pre-CCMAT and pre-CCMCT scores. Only between pre-CCMAT and pre-CCMCT was a significant moderate relationship. Therefore, the students in the experimental and control groups were similar at the beginning of the study with respect to these variables, except pre-test scores.

Post-test results demonstrated that there was a significant mean difference between experimental and control groups with respect to post-CCMAT and post-CCMCT scores, in the favor of experimental group when the effects of pre-CCMAT and pre-CCMCT scores were controlled. In addition, significant differences were detected among the low-, medium-, and high-achieving students with respect to these post-test scores, in the favor of experimental group. There were significant differences between low-achieving and medium-achieving, low-achieving and high-achieving students on both pre-CCMAT and pre-CCMCT scores. Moreover, there was a significant interaction effect between treatment and achievement level with respect to post-CCMAT scores but there was no significant interaction effect between group and achievement level with respect to post-CCMCT scores. Low-, medium-, and high-achieving students performed closer to each other on post-CCMAT in the experimental group but in the control group, there were differences among three achievement levels. High-achieving students scored higher than medium-achieving and medium-achieving scored higher than low-achieving students in the control group. However, the difference between high-achieving students in the experimental and control groups was not significant. It was observed that low-achieving students in the experimental group significantly outperformed low-achieving students in the control group with respect to post-CCMAT scores. Likewise, medium-achieving students in the experimental group significantly scored higher than medium-achieving students in the control group did. However, the difference between high-achieving students in the experimental and control groups was not significant. At the beginning of the treatment, there were differences between the achievement levels in both groups but the mean differences among the achievement levels disappeared at the end of the treatment while it still existed in the control group.

Students' responses on each item of post-CCMAT and post-CCMCT were also examined in this study. The proportions of students' correct responses in the experimental group were greater than that of in the experimental group on post-CCMAT. In addition, post-CCMCT results demonstrated that treatment had an effect on elimination of students' misconceptions in both chemical changes and mixtures units. For each item, the proportion of students' correct responses and misconceptions were examined. In the first tier items, the proportions of students' correct responses were higher than their second tier items, in favor of experimental group. In the second tier items, some students in both groups had partial understanding, some had no understanding, and some held misconceptions when they were explaining the reason of their choice to the multiple-choice questions given in the first tier items. There were differences in the proportion of misconceptions related to chemical changes and mixtures between experimental and control groups. The proportion of misconceptions held by students in control groups was higher than that of in the experimental groups in most of the items.

Interviews were conducted with 21 students in both groups. The purpose of interviews was to analyze students' reasoning about chemical change and mixture concepts. 13 students from experimental group and 8 students from control group participated in interviews voluntarily. The students were a mixture of high-, medium- and low-achievers in both groups. The results indicated that students in SWH groups had more scientific understanding of chemistry concepts compared to those in control groups. The interviews helped to clarify students' misconceptions observed in post-CCMCT. Students had a difficulty in distinguishing between physical and chemical changes. In addition, they had a difficulty in defining solution, and homogenous and heterogeneous mixture. The students failed to explain the meaning of physical and chemical changes.

13 students from the experimental group were participated in semi-structured interviews. The purpose was to elicit their ideas about the implementation of SWH. The results indicated that a variety of data obtained from the students regarding ‘comparison of the SWH and traditional classes’, ‘changes in students’, and ‘general ideas’. All the interviewed students enjoyed the activities done in SWH approach and expressed that they understood the chemistry concepts in SWH classes more than in traditional classes. They preferred to have chemistry classes in SWH format. The students stated laboratory experiments, group work, and writing style as the main differences between SWH and traditional approach. The students felt them more active in chemistry classes compared to their previous semester chemistry classes. SWH approach also improved students’ attitudes toward chemistry.

The main aim of the classroom observation was to describe the implementations of SWH and traditional approaches in experimental and control groups, respectively. The roles of the teacher and students, the classroom activities and the interactions among students, and between teacher and students were examined in order to provide treatment verification. Classroom observations in two groups revealed that SWH approach was more effective than traditional approach in terms of gaining students’ interest in the chemistry topics, and active participation in classes.

CHAPTER 5

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

5.1 Discussion of the Results

The main purpose of this study was to investigate the comparative effectiveness of SWH and traditional approaches on 9th grade students' understanding of chemistry concepts and chemistry achievement in two consecutive chemistry units on chemical changes and mixtures. In this study, pre-tests assessing students' chemistry achievement and understanding of chemistry concepts in the units of chemical changes and mixtures were administered to the students in both groups for eliciting their prior learning before the instruction. Pre-test analyses indicated that mean scores on pre-CCMAT and pre-CCMCT were higher in the experimental group when compared to control group. The mean scores on pre-CCMAT and CCMCT were 7.73 and 27.71 in the control group, and 9.18 and 28.71 in the experimental group. Considering the minimum and maximum values that can be obtained from pre-CCMAT (min = 0, max = 22) and pre-CCMCT (min = 0, max = 80), the mean scores of pre-CCMAT and pre-CCMCT were generally low in both groups. That means, the level of students' previous knowledge in chemical changes and mixtures was generally low prior to the instruction, but students in the experimental group held more knowledge about the chemical changes and mixtures than those in control group. The significance of the group differences in pre-test scores was tested and it was found that there were significant differences between the students in the experimental and control groups with respect to their understanding of chemistry concepts and chemistry achievement in the units of chemical changes and mixtures before the treatment. Prior learning is very important in construction of knowledge, and it may affect students' further learning positively or negatively. In the literature, prior knowledge was stated as the most influential predictor of science achievement (Gooding et al., 1990; Lawson, 1983) and the degree to which prior knowledge is consistent with the new concepts (subject matter) is an indicator of the improved science learning. In order to partial out the unwanted effects of previous knowledge on post-test scores, students' previous knowledge was controlled in post-test analyses by using MANCOVA. Previous learning in the units of chemical changes and mixtures made a statistically significant contribution to the variation in students' understanding of understanding of chemistry concepts and chemistry achievement measured by the post-tests. The proportion of the variances of students' chemistry achievement and understanding of chemistry concepts measured by the post-tests associated with the previous learning were 8.8%, and, 5.7%, respectively, indicating a medium effect size (Cohen, 1992). In addition, there were significant differences among the low-, medium-, and high-achieving students in both experimental and control group at the beginning of the treatment. High-achievers scored significantly better than low-achievers on both pre-CCMAT and pre-CCMCT. There were differences between low- and medium-achieving, and medium- and high-achieving students with respect to pre-CCMCT.

Affective variables also affect science learning as well as cognitive variables (Oliver & Simpson, 1988; Pinrich et al., 1993). Attitude is one of the important constructs significantly contributing to science achievement and conceptual change (Germann, 1988; Hough & Piper, 1982; Mitchell & Simpson, 1982; Salta & Tzougraki, 2004; Talton & Simpson, 1987). For this reason, students' attitudes toward chemistry were also examined at the beginning of the study. It was found that students had the mean attitude score of 54.65 in the experimental and 53.03 in the control group. Considering the maximum score (75), and minimum score (15) that can be obtained from the attitude scale, these mean scores indicated that students' attitudes toward chemistry were positive but not high at the beginning of the study. In addition, students' mean attitude scores were closer to each other in both groups and this mean difference was not significant. Therefore, it can be concluded that students' attitudes toward chemistry influenced their learning in both groups in the same way.

The potential confounding variables were also taken into consideration at the beginning of the study. Socio-economic status (SES), gender, and age were considered as potential confounding variables for this study. The mean scores of SES were 7.88 in the control group and 7.93 in the experimental group, indicating that the groups' SES mean scores were closer to each other. Considering the maximum (15) and minimum (3) scores that can be obtained for SES variable, these mean scores in both groups indicated that students' socio-economic status were at medium level. The data also indicated that most of the students in both groups were born in 1994, and the proportion of males was higher than that of females in both groups. That means, students' characteristics were almost same in both groups. Moreover, these variables (SES, age and gender) were not interacting with the pre-test scores.

In the post-test analyses, the dependent variables (post-CCMAT and post-CCMCT) were put together using MANCOVA because there was a moderate relationship between these variables ($r = .50$). MANCOVA reduced the error variance by adjusting Type I error (Pallant, 2005). The descriptive statistics revealed that the post-CCMAT and post-CCMCT mean scores of the students in the experimental group were higher than that of in the control group. When the minimum and maximum values that can be obtained from post-CCMAT (min = 0, max = 22) and post-CCMCT (min = 0, max = 80) were considered, the post-CCMAT mean scores were moderate (EG = 13.75, CG = 8.98), but the post-CCMCT mean scores were still low (EG = 36.74, CG = 30.01. However, when these post-test mean scores were compared with corresponding pre-test mean scores, there was a considerable improvement in students' understanding and achievement of the chemical change and mixture concepts. The mean differences between the groups with respect to post-test scores were also tested statistically by controlling the effects of pre-test scores through the use of MANCOVA. The results showed that students instructed by SWH approach scored significantly higher than those instructed by traditional approach on both post-CCMCT and post-CCMAT. The proportions of variances of the achievement in chemical changes and mixtures, and understanding of chemical change and mixture concepts explained by the treatment were 39% and 8%, respectively. The size of the observed group differences in achievement of chemical change and mixture was large while that of in understanding of chemical change and mixture was medium according to Cohen's (1992) criteria. The findings obtained from this study are consistent with the findings of other national and international studies in terms of supporting the idea that SWH approach leads to greater conceptual understanding (Akkus et al., 2007; Keys et al., 1999). When the characteristics of the SWH approach are considered, these findings can be considered as expected outcomes, because inquiry-based activities, writing activities, and small-group and whole-class negotiations were used together in SWH classes and all of them contributed to the student learning. The students were engaged in laboratory investigations through which they sought answer for their own questions. Seeking answer for their own questions was meaningful for the students, which naturally stimulated them to learn. Students actively involved in the learning process and they constructed their own knowledge (Krajcik & Sutherland, 2010). The students were also engaged in small group and whole-class negotiations. Discussion of the concepts in a social context facilitated students' understanding of the concepts. Students became persuaded that the scientifically acceptable new conception was more meaningful. Sharing ideas through the interactions between student-student and teacher-student interactions influenced students' construction of scientific knowledge (Burke et al., 2005; Fellows, 1994b). Students were also engaged in writing activities through the laboratory report writing in SWH format. The students were involved in writing activities before, during, and after the instruction. Before the instruction, students wrote their beginning ideas and their own questions, and the procedure for their investigations. During the instruction, they wrote data and observations based on their experimentation, and wrote claims and evidences based on their data and observations. At the end of the instruction, students read from other sources and compared their interpretations with that of other sources and their peers, and then wrote them on the report. They also wrote their reflections throughout the learning process. The reflection part on the laboratory report format helped students compare their beginning ideas with the ideas that learnt through the classroom activities. These writing activities facilitated construction of new concepts in a scientific way (Driver, 1988; Fellows, 1994b). Moreover, SWH was a good mean of knowledge construction through the integration of the laboratory investigations. Related to this issue, Solsona et al. (2003) argued that many students could not remember the experiments in the classroom. Students had a difficulty in incorporating the information related to the experiments into their explanations about chemical change. The authors further claimed that integration of content of the laboratory work is essential for the students' meaningful construction of scientific knowledge.

Moreover, students' chemistry achievement scores differed on both units with respect to their achievement levels significantly. The results revealed a significant interaction effect between treatment and achievement level indicating that benefiting from SWH approach was related to students' achievement levels. That is, low-achieving and middle-achieving students in experimental groups outperformed low-achieving and middle-achieving students in control groups. It was shown that implementation of SWH approach was effective in closing the gap among the achievement levels. Implementation of SWH approach helped low-achieving students develop conceptual understanding of chemistry concepts. The achievement gap between low-achieving and high-achieving students in the experimental group was disappeared at the end of the study. However, the gap between achievement levels in the control group was still significant at the end of the study. Low-achieving students in experimental groups outperformed low-achieving students in control groups. There is not much study investigating the effect of SWH approach on students' academic performance in relation to achievement levels. Akkus et al. (2007) conducted such a study and found that low-achieving science students benefited most from the implementation of the SWH approach. In this study, similar results were found in a different setting. Students' science performance in relation to achievement level was also investigated by the researchers by using interventions rather than SWH approach. Park, Khan, and Petrina (2009) examined students' science performance with respect to achievement level and found that the lowest achievement group demonstrated most significant improvement in science achievement because of the implementation of computer-assisted instruction. An improvement in student achievement in science significantly influenced their attitudes toward science (Park et al., 2009). The reason why low-achievers benefited from the SWH approach could be explained by the consideration of student prior learning and active involvement in classroom activities. If the teachers ensure that students have the essential prerequisite chemistry knowledge for learning the new information, high- and low-achievers can benefit from the instruction of new concepts equally (Chandran et al., 1987).

Students' responses to both post-CCMCT and post-CCMAT were examined in detail by conducting item analyses. For post-CCMAT, the proportions of students' correct responses were examined. There were differences in the proportions of correct responses between experimental and control groups, in favor of the experimental group. For the post-CCMCT, students' correct responses and misconceptions were investigated in both groups. In both experimental and control groups, students held some misconceptions related to chemical change and mixtures even after the instruction. Prior conceptions were not abandoned by the learner because learning is the restructuring of the ideas (Garnett et al., 1995). In the unit of chemical changes, students could not discriminate between physical and chemical changes. Many students thought that chemical changes were irreversible, while physical changes were reversible (Abraham et al., 1994; Eilks et al., 2007; Gabel, 1999; Gensler & Redlich, 1970; Johnson, 2000a; Palmer & Treagust, 1996; van Driel et al., 1998). However, most of the chemical changes are reversible. For example, when the students were asked the type of change when a silver ring tarnishes, many students claimed that's a physical change because it is easily reversible. Students probably developed this concept because of the teacher's practice in control group. During the classroom observation, it was recognized that the teachers emphasized on the reversibility in the discrimination between physical and chemical change in control groups. The scientific explanation which discriminates chemical change from the physical change as the formation of new substances with different chemical identity was seldom mentioned by the students in control group. The students are expected to be capable of discriminating among the concepts like element, compound, mixture, atom and molecule for a sound understanding of the concepts of chemical change and mixture. In addition, students must understand the interaction between the particles of matter and the arrangement of the atoms in a chemical reaction (Ahtee & Varjola, 1998). The knowledge about particulate nature of matter has a constructive role in the development of the ideas of the chemical change and mixture (Ardac & Akaygun, 2004; Johnson, 2005).

Other common misconceptions were ‘when a candle burns, there is a physical change’, and ‘when a nail rusts, there is a physical change’ (Hesse & Anderson, 1992). The literature also has shown that students have great difficulty in understanding chemical changes and mixtures. For example, students find it difficult to make clear distinctions between physical and chemical changes. In both experimental and control groups, students held some misconceptions related to chemical changes and mixtures even after the instruction. However, the proportion of misconceptions held by students in control groups was higher than that of in the experimental groups. The difference between classroom activities provided in SWH and traditional approaches may cause the difference in students’ acquisition of the scientific conceptions. Teaching for conceptual change requires identification of prior learning, resolution of the conflict between prior understandings and new information, and the application of new concepts into new situations. These steps were embedded in the implementation of SWH approach. In the experimental group, students’ prior conceptions were taken into account, and their misconceptions were activated through discussions in the argument-based inquiry activities. Students were dissatisfied with their existing conceptions through the laboratory investigations. Then, scientific conceptions were negotiated in small group and whole-class discussions. The important part of SWH approach was the social interaction because the scientific concepts were discussed through student-student and student-teacher interaction. These discussions facilitated students' understanding of chemical change and mixtures concepts, and encouraged the involvement of the students in the learning process. On the other hand, in the control group, traditional approach was used in chemistry instruction. The teacher taught the concepts of chemical change and mixture directly without considering students' existing conceptions. According to Pintrich et al. (1993), classroom activities that are designed to be more open-ended and creating student-student and teacher-student interactions facilitates the process of conceptual change, as in the SWH approach. A practical way of fostering conceptual change in science is to provide students with opportunities to experience scientific phenomena through laboratory investigations and to relate scientific conceptions with everyday life. When students operate and manipulate experimental equipment, observe changes, take measurements, negotiate and discuss with peers during laboratory activities, they are actively participating in learning process (Park et al., 2009). The results of this study support the notion that it is not easy to eliminate misconceptions just by employing traditional instructional methods (Canpolat et al., 2006; Pınarbaşı et al., 2006). The current study also revealed that there were still some misconceptions held by a considerable number of students even after instruction. In other words, the conceptions that are not scientific can be transformed into desired conceptions only to some extent with the instruction because they are very resistant to change (Andersson, 1986; Bilgin & Geban, 2006; Canpolat et al., 2006; Çalik et al, 2010; Driver & Easly, 1978; Duit, 2007; Pınarbaşı et al., 2006).

The interviews helped to clarify students' misconceptions in an in-depth manner. It was found that the misconceptions observed in the interviews were consistent with those detected as a result of the concept test. Interview results also revealed that many interviewed students in the control group and some students in the experimental group could not support their ideas scientifically. For example, when the students asked the type of change when a candle burns, they answered in such a way that all burning processes were a type of chemical change. When they were asked for further explanation, most of them failed to explain, they asserted that they were always told that all burning processes were chemical change. These students were engaged in verbatim learning in their previous years, they just memorized without considering the meaning of the concepts or without thinking what was happening at the microscopic level because in traditional classrooms, the teacher aims to teach the content rather than the concepts. If the focus of the teaching becomes content, the expected information from the students becomes more. For this reason, most of the students involve in rote learning in traditional chemistry classes. However, SWH classes focus on acquisition of scientific concepts rather than the content, and big ideas are determined in advance (Ebenezer, 1992). In addition, the examples of physical and chemical changes given by the students were very similar. Students probably developed these examples because the majority of the examples presented in textbooks or practiced in classroom environment have those examples. Generally, the students failed to explain the meaning of physical and chemical changes; they had a difficulty in distinguishing between physical and chemical changes, in defining solution, and homogenous and heterogeneous mixtures.

Personal interviews could be an indicator of student attitude (Koballa & Glynn, 2004). Using the semi-structured interview protocol, students were questioned about their attitudes toward chemistry and implementation of the SWH approach. All the interviewed students enjoyed the activities in SWH classroom and claimed that they understood the chemistry concepts in SWH classes more than in traditional classes. Students were very enthusiastic about being given control over the design of the experiment and planning their own investigations. They preferred to have chemistry classes in SWH format. One of the students stated that ‘I want to have chemistry classes like this semester, because it is more enjoyable, concepts are more understandable, and they are not going to be forgotten easily’. The students stated laboratory experiments, group work, and writing style as the main differences between SWH and traditional approaches. The students found them more active in chemistry classes compared to their previous semester chemistry classes. SWH approach also affected students’ attitudes toward chemistry positively. One of the students mentioned, “I started to like chemistry in this semester”. Students also found the writing portion of the SWH approach very effective in terms of the durability of the chemistry concepts that they learnt. An improvement in students' attitudes toward chemistry and SWH were supported by the previous studies (Gunel et al., 2003, Günel et al., 2010; Erkol et al., 2008, 2010; Kabatas et al., 2008; Rudd II et al., 2001). Students' attitudes toward science can be improved by using effective instruction, including hands-on activities, laboratory activities, inquiry-based activities (Kyle, Bonnstetter, & Gadsden, 1988), and relevance of science to daily life. Science activities that are fun and personally fulfilling have the potential of leading positive attitudes toward science and conceptual understanding (Koballa & Glynn, 2004). An improvement in student achievement in science significantly influences their attitudes toward science (Park et al., 2009).

5.2 Internal Validity

In evaluating the results of an experimental study, consideration of the possible threats to internal validity is an important issue (Frankel & Wallen, 2003). The possible threats to internal validity of this study are, subject characteristics, mortality, location, instrumentation, testing, history, maturation, attitudinal effect, regression, and implementation. Controlling these threats as much as possible increases the possibility of detecting a significant difference between the groups due to the treatment.

The major threat to the internal validity of a quasi-experimental study is subject characteristics threat. In this study, groups, not individuals, were selected, and the individuals were not assigned to the group randomly, which limits the control of subject characteristics threat. Therefore, many subject characteristics (previous knowledge, age, attitude, gender, socio-economic status, etc.) might affect the results of the study. To control this threat, the students' previous achievement and conceptual understanding scores, their attitudes toward chemistry scores, and the data about their socio-economic status, age, and gender, were obtained and assessed at the beginning of the treatment. The experimental and control group students were not differing with respect to attitudes toward chemistry, SES, age and gender prior to the study but there were significant differences between the groups in favor of the experimental group at the beginning of the treatment. For this reason, students' pre-test scores were taken as covariate in conducting the post-test analyses.

Mortality threat, which defined as loss of subject, was handled by carrying out missing data analyses. There were not any loss of subjects during the instruction. There were some absent subjects during the data collection. Missing data analyses were done to limit the effects of this threat.

Location threat occurs when different contexts were used in carrying out the intervention or collecting the data. Because the students were instructed and tests were administered in regular class hours at school, location threat was under control.

There was no change in the nature and scoring procedure of the instruments during the study to eliminate instrument decay threat. The teachers rather than the researcher administered the tests to the students to eliminate the threats that arise from data collector characteristics in regular class hours at school. In addition, data collectors were trained to eliminate data collector bias.

Testing threat occurs when an improvement of the subjects in post-test is observed due to the use of pre-test. In this study, pre-tests were administered to both groups at the same time. Testing threat was controlled by administering the post-test 11 weeks later than the administration of the pre-test. This time range was sufficient for the desensitization. Moreover, because both groups were pre-tested, they were affected in the same way if there was any effect of testing that was not controlled.

History threat occurs when unanticipated or unplanned events affect the responses of subjects. The researchers were continually alert to any such influences that may occur during the implementation of the study in order to control history threat. The researcher was at the school throughout the implementation and data collection processes. There was not any unanticipated or unplanned event affecting the subjects during the course of the study.

Maturation threat occurs when an improvement is observed because of assessing time rather than the treatment. In this study, all the students were at the same grade level and age. In addition, students were coming from the same environment and had similar background characteristics in both groups. As time passes during the study, any change on students due to age and experience is expected to be equal. Therefore, maturation was not a serious problem for this study.

Attitude of subjects can be a threat when the subjects view the intervention as novel. In this study, students in the experimental group were aware of the new instruction and they were talking about it to their peers in control groups. Through the implementation of SWH, students began to use the laboratory and they were talking about the laboratory. The teachers told them laboratory was a part of their instruction in order to make using the laboratory less novel. In order to prevent the occurrence of negative attitudes in the control groups, the teachers used the laboratory in the control groups, although it was not a part of their regular instruction. However, laboratory was used for the experiments suggested in their textbooks in traditional format.

Treatments were given by the teachers of the groups and implementation threat was controlled by training the teachers implementing the both approaches. Moreover, the permission was granted from the teachers to observe the control and experimental groups. In order to minimize this threat, treatment verification was conducted as discussed in Section 3.3.5.

Regression threat was not a serious problem for this study because it usually occurs in studies in which only one group is used. There was a comparison group in this study and the subjects were not selected from low- or high-achieving students. In addition, students' pre-test scores were controlled in the post-test analyses.

The ethical issues were also taken into consideration in this particular study. This study did not cause any physical or psychological harm, discomfort, or danger. The proposal of this study, the instruments and the activities used in this study were examined by ethic committee of the university to assess whether there is possible harm to students. The committee found all the procedures followed in this study ethic. In addition, the names of the students were not asked in the questionnaires, only their id numbers were asked in order to match students' data obtained from different instruments. It was ensured that no one else except the researcher had a chance to access the data, and the results of the study was only used for the research purposes.

5.3 External Validity

External validity implies the extent to which the results of a study can be generalized beyond the sample (Frankel & Wallen, 2003). The nature of the sample and the environmental conditions gives an idea about the generalizability.

In this study, convenience sampling technique was used because in Turkey it is difficult to obtain a sample through the random selection of the subjects. Convenience samples cannot be considered as representative of the population. The target population was Ankara, and the accessible population was Çankaya. There were 17 general high schools in Çankaya, and at each general high school there were 200-250 students at 9th grade level. For this study, the sample included 122 students in a high school, and the number of the participants corresponded to between 2.9% and 3.6% of the accessible population. Because the proportion of the sample of the study to the accessible population was low and convenience sampling technique was used in this study, it can be concluded that population generalizability of this study was limited. The sample of this study mainly consisted of students having low previous knowledge about the chemical change and mixture. The students' ages ranged between 15 and 17, and they were coming from middle-class families. The school was located in an urban environment and had a well-equipped laboratory including all the materials necessary for conducting the experiments at high school level. This study was conducted in the spring semester, encompassing March, April and May. The classes were not crowded, there were between 28 and 32 students in each class. Therefore, this study can be generalized to other high schools having the similar characteristics. In order to enhance the generalizability of this study, more studies can be conducted with similar samples in similar settings.

5.4 Implications

Such findings of this study can contribute to Turkish chemistry education by introducing the SWH approach to chemistry education. There is not much study about the implementation of SWH approach in chemistry education in Turkey. The findings can also serve as a guide to teachers, textbook writers and curriculum developers in Turkey and other countries when designing an effective chemistry instruction in the topic of chemical changes and mixtures. Chemistry textbooks, as a main source of knowledge in schools, might be revised and designed by considering the active participation of the students and following the SWH approach. Teachers and textbook writers should present and discuss with students a variety of examples of chemical changes including reversible and irreversible. The teaching of chemistry should give students the opportunity to construct the chemical change concept, as a phenomenon in which one or two substances are transformed into new substances that are completely different from the initial ones. Students should develop scientific criteria rather than personal criteria for the identification of chemical changes. Based on these scientific criteria, they should understand whether there is conservation or change of substance's identity during a matter transformation.

In recent years, there have been some curricular changes at elementary and secondary levels in Turkey. In line with these revisions, high school chemistry curriculum also has been revised as more student-centered. However, most chemistry teachers at high schools have in trouble with designing student-centered activities. From this aspect, this study may be a guide to the high school teachers in terms of the implementation of a student-centered approach. In addition, a guidebook including information and activities about SWH approach may be prepared for the teachers, or the guidebooks (Norton-Meier, Hand, Hockenberry, & Wise, 2008; Hand et al., 2009) written for the teachers in English can be translated into Turkish. Development of students' understanding of chemical change and mixtures is an important issue in chemistry education because most of the phenomena in chemistry occur at the atomic or molecular level, and they are difficult for students to understand them due to its abstract character (Gabel, 1999; Garnett et al., 1995). In order to enhance students' conceptual understanding in chemistry, the teachers need to design instruction considering multiple representations (macroscopic, symbolic and microscopic) of the chemistry concepts. Teachers may teach the abstract concepts in a concrete way (Chandran et al., 1987), e.g. they may use various particulate drawings in order to make students discriminate among homogeneous mixtures, heterogeneous mixtures and pure substances (Sanger, 2000). The knowledge about particulate nature of matter has a constructive role in the development of the ideas of the chemical change (Ardac & Akaygun, 2004; Johnson, 2005).

Due to the spiral nature of the Turkish chemistry curriculum, understanding of chemical change concepts at 9th grade enhances students' understanding of chemical reactions and chemical equilibrium concepts, which are the topics of higher-grade chemistry. Likewise, understanding of mixtures concepts at 9th grade enhances students' understanding of the solution concepts at 10th and 11th grades. Because students' prior learning affects their further learning, the teachers should be aware of students' prior learning and they should deal with these misconceptions by embedding it within the instruction based on constructivism, like SWH approach. In order to consider students' misconceptions, the teachers should know the possible misconceptions that their students can likely to have. The more the teachers are aware of their students' misconceptions, the more they could design classroom activities for the remediation of the specified misconceptions (Andersson, 1986).

This study can be a guide for the chemistry teachers about the ways of eliciting students' prior learning. In this study, multiple-choice items, open-ended items, and pre-class discussions were used in the determination of students' previous knowledge. Teachers should take into account students' prior knowledge and alternative conceptions, because they account for a significant proportion of student achievement in science (Pınarbaşı et al., 2006). Many of the misconceptions result from teacher implementation, imprecise use of language and the abstract nature of chemistry. For this reason, teachers should not only be aware of the students' prior conceptions but also the problems influencing their construction of scientific knowledge. The use of everyday language in explaining chemistry phenomena, using multiple definitions, confusion of the related concepts, memorization of the concepts, students preconceptions obtained via experiences, inadequate prerequisite knowledge, and confidence on prior knowledge may influence students' understanding of the chemistry concepts (Garnett et al., 1995). The teacher may cause the development of alternative conceptions. For this reason, they should be very careful in using the correct language when they are talking about the chemical phenomena. For example, a teacher can explain his/her understanding of the water molecule by stating that water consists of hydrogen and oxygen. The student who does not have adequate prior knowledge may misinterpret water as a mixture of hydrogen and oxygen (Andersson, 1986).

Moreover, this study can also be a guide in assessing the students' chemistry conceptions because in this study it was shown that multiple-choice test items, open-ended test items and interviews were used for assessing students' conceptions. Moreover, SWH approach can be implemented at schools in closing the achievement gap among the students at high school. Normally, the aim of the education is to make all students scientifically literate, and achieve the basic science concepts and principles. Some of the teachers argue that the level of their students' achievement was very low, and those students could not perform the activities in a student-centered learning environment. Because implementation of SWH approach is working at all achievement levels, and effective in closing the gap among the achievement levels, the teachers can safely use this approach.

5.5 Recommendations

Based on the results of the study, the followings can be suggested:

1. Similar research studies can be conducted with a larger sample size and in different high schools for the generalization of the findings to a larger population.
2. The SWH approach can be implemented for different grade levels.
3. The SWH approach can be used for teaching different science topics.
4. This study was a short-term study, including two chemistry units. Long-term studies of the SWH approach could be tested at different grade levels and chemistry topics.
5. Further research can be conducted in order to investigate the effects of SWH approach on students' motivation, science process skills, critical thinking skills, and epistemological beliefs, in addition to the conceptual understanding and academic achievement.
6. Further research can be carried out to examine the effect of SWH approach on retention of the concepts.
7. Further studies in which SWH class sessions were video-recorded could be conducted. Then, the videotapes can be examined for the treatment verification.
8. In further studies, discourse analyses of the classroom interaction in SWH learning environment can be conducted.

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APPENDIX A

STUDENT BACKGROUND QUESTIONNAIRE

Sevgili Öğrenciler,

Bu çalışmada, sizlerin Kimya dersine ilişkin kavramlarınızı ve başarınızı ortaya çıkarmak amacıyla testler ve Kimya dersine yönelik tutumunuzu belirlemeye yönelik de bir anket uygulanacaktır. Bu araştırma Kimya dersinin geliştirilmesi için çok önemlidir. Yapacağınız katkılardan dolayı teşekkürler.

1. Sınıfınız: ....

2. Okul Numaranız: ....

3. Cinsiyetiniz: ☐ Kız ☐ Erkek

4. Doğum Tarihiniz (yıl): ....

5. Geçen Döneme Ait Kimya Dersi Karne Notunuz: ....

6. Annenizin Eğitim Durumu:

☐ İlkokul ☐ Ortaokul ☐ Lise ☐ Üniversite ☐ Lisans Üstü

7. Anneniz çalışıyor mu? ☐ Evet ☐ Hayır

Yanıtınız "evet" ise mesleği: ....

8. Babanızın Eğitim Durumu:

☐ İlkokul ☐ Ortaokul ☐ Lise ☐ Üniversite ☐ Lisans Üstü

9. Babanız çalışıyor mu?: ☐ Evet ☐ Hayır

Yanıtınız "evet" ise mesleği: ....

10. Kullandığınız okul kitapları hariç evinizdeki kitap sayısı:

☐ 0 - 25 ☐ 26 - 60 ☐ 61 - 100 ☐ 101 - 200 ☐ 200'den fazla

12. Evinizde size ait çalışma masası var mı?: ☐ Evet ☐ Hayır

APPENDIX B

CHEMICAL CHANGE AND MIXTURE CONCEPT TEST

Açıklama: Aşağıda kimyasal değişim ve karışımlar konularındaki kavramlarınızı ölçmeye yönelik hazırlanmış 40 soru yer almaktadır. Soruları dikkatle okuyunuz ve her soruyu cevaplandırmaya çalışınız.

1. Mumun yanması nasıl bir olaydır?

   a. Fiziksel bir olaydır.
   b. Kimyasal bir olaydır.

2. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
   ....
   ....
   ....

3. Buzun su haline gelmesi nasıl bir olaydır?

   a. Fiziksel bir olaydır.
   b. Kimyasal bir olaydır.

4. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
   ....
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   ....

5. Bir çay kaşığı tuz bir bardak su içerisine atılarak karıştırılıyor. Bu durumla ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

   a. Fiziksel bir olay gerçekleşir.
   b. Kimyasal bir olay gerçekleşir.

6. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
   ....
   ....
   ....
7. Soğuk bir günde odanın camının iç yüzeyinde su damlacıklarının oluşması nasıl bir olaydır?

   a. Fiziksel bir olaydır.
   b. Kimyasal bir olaydır.

8. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
   ....
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   ....

9. Gümüş yüzüğün kararması nasıl bir olaydır?

   a. Fiziksel bir olaydır.
   b. Kimyasal bir olaydır.

10. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
    ....
    ....
    ....

11. Bir mum elektronik terazinin kefesine konularak tartılıyor ve sonra da yakılıyor. Bir saat sonra terazide okunan değer ilk okunan değere göre nasıl değişir?

    a. Azalır
    b. Artar
    c. Değişmez

12. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
    ....
    ....
    ....

13. Çivinin paslanması nasıl bir olaydır?

    a. Fiziksel bir olaydır.
    b. Kimyasal bir olaydır.

14. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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15. Bir çivi paslandığında çivinin ağırlığı ilk durumuna göre nasıl değişir?

a. Azalır
b. Artar
c. Değişmez

16. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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17. Metal bir çivinin paslanması ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

a. Soğuk çivinin paslanmasına sebep olur.
b. Paslanma esnasında demir başka elementlere dönüşür.
c. Çivinin pası temizlenirse, çivinin ağırlığı ilk durumuna göre daha hafif olur.

18. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

19. Kibritin yanması ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

a. Kibritin yanması sonucu enerji açığa çıkar (ekzotermik bir olaydır).
b. Kibritin yanması için enerji harcanır (endotermik bir olaydır).

20. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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21. Karışımların görünümleri ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

a. Karışımların tamamı homojen görünümlüdür.
b. Karışımların tamamı heterojen görünümlüdür.
c. Karışımlar hem homojen hem de heterojen görünümlü olabilir.

22. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

23. Karışımların yapısı ile ilgili olarak aşağıdaki ifadelerden hangisi/hangileri <u>kesinlikle</u> doğrudur?

    a. Karışımlar yapılarında en az iki çeşit element bulundurur.
    b. Karışımlar yapılarında en az iki çeşit bileşik bulundurur.
    c. Karışımlar yapılarında en az iki çeşit saf madde bulundurur.
    d. Karışımlar yapılarında her zaman iki çeşit saf madde bulundurur.
    e. Karışımlar yapılarında tek cins madde bulundurur.

24. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

25. Buzlu su ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

    a. Homojen karışımdır.
    b. Heterojen karışımdır.
    c. Heterojendir ancak karışım değildir.

26. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

27. 1 gram tuz 20 gram su içerisinde çözünürse oluşan çözeltinin kütlesi ne olur?

    a. 21 gramdan daha az
    b. 21 gram
    c. 21 gramdan daha fazla

28. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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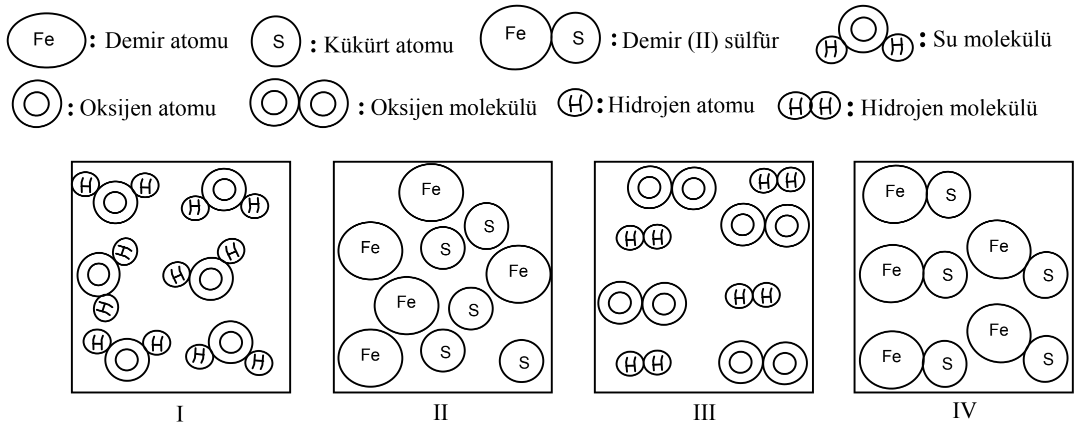
29. Aşağıdaki şekillerde atomlar ve moleküller gösterilmektedir. Bu şekillerden hangisi/hangileri bir karışıma aittir?



A. Yalnız II
B. I ve III
C. II ve III
D. I ve IV
E. II ve IV

30. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

31. Bir gazozun kapağı açılırsa içerisinde çözünmüş CO_2 miktarı nasıl değişir?

a. Artar
b. Azalır
c. Değişmez

32. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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....

33. Bir gazoz buzdolabına konulursa içerisinde çözünmüş CO_2 miktarı nasıl değişir?
a. Artar
b. Azalır
c. Değişmez

34. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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35. Aşağıdaki işlemlerin hangisinde çözünme olur?

a. Suya tuz katılması
b. Suya buz katılması
c. Suya yağ damlatılması

36. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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37. Bir kaşık şeker bir bardak suya atılarak karıştırılıyor. Bu durumla ilgili olarak aşağıdaki ifadelerden hangisi/hangileri doğrudur?

a. Şeker erir.
b. Şeker suda çözünür.
c. Şeker suda kaybolur.

38. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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39. Çözeltilerle ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

a. Tamamı sıvı halde bulunur.
b. Sıvı veya gaz halde bulunabilir.
c. Sıvı veya katı halde bulunabilir.
d. Katı, sıvı veya gaz halde bulunabilir.

40. Bir önceki soruya verdiğiniz cevabın nedenini açıklayınız.
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APPENDIX C

OBJECTIVES

1. Kimyasal tepkimelerde maddelerin kimlik özelliklerinin değiştiğini açıklar
2. Kimyasal özelliklerin kimyasal değişimler ile ortaya çıktığını fark eder.
3. Kimyasal değişmelere enerji değişmelerinin de eşlik ettiğini örneklerle gösterir.
4. Kimyasal değişim ve fiziksel değişimi birbirinden ayırt eder.
5. Yanıcılık, asitlik-bazlık, asallık gibi kimyasal özelliklere temel olan örnek tepkimelerin denklemlerini yazar.
6. Basit çözünme-çökelme tepkimelerinin denklemlerini yazar.
7. Nötralleşme tepkimelerinin genel özelliğini açıklar.
8. Çözünme-çökelme ile nötralleşme tepkimelerinin ortak özelliği belirtilir.
9. Elektron alışverişi ile yürüyen değişmelerde indirgeni ve yükseltgeni belirler.
10. Yaygın yükseltgen ve indirgen maddelere kullanım alanları ile birlikte örnekler verir.
11. Heterojen ve homojen karışımları ayırt eder.
12. Çözücü, çözelti, çözünürlük kavramlarını ilişkilendirerek açıklar.
13. Sıcaklığın ve basıncın çözünürlüğe etkisini örneklerle açıklar.
14. Farklı maddelerin çözünürlüklerini karşılaştırarak çözünürlüğün maddenin kimlik özelliklerinden olduğunu fark eder.
15. Karışımların bileşenleri değiştikçe bazı fiziksel özelliklerinin değiştiğini deneyerek fark eder.
16. Tanecik boyutu farkından yararlanılarak geliştirilen ayırma yöntemlerini açıklar.
17. Maddelerin birbirinden ayrılmasında yoğunluk farkından yararlanan yöntemleri keşfeder.

18. Çözünürlük farklarının maddeleri ayırmada kullanılabildiğini fark eder.
19. Kaynama noktası farkından yararlanarak karışımların ayrılmasına örnekler verir.
20. Verilen karışımlar için uygun ayırma yöntemleri önerir.

APPENDIX D

CHEMICAL CHANGE AND MIXTURE ACHIEVEMENT TEST

Açıklama: Aşağıda kimyasal değişim ve karışımlar konularındaki başarılarınızı ölçmeye yönelik hazırlanmış beş şıklı toplam 22 soru vardır. Soruları dikkatle okuyunuz ve her soruyu cevaplandırmaya çalışınız.

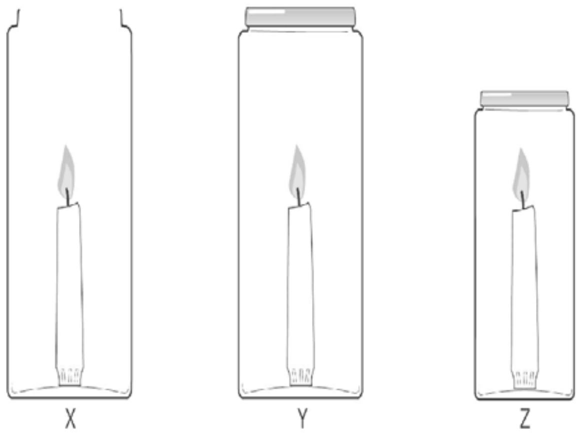
1. Aşağıdakilerden hangisi kimyasal değişime bir örnektir?
   A. Buzun erimesi
   B. Suyun buharlaşması
   C. Camın kırılarak parçalanması
   D. Odunun talaş haline getirilmesi
   E. Kömürün küle dönüştürülmesi

2. Aşağıdakilerin hangisinde verilen maddeden karşısındaki ürün elde edilirken fiziksel değişme olur?

	Madde	Ürün
A.	Süt	Peynir
B.	Süt	Yoğurt
C.	Yoğurt	Ayran
D.	Elma	Sirke
E.	Üzüm	Şarap

3. Petrolün yanması sırasında gerçekleşen kimyasal reaksiyonla ilgili olarak aşağıdakilerden hangisi doğrudur?
   A. Herhangi bir enerji değişimi olmaz.
   B. Reaksiyon sonucu enerji açığa çıkar.
   C. Reaksiyonun gerçekleşmesi için enerji harcanır.
   D. Hem enerji açığa çıkar hem de enerji harcanır.
   E. Petrolün yapısına bağlı olarak bazen enerji açığa çıkar bazen de enerji harcanır.

4. Üç özdeş mum aşağıdaki şekilde gösterildiği gibi 2 litrelik ve 1 litrelik kavanozlara konuluyor ve aynı anda yakılıyor. Y ve Z mumlarının konulduğu kavanozların ağzı kapatılırken X mumunun konulduğu kavanozun ağzı açık bırakılıyor. X, Y ve Z mumlarından hangisinin alevi daha önce söner? Neden?



2 L 2 L 1 L

A. X, Y ve Z kavanozlarındaki mumlar aynı anda söner çünkü mumlar özdeştir.
B. Y ve Z kavanozlarındaki mumlar aynı anda ve X kavanozundaki mumdan daha önce söner çünkü Y ve Z kavanozları kapalıdır.
C. X kavanozundaki mum daha önce söner çünkü kavanoz açık olduğundan rüzgar mum alevini söndürür.
D. Y kavanozundaki mum daha önce söner çünkü Y kavanozunda biriken karbondioksit miktarı daha fazladır.
E. Z kavanozundaki mum daha önce söner çünkü Z kavanozu içerisindeki hava miktarı daha azdır.

5. Bir kamp gezisi sırasında Deniz'i bal arıları sokuyor. Bal arısı sokma esnasında asidik bir salgı salgılıyor. Fakat, Deniz'in ilaç bulma imkanı yok ve elinde aşağıdaki maddeler var. Bu maddelerin pH değerleri ve turnusol kağıdına olan etkisi aşağıdaki tabloda verilmiştir. Deniz acısını hafifletmek için bu maddelerden hangisini kullanmalıdır?

	pH	**Turnusol kağıdına etkisi**
süt	6.7	Turnusol kağıdına etki etmez.
sirke	3.2	Mavi turnusol kağıdını kırmızıya dönüştürür.
alkol	6.5	Turnusol kağıdına etki etmez.
yoğurt	4.2	Mavi turnusol kağıdını kırmızıya dönüştürür.
amonyaklı su	10.1	Kırmızı turnusol kağıdını maviye dönüştürür.

A. Süt
B. Sirke
C. Alkol
D. Yoğurt
E. Amonyaklı su

6. Ailenizle hafta sonu tatilini geçirmek için Ankara dışına çıktınız. Pazar akşamı eve döndüğünüzde evde elektrikler kesikti. Buzdolabınızın kapağını açtığınız zaman, buzun eridiğini, sütün ekşidiğini, tereyağının acıdığını, peynirin küflendiğini ve etin bozulduğunu fark ettiniz. Buz, süt, tereyağı, peynir ve ette meydana gelen değişikliklerden hangileri fiziksel, hangileri kimyasal değişimdir?

	Buzun erimesi	**Sütün ekşimesi**	**Tereyağının acıması**	**Peynirin küflenmesi**	**Etin bozulması**
A.	Fiziksel	Kimyasal	Kimyasal	Kimyasal	Kimyasal
B.	Fiziksel	Kimyasal	Fiziksel	Fiziksel	Fiziksel
C.	Kimyasal	Fiziksel	Fiziksel	Kimyasal	Kimyasal
D.	Kimyasal	Fiziksel	Fiziksel	Kimyasal	Fiziksel
E.	Fiziksel	Kimyasal	Kimyasal	Kimyasal	Fiziksel

7. Yükseltgen maddeler yaygın bir şekilde dezenfektan (mikrop öldürücü) olarak kullanılmaktadırlar. Aşağıdaki maddelerden hangisi/hangileri dezenfektan olarak kullanılabilir?
   I. Ozon (O_3)
   II. Klor (Cl_2)
   III. Potasyum permanganat ($KMnO_4$)
   IV. Karbon monoksit (CO)
   V. Oksijen (O_2)

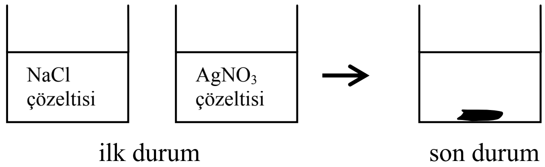
   A. Yalnız IV
   B. I ve II
   C. I, II ve III
   D. I, II, III ve V
   E. I, II, III, IV ve V

8. Bir ev yeni inşa edildiği zaman mutfaktaki sıcak ve soğuk bakır su boruları parlaktır. Çok geçmeden bu boruların dışı matlaşır ve kararır. Boruların dışında koyu renkli ince bir tabaka oluşur. Sıcak su borusunun dışı soğuk su borusunun dışına göre daha çok kararır.

   Bu olayla ilgili olarak, aşağıdaki ifadelerden hangisi/hangileri doğrudur?
   I. Fiziksel değişme olur.
   II. İndirgenme–yükseltgenme reaksiyonu olur.
   III. Bakır yükseltgenir.
   IV. Sıcaklık reaksiyon hızını artırır.
   V. Kimyasal reaksiyon sonucunda CuO veya Cu_2O oluşur.

   A. Yalnız I
   B. II ve III
   C. II, III ve V
   D. II, IV ve V
   E. II, III, IV ve V

9. NaCl ve $AgNO_3$ çözeltileri karıştırıldığında, şekilde de gösterildiği gibi bir miktar katının dibe çöktüğü gözlemleniyor. Buna göre aşağıdaki ifadelerden hangisi/hangileri doğrudur?



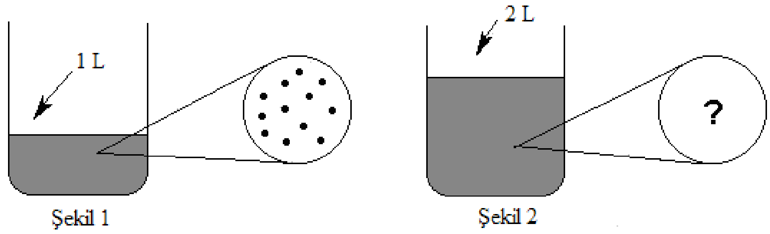
I. Çözünme ve çökelme tepkimesi olmuştur.
II. Tepkime sonucu $NaNO_3$ çökeleği oluşur.
III. Tepkime denklemi $NaCl_{(suda)} + AgNO_{3\,(suda)} \rightarrow AgCl_{(k)} + NaNO_{3\,(suda)}$ şeklindedir.
IV. İndirgenme-yükseltgenme olayı gerçekleşir.

A. Yalnız I
B. I ve II
C. I ve III
D. I, II ve III
E. I, II, III ve IV

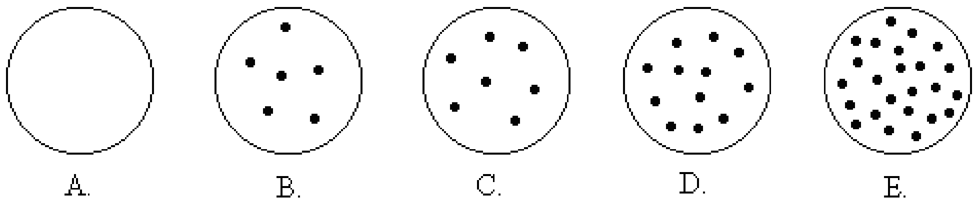
10. Aşağıdakilerden hangisi karışıma bir örnektir?
A. Hava
B. Tuz
C. Şeker
D. Demir
E. Ozon

11. Aşağıdakilerden hangisi heterojen karışıma bir örnektir?
A. Süt
B. Buz
C. Buzlu su
D. Musluk suyu
E. Şekerli su

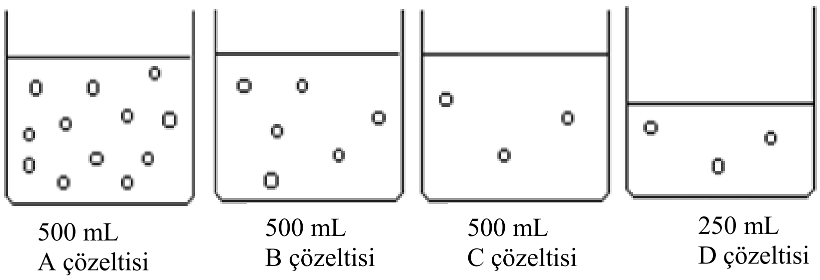
12. Aşağıda gösterilen Şekil 1, 1L şekerli su çözeltisine aittir. Daire içine alınmış büyütülmüş alandaki noktalar şeker moleküllerini temsil etmektedir. Çizimi karmaşık hale getirmemek için su molekülleri gösterilmemiştir.



Şekil 1'deki şekerli su çözeltisine 1 L su eklenirse (Şekil 2), Şekil 1 de gösterilen büyütülmüş alan aşağıdakilerden hangisi gibi olur?



13. Aşağıdaki şekillerde sulu çözeltilerin bulunduğu kaplar gösterilmektedir. Her bir "o" işareti çözünen maddeyi göstermektedir. Buna göre aşağıdaki ifadelerden hangisi doğrudur?

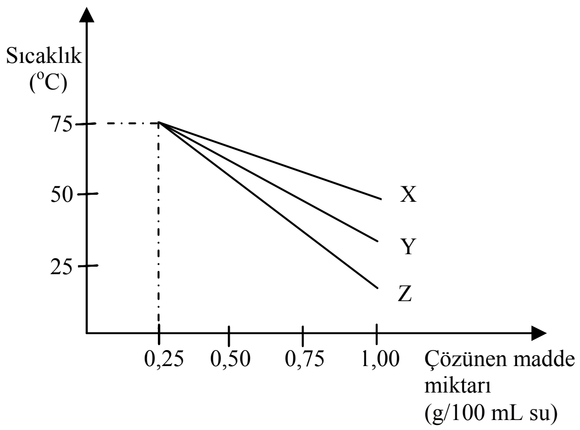


A. B çözeltisi en derişik çözeltidir.
B. D çözeltisi en seyreltik çözeltidir.
C. B ve D çözeltilerinin derişimleri (konsantrasyonları) eşittir.
D. C ve D çözeltilerinin derişimleri eşittir.
E. A, B ve C çözeltilerinin derişimleri eşittir.

14. Halk arasında tuzlu su olarak da bilinen serumun 100 mililitresinde 0.9 gram NaCl bulunmaktadır. Serum ile ilgili olarak aşağıdaki ifadelerden hangisi doğrudur?

A. Su, çözünen maddedir.
B. NaCl, çözücü maddedir.
C. Serum seyreltik bir çözeltidir.
D. Serumun kütlesi 100 gramdır.
E. 100 mL serumda 0.9 gram NaCl ile 99.1 gram su bulunur.

15. Uçucu olmayan X, Y, Z arı katılarının farklı sıcaklıklarda hazırlanan sudaki doygun çözeltilerindeki çözünen madde miktarlarının sıcaklıkla değişimi grafikteki gibidir.



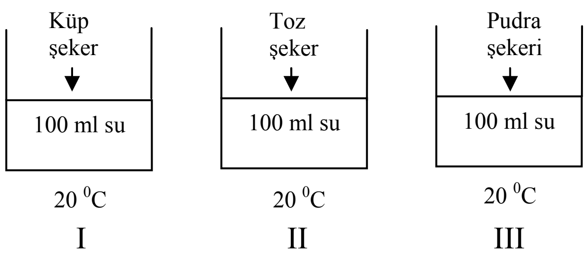
Buna göre, X, Y, Z maddelerinin sudaki çözeltileriyle ilgili aşağıdakilerden hangisi doğrudur?

A. 50 °C de en az X çözünür.
B. 75 °C de en fazla X çözünür.
C. Her üçünün de suda çözünmeleri sıcaklık arttıkça artar.
D. Z katısının 0,75 gramını çözmek için sıcaklık 50 °C den yüksek olmalıdır.
E. 75 °C de X, Y, Z nin 100 mL suda çözünen madde miktarları eşittir.

16. I. Dalgıçların, denizin derinliklerinden yüzeye ani çıkması durumunda, vücutlarında çözünmüş olan azotun çözünürlüğünün azalması sonucu oluşan vurgun olayı
II. Oda sıcaklığında, bir gazoz şişesinin kapağı açılıp şişenin ağzına hemen elastik bir balon geçirilmesiyle gazozdan çıkan karbondioksit gazının balonu şişirmesi
III. Sığ göllerde, yaz aylarında balık ölümlerinin kış aylarına göre daha çok olması

Yukarıdaki durumlardan hangisinin/hangilerinin nedeni, gazların çözünürlüğünün basınç değişimine bağlı olmasıyla açıklanır?
A. Yalnız I
B. Yalnız II
C. I ve II
D. I ve III
E. II ve III

17. Yandaki şekilde gösterilen kaplar içerisine eşit kütlelerde küp şeker, toz şeker ve pudra şekeri atılıyor. I,, II. ve III. kaplardaki şekerin çözünme hızını büyükten küçüğe doğru sıralayınız?



A. I = II = III
B. I > II = III
C. I > II > III
D. III > II > I
E. III = II > I

18. Bronz, bakır ve kalaydan elde edilen bir alaşımdır ve genellikle heykel yapımında kullanılmaktadır. Bir deneyde 3 farklı bronz heykelden alınan bronz örnekleri incelenmiştir ve sonuçlar aşağıdaki tabloda verilmiştir.

Bronz heykel	Kütlece bakır yüzdesi	Kütlece kalay yüzdesi
1	85	15
2	83	17
3	86	14

Verilen bilgilere göre, bronz ile ilgili olarak aşağıdakilerden hangisi söylenebilir?
A. Bakır ve kalayın kütlece birleşme oranı sabittir.
B. Bronz, bakır ve kalayın özelliklerini taşır.
C. Bronz, fiziksel yöntemlerle bakır ve kalaya ayrıştırılamaz.
D. Bronzun kütlesi içerdiği bakır ve kalayın kütleleri toplamından farklıdır.
E. 1., 2. ve 3. bronz heykellerden alınan bronz örneklerinin yoğunlukları birbirine eşittir.

19. Bir öğrenci yaptığı deney sonucunda aşağıdaki tabloyu elde ediyor. Bu öğrenci deneyi aşağıdaki sorulardan hangisini yanıtlamak için yapmış olabilir?

Madde	**Kütle (g)**	**Sıcaklık (^0C)**	**Basınç (atm)**	**Çözünürlük (g/100 g su)**
Azot	1	20	1	0,0019
Oksijen	1	20	1	0,0043
Karbondioksit	1	20	1	0,169

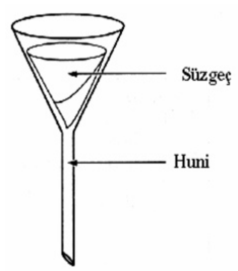
A. Gazların çözünürlüğü, gazın cinsine bağlı mıdır?
B. Gazların çözünürlüğü, gazın kütlesine bağlı mıdır?
C. Gazların çözünürlüğü, ortamın sıcaklığına bağlı mıdır?
D. Gazların çözünürlüğü, ortamın basıncına bağlı mıdır?
E. Gazların çözünürlüğü hem ortamın sıcaklığına hem de basıncına bağlı mıdır?

20. Şekildeki tabloda su ve asetonun bazı fiziksel özellikleri verilmiştir.

	Molekül Ağırlığı	**Yoğunluk**	**Kaynama Noktası**	**Donma Noktası**	**Polarite**
Su	18 g/mol	$1g/cm^3$	100	0^0C	Polar
Aseton	58 g/mol	$0.79\ g/cm^3$	56	-95.4^0C	Polar

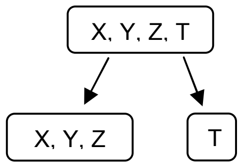
Karışım halinde bulunan su ve asetonu birbirinden ayırmak için en uygun yöntem aşağıdakilerden hangisidir?
A. Süzme
B. Buharlaştırma
C. Kristallendirme
D. Ayrımsal damıtma
E. Ayırma hunisi ile ayırma

21. Yanda gösterilen süzme aracı hangi materyalleri ayırmak için kullanılabilir?
A. Tuzlu su
B. Alkollü su
C. Kum ve talaş karışımı
D. Biber ve su karışımını
E. Tuz ve biber karışımını

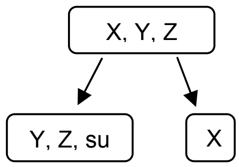


22. Bir öğrenciye tuz, kum, demir tozu ve küçük mantar tıpalardan oluşan bir karışım veriliyor. Öğrenci verilen karışımı aşağıdaki şekilde de gösterildiği gibi 4 adımdan oluşan bir yöntemle ayırıyor. X, Y, Z ve T harfleri, verilen karışımdaki her bir bileşeni temsil etmektedir fakat bu harflerden hangisinin hangi bileşeni temsil ettiği bilinmemektedir.

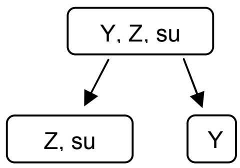
I. adım: Mıknatıs kullanma



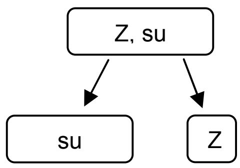
II. adım: Su ekleme ve suda yüzen bileşeni uzaklaştırma



III. adım: Süzme



IV. adım: Suyu buharlaştırma



Verilen bilgiler doğrultusunda karışımdaki X, Y, Z ve T bileşenleri hakkında aşağıdakilerden hangisi doğrudur?

	X	Y	Z	T
A.	Kum	Mantar tıpa	Tuz	Demir tozu
B.	Mantar tıpa	Tuz	Kum	Demir tozu
C.	Mantar tıpa	Kum	Tuz	Demir tozu
D.	Demir tozu	Kum	Tuz	Mantar tıpa
E.	Mantar tıpa	Kum	Tuz	Su

APPENDIX E

ATTITUDE SCALE TOWARD CHEMISTRY

Açıklama: Aşağıda Kimya dersine yönelik tutumunuzu ölçmeye yönelik ifadeler yer almaktadır. Cümleleri dikkatlice okuyarak size uygun olan tek bir yanıtı işaretleyiniz.

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

APPENDIX F

SEMI-STRUCTURED INTERVIEW SCHEDULE

A. Kavram Soruları

1. Fiziksel değişim nedir? Örnek veriniz.
2. Kimyasal değişim nedir? Örnek veriniz?
3. Mumun yanması nasıl bir olaydır? Neden?
4. Gümüş yüzüğün kararması nasıl bir olaydır?
5. Metal bir çivinin paslanması nasıl bir olaydır?
   - Paslanma esnasında demire ne olur?
   - Bir metal çivi paslandığında çivinin ağırlığı ilk durumuna göre nasıl değişir?
   - Bir metal çivinin pası temizlenirse, çivinin ağırlığı ilk durumuna göre nasıl değişir?
6. Karışım nedir? Örnek veriniz?
   - Karışımların özellikleri nelerdir?
7. Çözelti nedir?
   - Bütün karışımlar çözelti midir?
   - 1 gram tuz 20 gram su içerisinde çözünürse oluşan çözeltinin kütlesi ne olur?
   - Çözeltiler hangi hallerde bulunurlar? (katı-sıvı-gaz) Örnek verir misiniz?
8. Bir gazozun kapağı açılırsa içerisinde çözünmüş CO_2 miktarı nasıl değişir? Bir gazoz buzdolabına konulursa içerisinde çözünmüş CO_2 miktarı nasıl değişir?

B. Uygulama ile İlgili Sorular

9. Kimya dersini, bu dönem geçen dönemki ile aynı formatta mı işlediniz? Fark var mıydı? Fark varsa bu farklardan bahseder misiniz?

- Alternatif: Geçen dönemki Kimya dersiniz ile bu dönemki Kimya dersinizi nasıl karşılaştırıyorsunuz?
- Hangi sınıf aktiviteleri sizin kimyasal değişim ve karışımlar konularını anlamanıza daha çok yardımcı oldu? Açıklar mısınız?
- Bu dönem yaptıklarınız hoşunuza gitti mi?

10. Kimya dersinin bu dönemdeki gibi mi yoksa geçen dönemdeki gibi mi olmasını istersiniz? Neden?
11. Geçen dönem ile kıyasladığınızda bu dönem sizde değişiklikler oldu mu? Evet ise bu değişikliklerden bahseder misiniz?
12. Laboratuvar aktivitelerinde kendi sorularınızı kendinizin belirlemesi öğrenmenize yardımcı oldu mu? Evet, ise nasıl oldu?
13. Laboratuvarlarda ve deney raporlarınızda iddia ve delil oluşturmanızın öğrenmenize katkısı oldu mu? Evet, ise nasıl katkısı oldu?
14. Kimya dersinde geçen dönemki ve bu dönemki yazdıklarınızı nasıl karşılaştırıyorsunuz?

    Alternatif: Geçen dönem neler yazıyordunuz?
    Bu dönem neler yazdınız?
    Farklılıklar oldu mu?

    - Geçen dönemki mi yoksa bu dönemki mi yazdıklarınız öğrenmenize daha çok yardımcı oldu? Neden?
15. Laboratuvar sonunda deney raporu yazmanızın öğrenmenize katkısı oldu mu? Evet ise nasıl katkısı oldu?
16. Deney rapor formatı hakkında neler düşünüyorsunuz?
    - Deney raporunda en çok hangi bölümün öğrenmenize yardımcı olduğunu düşünüyorsunuz?
    - Deney raporunda en az hangi bölümün öğrenmenize yardımcı olduğunu düşünüyorsunuz?

17. Bu dönem yaptığınız etkinliklerde grup olarak ya da sınıfça yapılan tartışmaların öğrenmenize yardımcı olduğunu düşünüyor musunuz? Size ne katkısı oldu? Neden?
18. Laboratuvarda deney yaparken ya da deney raporu hazırlarken fikirlerinizin değiştiği durumlar oldu mu? Bir ya da iki örnek verebilir misiniz?
    Alternatif: Önceden yanlış bildiğiniz ancak deney yaparken ya da deney raporu yazarken yanlış bildiğinizi fark edip düzelttiğiniz kimya kavramları oldu mu?
19. Laboratuvarda yapacağınız deneyi seçerken veya deneyi tasarlarken kontrolün ne derece sizde olduğunu hissettiniz? Düşüncelerinizi açıklar mısınız?
20. Geçen dönem ile kıyasladığınızda bu dönem Kimya derslerinde problemler yaşadınız mı?
    Evet, ise bu problemlerden bahseder misiniz?
21. Kimya derslerinde genel olarak yaşadığınız problemler var mı? Evet, ise bu problemlerden bahseder misiniz?
22. Bu problemlere çözüm önerileriniz var mı? Varsa neler olabilir? Kimya konularını daha iyi öğrenmeniz için neler yapılabilir?

APPENDIX G

CLASSROOM OBSERVATION CHECKLIST

	0	1	2
1. Öğretmen dersin başında herhangi bir giriş etkinliği (tartışma, gösteri deneyi, vs.) yaptı mı?			
2. Öğretmen öğrencilerin ön bilgilerini dikkate aldı mı?			
3. Öğrenciler merak ettikleri sorularla mı geldi?			
4. Öğrencilerin merak ettikleri sorular sınıf ortamında tartışıldı mı?			
5. Tartışma sonucunda her grup için test edilecek sorular belirlendi mi?			
6. Her grup belirledikleri sorularını test etmeye yönelik uygun bir prosedür belirledi mi?			
7. Gruplar belirledikleri prosedürü takip ederek sorularını test ettiler mi?			
8. Gruplar deney sırasında gözlemlerini kaydettiler mi?			
9. Gruplar deney sonunda gözlemlerine ve verilerine dayalı olarak iddialar oluşturdular mı?			
10. Gruplar iddialarını desteklemek için deliller oluşturdular mı?			
11. Her grup iddia ve delillerini diğer gruplarla ve öğretmenle paylaştı mı?			
12. Öğrenciler soru sormaya teşvik edildi mi?			
13. İlgili konu günlük hayatla ilişkilendirildi mi?			
14. Bütün öğrenciler aktif olarak derse katıldılar mı?			
15. Öğretmen derste ve etkinlikler esnasında yönlendirici miydi?			
16. Öğrenciler dersin işlenişinden hoşlandılar mı?			
17. Öğretmen öğrencilere dönüt verdi mi?			

APPENDIX H

HANDOUT FOR TEACHERS

Argümantasyon Tabanlı Bilim Öğrenme (ATBÖ) yaklaşımı öğrencinin aktif olarak, araştırma yaparak kavramsal öğrenmeyi gerçekleştirmesi için kullanılan bir yaklaşımdır. Bu yaklaşımın kullanıldığı ders iyi planlanır ve uygulanırsa öğrencinin önemli kavramları anlaması kolaylaşmaktadır.

ATBÖ yaklaşımında, öğrencilerin ön bilgilerinin dikkate alınmaktadır. Bu yaklaşımda soru, iddia, delil ve yansımalar aracılığıyla öğrencilerin düşünme, yazma ve tartışma faaliyetlerine yön verilmektedir. Bu yaklaşımda, öğrencilerin hazırlaması gereken laboratuvar raporu için ATBÖ rapor formatı kullanılmaktadır (bkz. Tablo 1).

Tablo 1. ATBÖ ve Geleneksel Laboratuvar Formatını Kıyaslama

Standart Rapor Formatı	ATBÖ *Öğrenci Şablonu*
1. Başlık, amaç.	1. Başlangıç Soruları – Sorularım nelerdir?
2. Prosedürün ana hatları.	2. Testler – Ne yaparım?
3. Veriler ve gözlemler.	3. Gözlemler – Ne görebilirim?
4. Tartışma.	4. İddialar – Ne iddia edebilirim?
5. Eşitlikler/denklemler, hesaplamalar, grafikler.	5. Kanıt - Nasıl bilebilirim? Neden bu tür iddialarda bulunuyorum?
	6. Benim fikirlerim diğer fikirler ile nasıl kıyaslanabilir?
	7. Benim fikirlerim nasıl değişti?

ATBÖ formatında gözlem yapma geleneksel deney formatına benzediği halde iddiaları ileri sürme ve onları kanıtlar ile destekleme süreci geleneksel laboratuvar formatından farklılık göstermektedir. Tablo 2 geleneksel laboratuvar ile ATBÖ laboratuvarı arasındaki bazı farklılıkların ana hatlarını şema halinde göstermektedir.

ATBÖ yaklaşımına göre, deney süresince toplanan veriler farklı şekillerde yorumlanabilmektedir. Yapılan gözlemler ve kaydedilen verilerle ilgili olarak çıkarımlarda bulunabilmek için öğrenciler arasında işbirliği çok önemlidir. Öğrencilerin bilgilerinin nasıl değiştiği konusunda düşünmeleri, olası yanlış anlama durumları ile karşı karşıya gelmelerine ve konuları daha derin kavramalarına yardımcı olmaktadır.

Yapılandırmacı öğrenme teorisinde de ifade edildiği gibi öğrenciler bilgilerini yapılandırarak öğrenmektedirler ve ATBÖ yaklaşımı da öğrencilerin aktif olarak sürece katılabilecekleri bir öğrenme ortamı sunmayı hedeflemektedir. Bu öğrenme ortamı içinde öğrenciler süreç içerisinde öğrenmeye daha ilgili olurlar ve sonuç olarak daha fazla öğrenirler. ATBÖ yaklaşımın kullanıldığı sınıflarda öğrenciler işbirliği içerisindedirler, verilerini ve gözlemlerini kaydederler, iddialar oluştururlar ve bu iddialarını delillerle desteklerler. Bu nedenle, grup içerisindeki öğrenciler birbirlerine karşı sorumludurlar. Gerek grup içerisinde gerek ise gruplar arasındaki tartışmalar öğrencilerin fikirlerini paylaşmalarında ve bilgilerini yapılandırma süreçlerinde aktif rol almaktadır. Öğrenciler laboratuvar etkinlikleri sonunda soru, test, gözlem ve veriler, iddia, deliller, okuma ve karşılaştırmalar ile yansımaların yer aldığı ATBÖ rapor formatına uygun bir şekilde deney raporlarını yazarlar.

ATBÖ SÜRECİ

1. Araştırma Sorusu

a. Araştırma sorusu laboratuvar etkinliklerine yön vermeli yani laboratuvarda test edilebilir olmalı.

b. Örneğin bir araştırma sorusu 'Bir değişken diğer bir değişkene nasıl bağlı olabilir?' şeklinde olabilir.

c. Araştırma için uygun olmayan sorular şu şekillerde olabilmektedir:
   - 'Neden?' soruları.
   - Deney yapmadan cevap verilebilen sorular.

2. Güvenlik Hususları

Laboratuvarda belirli kimyasallar, aletler ve prosedürler ile çalışırken hangi güvenlik sorunlarının dikkate alınması gerektiği üzerinde durulmalıdır.

3. Prosedür ve Testler

Araştırma sorusuna cevap bulabilmek için nasıl bir yol izleneceğine grup olarak karar verilip yazıya dökülmelidir.

4. Gözlemler ve Veriler

a. Deney süresince grup üyeleri gözlemlerini ve verilerini kaydederler.
b. Öğrenciler verilerini kaydederken metin yanında tablolar, matematiksel ifadeler, resimler, şekiller ve grafikler kullanabilirler.

5. İddia(lar)

Öğrenciler araştırma sorularına cevap verebilmek için deneyden elde ettikleri gözlemler ve veriler ışığında genel bir çıkarımda bulunurlar.

6. Kanıt ve Analiz

Öğrenciler iddialarını uygun delillerle desteklerler. Delil doğrudan veri demek değildir. Deliller verilerin yorumlanması ile oluşturulurlar.

7. Okuma ve Karşılaştırmalar

a. Sonuçlarınız sınıf arkadaşlarınızın sonuçları ile karşılaştırınız?
b. Sonuçlarınızı farklı kaynaklardan (ders kitabı, yardımcı kitaplar, internet, vs.) okuduklarınız ile karşılaştırınız?

8. Yansımalar

a. Fikirleriniz değişti mi?
b. Yeni sorularınız neler?
c. Düşünmek zorunda olduğunuz yeni şeyler nelerdir?
d. Deneyi yapmadan önceki düşünceleriniz ile deneyi yaptıktan sonraki düşünceleriniz arasında benzerlik ve farklılıklar var mı?
e. Bu deney sonucunda öğrendikleriniz günlük yaşam ile nasıl ilişkilendiriyorsunuz?

Tablo 2. Geleneksel ve ATBÖ Yaklaşımının Kıyaslanması

	Geleneksel Yaklaşım	*ATBÖ Yaklaşımı*
Laboratuvar öncesi etkinlik	· Öğretmen adım adım talimatlar verir ve ders kitabında yer alan deney ile ilişkili sorular sorar.	· Öğrenciler tahtaya araştırmak istedikleri soruları yazar. · Sınıf hep birlikte hangi soruların inceleceğini tartışır. · Öğrenciler, sorularını test edebilmek için nasıl bir yok izleyeceklerine karar verirler.
Öğrenciler Deneysel Çalışma Yürütürler	· Öğrenciler ders kitabındaki ve öğretmen tarafından ana hatları çizilmiş prosedürü takip ederler.	· Öğrenciler kendi sorularına cevap vermek için gerekli olan laboratuvar çalışması yürütürler. · Öğrenciler gözlemlerini ve elde ettikleri verileri kaydederler
Verileri yorumlama (İddia ve deliller oluşturma)	· Grup üyeleri tüm verilere sahip olduklarından emin olmak için birbirlerini denetler ve sonra ayrılırlar.	· Grup içerisindeki her öğrenci verilere ve gözlemlere dayalı olarak iddia ve deliller oluşturur. · Grup olarak öğrenciler kendi iddia ve delillerini paylaşırlar ve sonunda grup iddia ve delillerini oluştururlar.
Tartışma	· Öğrenci, grup arkadaşına ya da öğretmenine bir soru sorabilir ve sonra sınıftan ayrılabilir.	· Her bir grup sırasıyla diğer gruplara araştırdıkları soruyu, ne yaptıklarını, ve araştırma sonucunda ne iddia ettiklerini anlatır. He bir grup iddialarını delillerle destekler. · Bu sırada diğer gruplardan sorular gelebilir ya da öğretmen sorular sorabilir. Bu sayede sınıf içerisinde bir tartışma ortamı oluşur. · Tartışma sonunda öğretmen yapılan etkinliklerin o günkü dersin büyük düşüncesi ile ilişkilendirilmesine yardımcı olur.
Laboratuvar sonrası etkinlik	· Öğrenciler geleneksel rapor formatına uygun bir şekilde deney raporu yazarlar.	· Öğrenciler ATBÖ rapor formatına göre deney raporu yazarlar.

ÖRNEK ÖĞRENCİ DENEY RAPORU

Bakır Metalinin Esas/Doğal Kükürt Elementiyle Reaksiyonu

Araştırma sorusu:

Bakır metali ile kükürt elementinin reaksiyonu sonucu oluşan ürünün deneysel formülü kullanılan bakır metalinin kütlesine bağlı mıdır?

Güvenlik sorunları:

Uzun saçlar toplanmalıdır. Sıcak porselen veya metal malzemelere çıplak elle temas edilmemeli, kroze maşası kullanılmalı. Kükürt elementinin havadaki oksijen ile reaksiyonu sonucunda ortama sağlık için zararlı kükürt dioksit (SO_2) gazı yayılabileceğinden, deney çeker ocak altında yapılmalıdır. SO_2 gazının üst solunum yollarını tahriş edici etkisi vardır. SO_2 gazı burun ve akciğerlerdeki nem ile reaksiyona girerek asit oluşturabilir.

Deneyin Yapılışı:

1. Porselen bir krozeyi kapağıyla birlikte ısıtarak sabit tartıma getiriniz. Krozenin kapağının yere düşüp kırılma ihtimalini göz önünde bulundurarak kroze kapağının kütlesini ayrı olarak da hesaplayınız.
2. 15–25 cm uzunluğunda bir parça bakır tel alıp ölçünüz.
3. Zımpara kağıdı aracılığıyla bakır teli pürüzsüz hale getiriniz.
4. Bakır teli bir kalem etrafında halka ve helezon şeklinde dolandırın, bu bobini ya da sarmalı boş bir krozenin içine koyup kütlesini bulunuz.
5. Bakır bobini tamamen toz haline getirilmiş kükürt ile kaplayınız.
6. Kükürt ile kaplanmış bakır bobini porselen kroze içerisine koyup, krozenin kapağını kapatınız ve krozeyi reaksiyonun durduğuna dair işaretler ortaya çıkana kadar ısıtınız.
7. Bobini kaplamak için daha fazla kükürt ilave ediniz ve süreci tekrarlayınız.
8. Elde edilen ürünün kütlesini bulunuz.

Gözlemler

1. Bakır metal örneği parlak, esnek ve kızıl-kahverengi renkli bir metaldir.

2. Kükürt tozu sarıdır ve un ya da mısır nişastası kıvamındadır.
3. Kroze ısındığı zaman, mor alevler ve beyaz bir buhar ortaya çıkar. Bu buhar burunda ve boğazda tahrişe yol açar.
4. Bir parça kükürt erir ve dışa doğru damlar.
5. Elde edilen ürün kalın, koyu, yoğun, gri-siyah renkli bir sargı/bobindir (bakır telden daha kalındır). Ürün, kırılgandır ve kırıldığında, içinde daha fazla saf bakırın (Cu) olmadığı apaçık ortadadır çünkü bakır tamamıyla siyah renkli ürüne dönüşmüştür.

Deneyde elde edilen verilerin tablosu

Gruplar	Bakırın (Cu) Kütlesi	Bakırın (Cu) mol sayısı	Kükürdün (S) kütlesi	Kükürdün (S) mol sayısı	Bakırın (Cu) mol sayısı / Kükürdün (S) mol sayısı
1	0.4393	0.006913	0.1271	0.003963	1.744:1.000
2	0.4707	0.007407	0.1309	0.004082	1.815:1.000
3	0.9318	0.01466	0.2687	0.008379	1.750:1.000
4	0.8982	0.01413	0.2532	0.007895	1.790:1.000
*5	0.6473	0.01019	0.2535	0.007905	1.289:1.000
6	0.5111	0.008042	0.1604	0.005002	1.608:1.000
*7	0.8150	0.01282	0.3203	0.009988	1.294:1.000
8	0.5953	0.009367	0.1881	0.005865	1.597:1.000

* = Hatalı veri

Sınıfın ortalama mol oranı: 1.611 mol Cu: 1.000 mol S

Hesaplamalar:

$$\text{Bakırın (Cu) mol sayısı} = 0.9318 \text{ g Cu} \times \frac{1\,\text{mol Cu}}{63.55\,\text{g Cu}} = 0.01466 \text{ mol Cu}$$

$$\text{Kükürdün (S) mol sayısı} = 0.2687 \text{ g S} \times \frac{1\,\text{mol S}}{32.07\,\text{g S}} = 0.008379 \text{ mol S}$$

$$\frac{\text{mol Cu}}{\text{mol S}} = \frac{0.01466\,\text{mol Cu}}{0.008379\,\text{mol S}} = \frac{1.750\,\text{mol Cu}}{1.000\,\text{mol S}} \approx 2{:}1$$

İddia

Bakır (II) sülfatın deneysel formülü kullanılan bakır metalinin kütlesine (miktarına) bağlı değildir.

Kanıt

Deneysel olarak, 0.9318 gram bakır tel (0.01466 mol Cu), 0.2687 gram toz haline getirilmiş kükürt (0.008379 mol S) ile reaksiyona girmiştir. Bakırın mol sayısının kükürdün mol sayısına oranı yaklaşık olarak 2:1 dir. Bu sonuç tüm sınıf tarafından desteklenmektedir. Sınıfın ortalama verileri 1.611 mol Cu ile 1.000 mol S'nin (yaklaşık 2:1 oranı) kimyasal reaksiyona girdiğini göstermektedir.

Okuma ve Düşünme:

Her grup farklı uzunluklarda (15–25 cm aralığında) bakır tel kullandıkları halde, Cu'nun S'ye mol oranının nispeten sabit olarak kaldığı bulunmuştur: 1.611 mol Cu: 1.000 mol S. Bu arada iki grubun verilerinin hatalı olduğu tespit edilmiştir (*).

Elde edilen ürünün görünümü pas rengindedir. Bu duruma, bakır (I) sülfite ilaveten yan ürünlerin oluşması neden olabilir. Bakır-kükürt bileşikleri ile okuduklarımız neticesinde, bakır (II) sülfitin 103ºC'de eridiğini öğrendik, bu yüzden ürünümüz CuS olamaz. Bu reaksiyonda kullanılan kükürt miktarı önemli değildir çünkü reaksiyon sonucunda oluşacak ürün bakıra bağlıdır. $2Cu + S \rightarrow Cu_2S$ denklemine göre iki mol bakır ile bir mol kükürt sabit oranlar yasasına göre belirli bir oranda birleşmiştir. Cu_2S bileşiğinde bakır bir elektron vererek yükseltgenirken, kükürt iki elektron alarak indirgenmiştir. Bu reaksiyon hem sentez hem de redoks reaksiyonudur.

APPENDIX I

HANDOUT FOR STUDENTS

Argümantasyon Tabanlı Bilim Öğrenme (ATBÖ) öğrenci merkezli olduğundan dolayı, öğrenciler olarak öğrenme sürecine aktif olarak katılacaksınız ve kendi öğrenmenizden sorumlu olacaksınız. Öğretmeniniz, size bu süreç içerisinde destek olacaktır. Aşağıda sizin ATBÖ süreci esnasındaki sorumluluklarınızın neler olduğu ile ilgili bir taslak sunulmuştur.

1. Derse gelmeden önce

- Merak ettiğiniz ve cevap bulmak istediğiniz soruları belirleyiniz.
- Belirlediğiniz sorulara cevap bulabilmek için izleyeceğiniz aşamaları belirleyiniz.

2. Derste

- Grup olarak araştırmak istediğiniz soruya karar veriniz ve tahtaya sorunuzu yazınız.
- Her grup tahtaya araştırmak istediği soruyu yazdıktan sonar her grubun sorusunu öğretmen rehberliğinde tartışarak soruların deneyle araştırılabilir olup olmadığını tartışınız.
- Her grubun araştırmak istediği sorulara karar verilmesinin ardından her bir sorunun test edilebilmesi için önerilen yöntemlerin uygunluğunu sınıf olarak tartışınız.
- Tüm grup üyeleri aktif olarak katılarak ve uygun prosedürleri takip ederek deneyinizi yapınız.
- Deney süresince gözlediklerinizi ve elde ettiğiniz verileri kaydediniz.
- Verilerinizi yorumlayarak genel bir çıkarımda bulunarak iddianızı belirleyin.
- İddialarınızı uygun delillerle destekleyiniz. Delil olarak doğrudan verileri kullanmayınız. Elde ettiğiniz verileri yorumlayarak, iddianızı destekleyen deliller oluşturunuz.

- Grup olarak tartışarak grup iddianızı ve delillerinizi oluşturunuz.
- Grup olarak diğer gruplara soru, iddia ve delillerinizi sununuz.
- Grupların iddia ve delil sunumu sırasında anlayamadığınız durumlarda gruba sorular yöneltiniz. Sınıf olarak sonuçları tartışınız. Öğretmeniniz sizin tartışmanıza rehberlik edecektir.

8. Dersten sonra,

- Derste öğrendiklerinizi pekiştirmek ya da tartışmak için diğer uygun kaynaklara başvurun. Bu kaynaklar, ders kitabınız, yardımcı kitaplar, internet, öğretmeniniz, vb. olabilir.
- Deney raporlarınızı tamamlayıp bir sonraki haftaya teslim ediniz.

ATBÖ RAPOR FORMATI

1. Başlangıç Soruları

Haftalık olarak ders kitaplarınızdan yapacağınız okumadan sonra, deney yapılarak cevaplanabilecek bir ya da iki soru yazın. Sorular ilgili konu ile ilişkili olmalı ve deney yapılarak cevaplanabilmelidir. Örneğin araştırma sorularınız şu şekillerde olabilir: Kimyasal reaksiyonların hızı sıcaklığa bağlı mıdır? Kimyasal reaksiyonlarda kütle korunur mu? ‘Neden’ soruları deney yapılarak cevaplanamazlar, bu nedenle de araştırma sorusu olarak kullanmak uygun değildir. Örneğin, Neden büret kullanırız? Prosedürü ilgilendiren sorular da uygun değildir. Örneğin, ayrımsal damıtma için düzeneği nasıl kurabilirim?

2. Testler ve Prosedür

Araştırma sorunuza cevap bulabilmek için nasıl bir yol izleyeceğinize karar veriniz ve grup arkadaşlarınızla tartışınız.

3. Gözlemler ve Veriler

Deneyinizi yaparken gözlemlerinizi ve elde ettiğiniz veriler kaydediniz. Verileriniz kaydederken metin yanında resim, grafik, şekil, matematiksel ifade ya da tablo kullanabilirsiniz.

4. İddialar

İddia, sizin araştırma sorularınıza cevap veren ve deneyden elde ettiğiniz verilere dayanan bir ya da iki cümlelik genel bir ifadedir. Örneğin, uygun bir iddia şöyle olabilir: Eğer sıcaklık artar ise, kimyasal reaksiyonun hızı da artar. Uygunsuz, yersiz bir iddia ise şöyle olabilir: Sıcaklık 50^0C den 75^0C ye yükseltilmiştir.

5. Kanıt ve Analizler

Kanıt, iddialarınızı destekleyen açıklamalardır. İddialarınızı destekleyen deliller oluşturmak için deney sonucunda elde ettiğiniz gözlem ve verilerinizi yorumlayınız. Verilerin delil olabilmeleri için yorumlanmaya ihtiyacı vardır. Sadece verileri kullanmak iddialarınızı desteklemek için yeterli değildir. İddialarınızı desteklemek bu verilerin yorumlanması ve açıklanması gerekmektedir. Örneğin, sıcaklık arttığında kimyasal reaksiyonun hızının arttığı iddiası şu şekilde desteklenebilir: Sıcaklık artırılırsa kimyasal reaksiyondaki renk değişimi daha hızlı olur, sıcaklık düşürülürse renk değişimi daha yavaş olur, bu nedenle de kimyasal reaksiyonlarda sıcaklık artarsa reaksiyon hızı artar.

6. Okuma ve Karşılaştırma

Sonuçlarınızı diğer grupların elde ettiği sonuçlar ile karşılaştırınız. Sonuçlarınızı kendi ders kitabınız ya da okuduğunuz diğer kaynaklar ile nasıl karşılaştırırsınız?

7. Yansımalar

Deneyi yamadan önceki düşünceleriniz ile deneyi yaptıktan sonraki düşünceleriniz arasında nasıl bir benzerlik ve farklılık var? Fikirleriniz değişti mi? Yeni sorularınız var mı? Öğrendiklerinizi günlük yaşam ile nasıl ilişkilendirirsiniz?

APPENDIX J

MYSTERY ACTIVITY

Bir Gizemi Çözme: Gözlemler, İddialar, Kanıt ve Hesaplar

Siz ve arkadaşınız, zenginliği ve sessiz yapısı ile oldukça iyi bilinen zengin fakat tuhaf bir adam olan Bay Yıldız'ın ölümünü incelemek üzere kiralanmış olan özel dedektiflersiniz. O, her zaman endişe ve korku hisleriyle dolu olduğundan insanların etrafında bulunmaktan kaçınmıştır. Onun aynı zamanda paranoya rahatsızlığı olduğu da bilinmektedir. Hizmetlilerinin ona karşı gizli bir şekilde komplo kuruyor olmalarından korktuğu için uzun zaman önce işe aldığı hizmetlilerini işten çıkarmıştır. O her gece akşam yemeği olarak aynı yemeği, az-pişmiş kanlı iki biftek ve fırında pişmiş iki patates yerdi.

Size, olay yerine varmanızın üzerine, Bay Yıldız'ın bu sabah erken bir saatte evinde hizmetlileri tarafından ölü olarak bulunduğu anlatılmıştır. Aşçının Bay Yıldız için her zamanki yemeği hazırladığı dün akşam, korkunç fırtına olmasından dolayı, bay Yıldız hizmetlilerin evlerine sorunsuz dönebilmeleri için onlara erken izin vermişti. Hizmetliler sabah geri döndüklerinde Bay Yıldızı yemek odasında yüz üstü yatarken buldular.

Siz, odanın içine bakarak incelemelerinize başlarsınız. Yemek odasındaki büyük pencere camı kırılmış paramparça olmuştur. Cam dışarıdan darbe ile kırılmış gibi görünmektedir. Ölünün vücudunda kesik yaraları teşhis edilmekte ve masanın hemen yanında yüzüstü yatmaktadır. Ayrıca, cesedin tam altında halının üzerinde büyük kırmızı bir leke göze çarpmaktadır. Açılmış vaziyette bir şişe kırmızı şarap ve bir kısmı yenmiş bir biftek masanın üzerinde durmaktadır. Cesedin hemen yanında devrilmiş bir sandalye ve masanın altında üzerinde kan olan bir bıçak görülmektedir. Tüm bu bilgilerle, tek bir iddia ve Bay Yıldız'ın nasıl öldüğünü açıklayabilecek destekleyici kanıt ya da kanıtlar sunun. Söz konusu iddia ve kanıtı olayların gelişim senaryosu içinde anlatınız.

APPENDIX K

SWH LABORATORY REPORT

Deneyin Adı: ______________________________ Adı Soyadı: __________
Deney Masası: ______________________________ Tarih: _______________

1. Başlangıç düşünceleri... Soru ya da sorularım nelerdir? (Yani, bu konu/deney ile ilgili neleri merak ediyorum?)
2. Test... Sorularıma cevap bulmak için ne yaptım? (Yani, merak ettiklerime ulaşmak için ne yaptım?)
3. Gözlemler ve bulgular... Yaptıklarım sonucunda neler buldum? (Yani, merak ettiklerime ulaşmaya çalışırken bulduklarım ve gözlediklerim nelerdir?)

4. İddialar... Bulduklarım ve gözlediklerim sonunda ne iddia ediyorum? (Yani, merak edip araştırdıklarım ile ilgili bu deney sonunda vardığım genel kanaatim kısa ve öz olarak...)
5. Deliller (Kanıtlar)... Bulduklarım ve gözlediklerim sonunda yukarıdaki iddiamı yaptım çünkü delillerim şunlardır: (Yani, bulduklarım ve gözlemlerimden ortaya çıkardığım iddiamı destekleyen deliller...)
6. Okuma ve karşılaştırmalar... Düşüncelerimin başkaları ile karşılaştırılması... (Yani, düşüncemi arkadaşlarımın düşünceleri ile ve kitaptan okuduklarımla karşılaştırdım ve vardığım sonuç...)
7. Yansımalar... Düşüncelerim süreç içinde nasıl değişti? (Yani, konu ile ilgili deneyin başındaki düşüncelerimle deneyin sonundaki düşüncelerimi karşılaştırarak değişimim ile ilgili vardığım sonuç...)

APPENDIX L

SAMPLE SWH LESSON

1. Öğrencilerin ön bilgilerinin ortaya çıkarılması

Öğretmen öğrencilere fiziksel olay ve kimyasal olay denildiğinde ne anladıklarını sorar ve bunlara günlük yaşamlarından örnek vermelerini ister ya da örnekler vererek bunların kimyasal bir değişim mi yoksa fiziksel bir değişim mi olduğunu sorar. Bu sayede öğrencilerde var olan yanlış kavramalar ve bilgi eksiklikleri ortaya çıkarılır.

2. Laboratuvar öncesi etkinlikler

Öğrenciler deneyle cevaplanacak sorular hazırlayarak laboratuvara gelirler. Daha önceden kendi istekleri doğrultusunda oluşturdukları grup içerisinde bireysel olarak merak ettikleri soruları tartışırlar ve grup olarak cevap bulmak istedikleri soruya karar verirler. Her grup tahtaya araştırmak istedikleri soruları yazar. Öğretmen her grubun sorusunu dikkate alarak onlara neyi araştırmak istediklerini ve nasıl araştırmak istediklerini sorar. Bu sayede öğrenciler deney sırasında ne öğreneceklerinin ve neyi niçin yapacaklarının farkına varırlar. Örneğin, 2. gruptaki öğrenciler çay şekerinin fiziksel ve kimyasal değişiminin nasıl olduğunu merak etmiştir ve şu soruyu araştırma sorusu olarak belirlemişlerdir: Çay şekerinin fiziksel ve kimyasal yapısı nasıl değişir?

3. Laboratuvar etkinliğine katılma

Oluşturulan grupların her biri araştırma sorularına uygun prosedürleri takip ederek sorularına cevap bulmaya çalışırlar. 2. gruptaki öğrenciler şu malzemeleri kullanarak deneylerini yaparlar:

- Çay şekeri
- Su
- İspirto ocağı
- 2 adet deney tüpü

Öğrenciler çay şekerinin fiziksel ve kimyasal değişimini incelemek için deney tüplerinin içine 3 ‘er tane küp şeker atarlar. Deney tüplerinden birinin içine biraz su koyarak şekerin çözünmesini sağlarlar. Diğer tüpü ispirto ocağında ısıtırlar. İspirto ocağını kapatıp bir müddet bekledikten sonra deney tüpünün içindeki maddeyi incelerler. Öğretmen laboratuvarda gruplar arasında dolaşarak öğrencileri yönlendirir, gerektiğinde yardım eder ve yönlendirici sorular sorar.

4. Müzakere fazı – I

Öğrenciler bir yandan deneylerini gerçekleştirirken bir yandan da deney etkinliği sırasındaki gözlemlerini ve verilerini kaydederler. Örneğin 2. gruptaki öğrenciler deney tüplerine ait gözlemlerini kaydederler, bu değişimin nasıl bir değişim olduğunu ve neden öyle bir değişim olduğunu her öğrenci tek tek kaydeder.

Öğrencilerden deneye ait gözlem ve bulgularını yorumlamaları sırasında iddia ileri sürmeleri ve bu iddialarına kanıt göstermeleri istenir. Örneğin, 2. gruptaki öğrenciler I. deney tüpü ile ilgili olarak şöyle bir iddia ileri sürer: Şekerin suda çözünmesi fiziksel bir değişimdir. Bu iddialarına kanıt göstermek için öğrenciler, I. deney tüpünde oluşan maddenin şeker özelliği taşıyıp taşımadığına bakarlar. I. deney tüpünde şeker moleküler halde suda çözünerek suyun içinde dağılmıştır. O halde şekerin yapısı değişmemiş olup sadece dış görünüşü değişmiştir. Örneğin, öğrenciler II. deney tüpü ile ilgili olarak da şöyle iddia ileri sürebilir: Yanma olayı kimyasal bir değişimdir. Yanma sonucunda oluşan madde başlangıçtaki maddenin özelliklerini taşımaz. Bu iddialara kanıt göstermek için öğrenciler yanma sonucu oluşan maddenin şeker özelliği taşıyıp taşımadığına bakarlar. II. deney tüpünde şekerin yakılması sonucu, siyahlaşarak kömür haline geldiğini görürler. Şekerin yanması sonucu kimyasal yapısı değişmiş ve kömür haline gelmiştir.

5. Müzakere fazı – II

Her grup kendi içerisinde gözlemlerini paylaşırlar ve karşılaştırmalar yaparak ortak bir sonuca varmaya çalışır. Örneğin, 2. gruptaki öğrenciler ortak iddia ve delillerini şu şekilde oluşturmuşlardır:

İddia: Şekerin yanması kimyasal, çözünmesi fizikseldir.

Deliller: Şeker yanınca kömür gibi oldu. Kömür ile şeker farklı maddelerdir. Bundan dolayı şekerin kimyasal yapısı değişti. Su içine şeker atılarak ısıtıldığında şeker tanecikleri su içerisine dağıldı ve çözündü. Şeker su içerisinde çözündüğünde de şeker tadı alınabilir. Şekerli sudaki suyu buharlaştırarak şekeri kolayca elde edebiliriz. Bu nedenle de şekerin suda çözünmesi fiziksel bir değişimdir.

6. Müzakere fazı - III

Her grup deneyden elde ettikleri bulguları diğer gruplarla paylaşır. Bunun için her grup tahtaya gelerek, neyi araştırdıklarını, nasıl araştırdıklarını ve sonuçta ortaya koydukları iddia ve delillerini paylaşırlar. Bu sırada öğretmen ve/ya öğrenciler sunum yapan gruba sorular sorarlar ve tartışma ortamı meydana gelir. Örneğin, 2. gruptaki öğrenciler iddialarını ve delillerini sunarken içlerinden biri 'şeker suda eridi' ifadesini kullanır. Araştırmacı daha önceden bu kavram yanılgısına karşı öğretmeni uyarmıştı. Bu nedenle öğretmen hemen bu ifade üzerine sınıfa erimenin ne olduğunu, çözünmenin ne olduğunu, şekerin erimesinin nasıl olduğunu, şekerin çözünmesinin nasıl olduğunu sorar. Ayrıca öğrenciler şekerin yanması sırasında kimyasal bir değişim olduğunu ifade ettikleri için, öğretmen onlardan bu ifadelerini denklemle ifade etmelerini ister. Öğrenciler öğretmenin bu isteği karşısında biraz şaşırırlar. Şaşırma sebepleri muhtemelen çay şekerinin günlük yaşamda kullandıkları bir madde olmasıydı. Öğrenciler çay şekerinin formülünü bilmediklerini ifade ederiler. Öğretmen öğrencilere bunu araştırıp daha sonra denklemle ifade etmelerini söyler.

7. Müzakere fazı – IV

Öğrenciler bu deneyin kendilerinde olan yansımalarını yazarlar. Örneğin, deneyden önce ne biliyorlardı, deney sayesinde ne öğrendiler, değişen fikirleri oldu mu, öğrenciler bu sorulara cevap teşkil edecek şekilde bir yazı yazarlar. Yansımalar sayesinde öğrenciler ön bilgileri ile yeni öğrendikleri bilgileri bütünleştirirler. Öğrencilerin bu yazıyı sınıfta yazması beklenmez, evinde de yazabilir. Öğrenciler evlerinde deneye ait bir rapor hazırlayarak bir sonraki derse bu raporu öğretmenlerine teslim ederler. Bu rapor geleneksel laboratuvar raporundan farklılık göstermektedir ve şu bölümlerden oluşmaktadır: başlangıç düşünceleri, test, gözlemler ve bulgular, iddialar, kanıtlar, okuma-karşılaştırmalar ve yansımalar.

8. Değerlendirme

Öğrencilerden laboratuvar etkinliğinin başından sonuna kadar bir değerlendirme süreci içerisindedirler. Öğrencilerin başlangıçta sorular yoluyla ön bilgileri ortaya çıkarılır. Deney yapma aşamasında sürekli öğretmen gruplar arasında dolaşarak onlara neyi niçin yaptıkları ile ilgili sorular sorar, öğrenciler kendi yaptıklarını diğer gruplarla paylaşırken de öğretmen sorular sorar. Ayrıca dersin sonunda bütün gruplar sunumlarını bitirdikten sonra o dersin büyük düşüncesini (Kimyasal olaylarda maddelerin kimlik özellikleri değişir) öğrencilere sorular da sorarak vurgular. Bu arada öğretmen etkinlikler sırasında rastlanan kavram yanılgılarına tekrar vurgu yapar.

APPENDIX M

SAMPLE STUDENT LABORATORY REPORTS

Kimya Laboratuarı Uygulamaları Deney Raporu

Deneyin Adı: Çay Şekerinin Fiziksel ve Kimyasal Değişimi   Adı Soyadı: ____________

Deney Masası: Grup Altıgen (2. Masa)   Tarih: 18/03/2008

1. Başlangıç düşünceleri... Soru ya da sorularım nelerdir?
(Yani, bu konu/deney ile ilgili neleri merak ediyorum?)

1/ Çay şekerinin yanması kimyasal bir değişim midir?

2/ Çay şekerinin çözünmesi fiziksel bir değişim midir?

2. Test... Sorularıma cevap bulmak için ne yaptını?
(Yani, merak ettiklerime ulaşmak için ne yaptım?)

Deney için kullandığım malzemeler; çay şekeri, ispirto ocağı, su ve deney tüpü.
İlk olarak birinci deney tüpüne şeker ve su; diğer deney deney tüpüne ise sadece şeker koydum. Sadece şeker koyduğum deney tüpünü ispirto ocağında ısıttım. Şeker bir süre sonra ısının etkisi ile yandı.

Sonraki adımda ise şeker ile su koyduğum deney tüpünde şeker bir süre sonra suyun içinde çözündü.

3. Gözlemler ve bulgular... Yaptıklarım sonucunda neler buldum?
(Yani, merak ettiklerime ulaşmaya çalışırken bulduklarım ve gözlediklerim nelerdir?)

- Şeker, beyaz rengi olan katı bir maddedir.
Ancak şeker yandığı zaman rengi değişerek kahverengi olmuştur. Buradan da anlaşılacağı gibi maddenin (şekerin) yapısı değişmiştir.
Şeker yandıktan sonra eski haline getirilemeyeceğinden şekerin yanması kimyasal bir değişmedir.
- Şeker, su içerisinde çözünerek renksiz bir çözelti oluşturdu. Oluşan bu çözeltide şeker ile su birbirinden ayrıldığı zaman eski haline getirilebileceğinden şekerin suda çözünmesi fiziksel bir değişimdir.

4. İddialar...Bulduklarım ve gözlediklerim sonunda ne iddia ediyorum?
(Yani, merak edip araştırdıklarım ile ilgili bu deney sonunda vardığım genel kanaatim kısa ve öz olarak...)

1) şekerin yanması kimyasal bir değişimdir.

2/ Şekerin suda çözünmesi fiziksel bir değişimdir.

5. Deliller (Kanıtlar)...Bulduklarım ve gözlediklerim sonunda yukarıdaki iddiamı yaptım çünkü delillerim şunlardır:
(Yani, bulduklarım ve gözlemlerimden ortaya çıkardığım iddiamı destekleyen deliller...)

- Yanan bir maddenin (şekerin) geri dönüşümü olmaz. çünkü maddenin yapısı, şekli vb. gibi özellikleri değişir. Bu nedenle yanma olayları kimyasaldır.
- Maddenin fiziksel değişiminde maddenin (şekerin) dış görüntüsünde değişme olur ve madde tekrar eski haline getirilebilir. Bu nedenle şekerin suda çözünmesi fiziksel-dir.

6. Okuma ve karşılaştırmalar...Düşüncelerimin başkaları ile karşılaştırılması...
(Yani, düşüncemi arkadaşlarımın düşünceleri ile ve kitaptan okuduklarımla karşılaştırdım ve vardığım sonuç...)

Daha önce sınıfta kağıdın yanmasını gözlemlemiştik. kağıt yandığı için kimyasal bir değişime uğramıştı.
Bu deneyde de şeker yanarak, kimyasal değişime uğramış oldu.
şekerin yanma denklemi : $C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$ 'dir.
Su içerisinde çözünen şeker ise fiziksel değişime uğradı.
Kitaptan okuduğum bilgilere göre de yanma olayları kimyasal; çözünme olayları ise fizikseldir.

7. Yansımalar...Düşüncelerim süreç içinde nasıl değişti?
(Yani, konu ile ilgili deneyin başındaki düşüncelerimle deneyin sonundaki düşüncelerimi karşılaştırarak değişimim ile ilgili vardığım sonuç...)

Bu deneyi yapmadan önce suda şekerin çözünmesi sonucunda yapısında bazı değişikliklerin olabileceğini düşünüyordum. Ancak bu deneyi yaptıktan sonra çözünme olaylarında maddenin yapısında bir değişiklik olmadığını, bundan dolayı da fiziksel değişime uğradığını öğrendim. Yanma olaylarında da maddenin yapısının tamamen değiştiğini ve bu nedenle kimyasal değişime uğradığını öğrendim.

Kimya Laboratuarı Uygulamaları Deney Raporu

Deneyin Adı: Ayrışma Adı Soyadı: ____________

Deney Masası: 1. Masa (Soygazlar) Tarih: 13.05.2009

1. Başlangıç düşünceleri... Soru ya da sorularım nelerdir?
(Yani, bu konu/deney ile ilgili neleri merak ediyorum?)

Her maddenin ayrışma türü aynımıdır?
Ayrışma nedir?
Ayrıştırma yöntemleri ile ayırma nasıl yapılır?

2. Test... Sorularıma cevap bulmak için ne yaptım?
(Yani, merak ettiklerime ulaşmak için ne yaptım?)

Bir beherglas aldık.
İçine biraz su koyduk.
Sonra bir miktar demir tozu ekledik.
Biraz bekledik ve içine tahta parçaları koyduk.
İçine birde bir miktar şeker ekledik.
Ve beklemeye başladık.
Hepsini beraber iyice karıştırdık.

3. Gözlemler ve bulgular... Yaptıklarım sonucunda neler buldum?
(Yani, merak ettiklerime ulaşmaya çalışırken bulduklarım ve gözlediklerim nelerdir?)

Bekledik ve demir tozu dibe çöktü. Tahta parçaları suyun üstüne çıkıp yüzmeye başladı. Burdan demir tozunun özkütlesinin tahta parçalarından yüksek olduğunu gördük. Şeker suyun içinde çözündü. Tahta parçalarını yüzdürme yöntemiyle bu karışımdan ayırdık. Karışım içinde demir tozu, şeker ve su kaldı. Süzgeç kâğıdı yardımıyla demir tozunu su ve şeker çözeltisinden ayırdık. Sonra sadece şeker ve su çözeltisini ısıtarak suyu buharlaştırdık ve şeker dipte kaldı.

4. İddialar... Bulduklarım ve gözlediklerim sonunda ne iddia ediyorum?
(Yani, merak edip araştırdıklarım ile ilgili bu deney sonunda vardığım genel kanaatim kısa ve öz olarak...)

Her maddenin farklı bir özelliği vardır. Bütün maddeler birbirine benzemez. Bu nedenle ayrışma yöntemleride birbirinden farklıdır.

5. Deliller (Kanıtlar)... Bulduklarım ve gözlediklerim sonunda yukarıdaki iddiamı yaptım çünkü delillerim şunlardır:
(Yani, bulduklarım ve gözlemlerimden ortaya çıkardığım iddiamı destekleyen deliller...)

Çünkü, demir tozu, tahta parçaları, şeker ve suyu karıştırdık ama aynı yöntemlerle birbirinden ayrılamadılar. Tek bir yöntemle birbirlerinden ayrılamadılar. Tahta parçalarını yüzdürme yöntemiyle ayırdık. Tahta parçaları suyun üstünde yüzüyordu. Demir tozunu süzme yöntemiyle ayırdık. Su ve şekeride ısıttık su buharlaştı. Şekerde dipte kaldı.

6. Okuma ve karşılaştırmalar...Düşüncelerimin başkaları ile karşılaştırılması...
(Yani, düşüncemi arkadaşlarımın düşünceleri ile ve kitaptan okuduklarımla karşılaştırdım ve vardığım sonuç...)

Buna benzeyen bir deney olarak kum, tuz, su çözeltisi yapmıştık. Kumu süzme yöntemiyle ayırmıştık. Tuzu sudan ise yine buharlaştırma yöntemiyle ayırmıştık. Tuzda dibe çökmüştü. Kitaplardan okuduğum ve öğretmenlerimizin anlattıklarına göre bu deneyi düzgün bir şekilde yapmış oldum. Böylece ayrışma yöntemlerini öğrenmiş olduk.

7. Yansımalar...Düşüncelerim süreç içinde nasıl değişti?
(Yani, konu ile ilgili deneyin başındaki düşüncelerimle deneyin sonundaki düşüncelerimi karşılaştırarak değişimim ile ilgili vardığım sonuç...)

Ayrışmaların hangi maddelerde nasıl meydana geldiğini bilmiyordum. Bu deneyle hem ayrışma yöntemlerini hem de bu yöntemlerin hangi maddelerde meydana geldiğini öğrenmiş oldum. Başlangıç sorularıma cevap buldum.

CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS without Thesis	Selçuk U, Chemistry Education	2004
High School	Adana Laboratory Health HS	1999

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2005-	METU, Department of SSME	Research Assistant

FOREIGN LANGUAGES

Advanced English, Basic German