EFFECTIVENESS OF 5E LEARNING CYCLE MODEL ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF SOLUBILITY EQUILIBRIUM CONCEPT

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ABSTRACT

EFFECTIVENESS OF 5E LEARNING CYCLE MODEL ON HIGH SCHOOL STUDENTS' UNDERSTANDING OF SOLUBILITY EQUILIBRIUM CONCEPT

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The purpose of this study was to investigate the effect of instruction based on 5E learning cycle model (LCI) compared to Traditional Instruction (TI) and gender on 11^{th} grade students' understanding of solubility equilibrium concept, students' perceived motivation, use of learning strategies, and attitudes towards chemistry. There were 53 students in the experimental group instructed by the LCI and 56 students in the control group instructed by the TI. Solution Concept Test and Science Process Skills Test were administered to students in both groups as a pre-test. Attitude Scale towards Chemistry and Motivated Strategies for Learning Questionnaire were given to students in both groups before and after the treatment. Moreover, Solubility Equilibrium Concept Test was administered to both groups as a post-test and retention test two months after treatment. Treatment implementation continued for seven weeks. After the instruction, semi-structured interviews were conducted with six students from experimental group and six students from control group. Data were analyzed by using MANCOVA. The results revealed that LCI was more effective than the TI on students' understanding and retention of the solubility equilibrium concepts. In addition, LCI improved students' attitudes towards chemistry, intrinsic goal orientation, task value, self-efficacy for learning and performance, rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning. Moreover, females found as more positive towards chemistry and better organization and help seeking. Furthermore, interview results indicated that students in experimental group demonstrated better scientific understanding of solubility equilibrium concepts compared to those in control group.

Keywords: Learning Cycle Model, 5E Learning Cycle Model, Solubility equilibrium, Attitude towards Chemistry, Motivation

ÖZ

5E ÖĞRENME MODELİNİN LİSE ÖĞRENCİLERİNİN ÇÖZÜNÜRLÜK DENGESİ KONUSUNU ANLAMASINA ETKİSİ

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Bu çalışma, Geleneksel Kimya Ögretim Yöntemi (GKÖY) ile kıyaslandığında, 5E öğrenme döngüsü yönteminin (ÖDY) ve cinsiyetin 11. sınıf öğrencilerinin çözünürlük dengesi konusunu anlamaları, motivasyonları, öğrenme stratejilerini kullanmaları ve kimya dersine karşı tutumları üzerindeki etkisini incelemeyi amaçlamıştır. Deney grubunda 53 öğrenci bulunup ÖDY ile öğretim yapılırken kontrol grubunda 56 öğrenci olup GKÖY ile öğretim yapılmıştır. Çözünürlük Kavram Testi (ÇKT) ve Bilimsel İşlem Beceri Testi (BİBT) her iki gruptaki öğrencilere uygulamadan önce ön test olarak uygulanmıştır. Kimya Dersine Karşı Tutum Ölçeği (KTÖ) ve Öğrenmede Güdüsel Stratejiler Anketi (ÖGSA) uygulamadan önce ve sonra her iki gruba uygulanmıştır. Ayrıca Çözünürlük Dengesi Kavram Testi öğrencilerin çözünürlük dengesi kavramlarını anlamalarında öğretimin etkisini ölçmek için her iki gruba son test ve uygulamadan iki ay sonra tekrar testi olarak verilmiştir. Uygulama yedi hafta sürmüştür. Araştırmanın bitiminde deney grubundan 6 kontrol grubundan da 6 öğrenci ile yarı-yapılandırılmış görüşmeler yapılmıştır. Bu çalışmadan elde edilen nicel veriler MANCOVA yöntemi kullanılarak analiz edilmiştir. Sonuçta, geleneksel yönteme kıyasla 5E öğrenme döngüsü yaklaşımının 11. sınıf öğrencilerin çözünürlük dengesi kavramlarını anlama ve hatırlama düzeylerinde daha etkili olduğu bulunmuştur. Ayrıca, 5E ögrenme modeline dayalı ögretimin ögrencilerin kimyaya karşı tutumlarına, içsel motivasyon, değer verme, öğrenmeye yönelik öz-yeterlik, tekrar stratejileri, detaylandırma, örgütleme, eleştirel düşünme, bilişötesi özdüzenleme, çalışma ortamı ve zamanı ve eşli öğrenmelerine etkisi olduğu tespit edilmiştir. Kızların kimyaya karşı daha positif tutumlarının olduğu ve örgütleme ve yardım arama becerilerinde daha iyi oldukları bulunmuştur. Ek olarak, görüşmeden elde edilen sonuçlar deney grubundaki öğrencilerin kontrol grubundakilere kıyasla çözünürlük dengesi kavramlarını anlamada daha iyi olduğunu göstermiştir.

Anahtar Sözcükler: Öğrenme Halkası, 5E Öğrenme Modeli, Çözünürlük Dengesi, Kimyaya Karşı Tutum, Motivasyon

To my husband Murat Aydemir

&

To my daughter Nilüfer Elvan Aydemir

&

To my expected son

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LIST OF ABBREVIATIONS

SCT:	Solution Concept Test
SECT:	Solubility Equilibrium Concept Test
SERT:	Solubility Equilibrium Retention Test
ASTC:	Attitude Scale toward Chemistry
SPST:	Science Process Skill Test
MSLQ:	Motivated Strategies for Learning Questionnaire
5EIM:	Instruction based on 5E Learning Cycle Model
TDCI:	Traditionally Designed Chemistry Instruction
IGO:	Intrinsic Goal Orientation
EGO:	Extrinsic Goal Orientation
TV:	Task Value
CLB:	Control of Learning Beliefs
SELP:	Self-Efficacy for Learning and Performance
TA:	Test Anxiety
R:	Rehearsal
E:	Elaboration
O:	Organization
CT:	Critical Thinking
MSR:	Metacognitive Self-regulation
TSE:	Time and Study Environmental Management
ER:	Effort Regulation
PL:	Peer Learning
HS:	Help Seeking
EG:	Experimental Group
CG:	Control Group

CHAPTER 1

INTRODUCTION

In recent years, studies in chemistry education have increased and especially how students learn and the factors that influence their learning have become important. Many researches in the literature revealed that students come to the classes with ideas, expectations, and conceptions (Bodner, 1986; Driver, Guesne, & Tiberghien, 1985). Generally, students bring these prior understandings from daily life experiences (Boo, 1998). These kinds of ideas are labed as misconceptions (Chambers & Andre, 1997; Nakhleh, 1992; Nussbaum, 1981), alternative conceptions (Gilbert & Swift, 1985; Taber, 2001) or children's ideas (Osborne & Wittrock, 1983). These ideas are personal, stable, and different from the scientifically accepted concepts. Many studies supported the notion that misconceptions are so powerful in that that they impede students' learning and they are not often completely eliminated even after the instruction (Andersson, 1986; Bilgin & Geban, 2006; Canpolat, Pınarbasi, Bayrakceken, & Geban, 2006; Calik, Kolomuc, & Karagolge, 2010; Driver & Easly, 1978; Duit, 2007; Pinarbasi, Canpolat, Bayrakceken, & Geban, 2006). Therefore, researchers sought ways to improve students' understanding of scientific conceptions and developed various instructional strategies based on constructivism.

Constructivism is a learning theory, which pays attention to the students' prior knowledge. According to constructivism, learners construct the knowledge in the their mind (Rowlands & Carson, 2001). Constructivism stems from the works of Piaget, Bruner, Vygotsky, and Ausubel. Piaget believed that individuals construct knowledge through a continuous self-construction process. Piaget defined three processes critical to cognitive development: assimilation, accommodation, and equilibration. If a child uses existing concepts to perceive new objects or events, this is called assimilation. When students' existing concepts are inadequate to explain new experience, then accommodation occurs. Equilibration encompasses both assimilation and accommodation and it determines the child's transition from one stage of development to the next. Bruner and Vygotsky stressed the importance of social and cultural factors on construction of knowledge. Moreover, Ausubel focused on meaningful learning by considering existing knowledge as the most influential factor efffecting learning (Driscoll, 1994). In constructivist view, it is important to eliminate students' misconceptions. Therefore, many learning models were developed to deal with misconceptions. One of them is conceptual change model.

Conceptual change is one of the most effective strategies in the application of constructivist ideas to science instruction (Hewson & Thorley, 1989). There is a difference between the ideas of conceptual change approach and constructivism. Constructivism emphasizes general process of learning, but conceptual change approach emphasizes the specific conditions which must be fulfilled for the modification of existing conceptions by new ones (Weaver, 1998).

Posner, Strike, Hewson, and Gertzog (1982) proposed first conceptual change model. According to conceptual change model, learning occurs through the construction of knowledge in appropriate conditions. Two type of conceptual change were specified: Assimilation and accommodation. For the assimilation, existing concepts are used to deal with new phenomena. However, for the accommodation, existing concepts are insufficient to understand new phenomenon. Accordingly, existing concepts are replaced or reorganized with adequate ones (Posner et al., 1982). Four conditions for accomodation were suggested Posner et al. (1982). These are: a) new conception must formed dissatisfaction with prior conceptions, b) there must be intelligible, c) there must be plausible, d) a new concept should be fruitful.

There are various conceptual change strategies targeting students' acquisition of scientific conceptions or remediation of misconceptions. One of the techniques used for elimination misconceptions is conceptual change text (Yuruk & Geban, 2001). In conceptual change model text, a question is asked students to make prediction about a situation. Later some common students' misconceptions in science are presented. Then, scientifically correct statements are given (Chambers & Andre, 1997). Many researches supported that conceptual change texts are effective for meaningful learning and conceptual change (Balci, Cakiroglu, & Tekkaya; 2006; Sungur, Tekkaya, & Geban, 2001; Uzuntiryaki & Geban, 2005).

Besides conceptual change texts, learning cycle model is also used for promoting conceptual change. Learning cycle model is grounded on constructivism: The three phase learning cycle was derived from Piaget's mental functioning model. The three phases were initially called preliminary exploration, invention, and discovery (Karplus & Thier, 1969). Later, the names of the phases in the learning cycle have been modified (Abraham & Renner, 1986; Glasson & Lalik, 1993). More recently, they were referred to as exploration, term introduction, concept application (Lawson, Abraham & Renner, 1989). In the exploration phase, students explore new materials and new ideas through their own actions with minimum guidance. In term introduction phase, the terms, which refer to the patterns discovered during the exploration phase, are introduced by the textbook, the teacher, a film or another medium. In concept application phase, the new concept is applied in additional situations (Lawson et al., 1989). The phases of learning cycle are consistent with the principles of Piaget's theory. The exploration phase facilitates assimilation, the term introduction phase demonstrates the information to be accommodated, and the concept application phase provides opportunities for the organization of newly acquired knowledge (Abraham, 2003). Learning cycles can be classified as descriptive, empirical-abductive, and hypothetical-deductive. In descriptive learning cycles, the data are gathered in a descriptive manner without explanation but in hypothetical-deductive learning cycles, alternative hypotheses are generated and tested. Empirical-abductive learning cycles are intermediate and data gathering process requires both description and explanation (Lawson et al., 1989).

The three phase learning cycle has been expanded into 4E, 5E, 6E, and 7E models by adding more phases. A popular form of the learning cycle is the 5E instructional model and it involves the five phases: Engagement, exploration, explanation, elaboration, and evaluation. It integrates two more phases into the three original learning cycle phases. The engagement phase is designed to gain students' attention, make connection between prior concepts and new concepts, and elicit students' misconceptions. The evaluation phase gives the opportunity for students to evaluate their understanding and for teachers to determine student's level of understanding. 5E instructional model is designed to facilitate conceptual change process (Bybee, Trowbridge, and Powell, 2004). Moreover, Eisenkraft (2003) expanded the 5E model into 7E model in order to ensure instructors do not omit 'transfer of learning' and 'eliciting prior knowledge' in their learning cycle lessons. In 7E model, engagement phase is expanded into elicitation and engagement phases, and elaboration and evaluation phases are expanded into elaboration, evaluation, and extension phases.

A large body of learning cycle research has been conducted including its effect on conceptual understanding (Ates, 2005; Musheno & Lawson, 1999), reasoning abilities (Johnson & Lawson, 1998; Lawson, 2001), attitudes (Cavallo & Laubach, 2001; Yilmaz & Huyuguzel Cavas, 2006), science process skills and logical thinking skills (Lavoie, 1999; Westbrook & Rogers, 1994), and elimination of misconceptions (Balci et al., 2006). These studies confirmed that learning cycle approach has many advantages over traditional instruction in terms of attitudes towards science, science process skills, thinking skills and conceptual understanding. Its power comes from the inductive use of the laboratory and defined phases of instruction (Abraham, 2003).

Students' misconceptions and learning difficulties in chemistry constitute a problem because most phenomena discussed in chemistry are abstract in nature, and thereby students have a lot of misconceptions in chemistry (BouJaoude, 1991). Most of the studies dealing with students' misconceptions in chemistry have been focused on chemical equilibrium (Gussarsky & Gorodetsky, 1990; Huddle & Pillay, 1996; Quilez-Pardo & Solaz-Portoles, 1995; Voska & Heikkinen, 2000; Thomas & Schwenz, 1998), thermodynamics (Kesidou & Duit, 1993; Thomas & Schwenz, 1998), stoichiometry (Huddle & Pillay, 1996), nature of matter (Haidar & Abraham, 1991; Lee, Eichinger, Anderson, Berkheimer, & Blakeslee., 1993; Renström, Andersson, & Marton, 1990), mole concept (Staver & Lumpe, 1995), chemical bonds (Boo, 1998), electrochemistry (Sanger & Greenbowe, 1999), general and organic chemistry (Zoller, 1990). On the other hand, there are few studies on solubility equilibrium (Cam, 2009; Onder & Geban, 2006; Raviolo, 2001). Solubility equilibrium is one of the most important topics in high school chemistry since students often hold misconceptions in this topic. In addition, solubility, solution, solute, Le Chatelier's principles, physical and chemical equilibrium are crucial pre-requisite concepts for learning solubility equilibrium. These pre-requisite concepts are also abstract in nature and students often misunderstand those concepts. Therefore, it is important to investigate how students change their misconceptions on solubility equilibrium.

Since science learning cannot be explained only by examining cognitive factors, learners' attitudes should also be considered. One of the affective constructs influencing students' learning is their attitudes towards subject matter. Several studies in science education investigated the relationship between students' attitudes towards chemistry and their achievement. There were different relationships between attitudes towards science and science achievement. Several studies detected that there was a positive correlation between attitude and achievement (e.g., Altun Yalcin, Acisli, & Turgut, 2010; Greenfield, 1997; Ozden, 2008; Sasmaz Oren & Tezcan, 2009).

Motivation and self-regulation effect students' learning in various disciplines (Pintrich & De Groot, 1990; Uredi & Uredi, 2005). Uredi and Uredi (2005) found that self-regulation is a significant predictor of student achievement with high-achieving students demonstrating a greater use of self-regulatory strategies than low-achieving students do. Previous research demonstrated that learning cycle model (Ceylan, 2008; Saygin, 2009; Yilmaz, 2007), and instructional approaches based on constructivism (Sungur & Tekkaya, 2006) are effective in developing students' perceived motivation and use of learning strategies.

As mentioned above, learning cycle model can be effective on students' acquisition of chemistry concepts by promoting the conceptual change, and has a potential of improving students' attitudes towards chemistry, motivation to learn chemistry and use of learning strategies. Therefore, the present study aimed to identify and examine students' misconceptions about solubility equilibrium concepts. This study also aimed to compare the effectiveness of instruction based on 5E learning cycle model and instruction based on traditional method with respect to a) understanding of solubility equilibrium concepts, b) students' attitudes towards chemistry as a school subject, c) students' perceived motivation, d) students' perceived use of learning strategies. Students' ideas about the implementation of 5E learning cycle model were further investigated in this particular research.

1.1 Significance of the Study

Students often hold some ideas, interpretations, and concerns even if they do not take any formal instruction regarding the subject matter (Chandran, Treagust, & Tobin, 1987; Reynolds & Walberg, 1992; Uzuntiryaki & Geban, 2005). Some of these prior understandings are not congruent with the scientific conceptions (Driver et al., 1985). These understandings are often labeled as misconceptions by many researchers (Chambers & Andre, 1997; Nakhleh, 1992; Nussbaum, 1981). Most of misconceptions are resistant to change and they are not completely eliminated through regular instruction (Driver & Easly, 1978; Fisher, 1985; Hynd, McWhorter, Phares, & Suttles, 1994) because they are embedded in students' alternative beliefs system (Boujaoude, 1991; Guzzetti, 2000; Hewson & Hewson, 1988; Taber, 2001).

Students' misconceptions in all chemistry grade levels create a main problem to science educators, researchers, students, and teachers (Nussbaum & Novick, 1982). Because most of the chemical phenomena are hard to understand due its abstract character, which results in various misconceptions (Gabel, 1999). Students having misconceptions in basic chemistry concepts struggle with learning further concepts because new conceptions are integrated with existing conceptions. It would be hard for the students having misconceptions to acquire new conceptions scientifically. Therefore, determination of students' misconceptions is very crucial in chemistry teaching. Once teachers identify their students' misconceptions, they can design their instruction based on those specified misconceptions and they can use various instructional strategies for the remediation of those misconceptions. Therefore, one of the aimes of the current research is to identify students' misconceptions about solubility equilibrium concepts. Another aim is to eliminate those specified misconceptions using instruction based on 5E learning cycle model.

Instruction based on 5E learning cycle model includes hands on activities, daily life examples, conceptual change texts, and demonstrations in order to eliminate misconceptions and promote meaningful learning. Daily life examples are helpful to take students' attention to the subject. Moreover, 5E learning cycle instruction including daily life examples and small group activities could eliminate students' misconceptions in chemistry topics and help students to construct new conceptions.

Solubility equilibrium is an important topic in chemistry since students should have scientific understanding of solubility, solution, solute, Le Chatelier's principles, physical and chemical equilibrium prior to the instruction of solubility equilibrium (Raviolo, 2001). Because of its abstract nature, solubility equilibrium concepts are hardly understood by the students and students often hold misconceptions in solubility equilibrium. Therefore, it is important to investigate how students change their misconceptions on solubility equilibrium. In addition, there is limited study related to students' misconceptions about solubility equilibrium (e.g., Cam, 2009; Onder, 2006; Raviolo, 2001). Therefore, in the present study, students' misconceptions about solubility equilibrium were investigated and instruction based on 5E learning cycle was applied in order to promote conceptual change in students.

Affective factors are influential in students' learning as well as cognitive factors (Duit & Treagust, 2003). Besides promoting scientific acquisition of scientific knowledge, an effective science instruction also encourages individuals to apply their acquired knowledge into new and real-world situations. Students having positive attitudes toward subject matter, who are motivated to learn and demonstrating use of learning strategies can plan a strategy for problem solving, are conscious of their own steps and strategies during problem solving, and can reflect on and evaluate their own decision-making processes (Baird, 2003). Because attitude, motivation, and self-regulation play a critical role in successful learning, it is worth to develop students' attitudes towards chemistry, motivation to learn chemistry and use of learning strategies by using appropriate instructional strategies. Learning cycle model was found effective in developing students' attitudes towards subject matter (Altun Yalcin et al., 2010; Sasmaz Oren and Tezcan, 2009), perceived motivation and perceived use of learning strategies (Ceylan, 2008; Saygin, 2009; Yilmaz, 2007). Therefore, the effect of instruction based on 5E learning cycle model on students attitudes towards chemistry, perceived motivation and perceived use of learning strategies were also investigated in this particular study.

1.2 Definition of Important Terms

In this section, the definitions of important terms were given.

Misconception: students' concepts or ideas that differs from the views of scientists (Nakhleh, 1992).

Constructivism: a theory of learning that emphasizes students' misconceptions in order to construct new scientific concepts.

Conceptual change approach: an effective strategy for eliminating students' misconceptions in science classes. In this approach, students should be dissatisfied with their existing ideas first. Then, students presented new concepts and it is explained that these concepts should be parallel to the knowledge in other areas. Finally, they should be led to new insights (Posner et al., 1982).

Traditional instruction: an instruction in which students are taught by means of lecture. That is, students are passive during the instruction.

Learning cycle: a three step instructional sequence that includes exploration, term introduction and concept application

5E learning cycle: an expanded version of three-phase learning cycle including engagement, exploration, explanation, elaboration, and evaluation.

Attitude towards chemistry: involves interest in chemistry, attitude about chemists, attitudes towards methods of teaching chemistry, and attitudes toward the use of chemistry (Parker, 2000).

Motivation: is an internal state that arouses, directs, and maintains behavior (Woolfolk, 1998).

CHAPTER 2

LITERATURE REVIEW

Many researches in the science education literature are concerned students' understanding of scientific phenomena. Learning new knowledge will be meaningful to the degree that learners can relate it to the ideas that they already understand. Therefore, learning in science should be seen as a rearrangement of previous ideas rather than just adding information to previous knowledge (Hackling & Garnett, 1985). Learning is an active process in which knowledge is constructed through the combination of new concepts with the prior concepts. Science educators have been focused on changing misconceptions with scientifically accepted ideas since the students have difficulty in changing their misconceptions in traditionally designed science lesson (Jones & Beeth, 1995).

Research in students' conceptual knowledge is based on a model of learning in which students construct their own concepts (Osborne & Wittrock, 1983). Students develop ideas even without teaching takes place. Some of these ideas are not consistent with the scientific understandings (Driver et al., 1985), and they are often called as misconceptions (Nakhleh, 1992). Students have misunderstandings and learning difficulties in various chemistry topics (Garnett, Garnett, & Hackling, 1995). Several studies dealt with identifying and eliminating students' misconceptions encountered in chemistry (Bilgin & Geban, 2006; Ceylan & Geban, 2009, 2010; Calik, Ayas, & Coll, 2007, 2009; Cetingül & Geban, 2011; Gussasky & Gorodetsky, 1990; Huddle & Pillay, 1996; Ozmen, 2008). The concept of solubility equilibrium is a main part of the chemistry curriculum. The studies on the concept of solubility equilibrium have shown that students struggle with learning solubility equilibrium concepts because similar to other topics of chemistry solubility equilibrium include abstract concepts, and therefore students do not understand solubility equilibrium concepts (Garnett et al., 1995). On this ground, the following review aims to provide a necessary background for the current study. The literature review consists of the following parts: Misconceptions, constructivism and conceptual change, learning cycle approach, research on learning cycle model, attitude, motivation and self-regulation, and summary of the findings of the reviewed studies.

2.1 Misconceptions

Concept is defined as a scientifically desired knowledge that is given to the learner through his/her formal education. It is established that children improve their personal ideas and experience during daily life (Andersson, 1986).

It has been widely accepted that students come to the class with certain ideas, expectations, and concepts. However, some of these intuitively held ideas differ from scientifically accepted ones. These kinds of ideas are referred to as "preconception" (Benson, Wittrock, & Baur, 1993), "misconception" (Brown, 1992; Chambers & Andre, 1997; Din, 1998; Gonzalez, 1997; Griffiths, 1994; Griffiths & Preston, 1992; Helm, 1980; Lawson & Thompson, 1988; Michael, 2002; Nakhleh, 1992; Nussbaum, 1981; Schmidt, 1997; Treagust, 1988), "alternative conception" (Dykstra, Boyle, & Monarch, 1992; Gilbert & Swift, 1985; Niaz, 2001; Palmer, 2001; Taber, 2001; Wandersee, Mintzes, & Novak, 1994), "alternative frameworks" (Gonzalez, 1997; Kuiper, 1994; Taber, 1999), "children's science" (Gilbert, Osborne & Fensham 1982; Stenhouse, 1986), "children's scientific intuitions" (Sutton, 1980), "naive conception" or "naive beliefs" (Caramaza, McCloskey & Green, 1981), and "intuitive ideas" (Hynd, et al., 1994).

Students' misconceptions in at all levels create a main problem of concern to science educators, scientist-researchers, students, and teachers (Nussbaum & Novick, 1982). Misconceptions are embedded in students' alternative beliefs system; therefore, most of misconceptions are resistant to change (Boujaoude, 1991; Guzzetti, 2000; Hewson & Hewson, 1988; Taber, 2001). Generally, the possible sources of students' misconceptions are "prior knowledge" (Driver & Easley, 1978; Driver & Erickson, 1983; Palmer, 1999; 2001; Posner et al., 1982; Taber, 2000), textbooks (Barrow, 2000; Chiu, 2005; Sanger & Greenbowe, 1999; Storey, 1989; Ozkaya, Uce, & Sahin, 2003), teacher (Birk & Kurtz, 1999; Calik & Ayas, 2005; Ebenezer & Erickson, 1996; Gilbert & Zylbersztajn, 1985; Valanides, 2000, Taber, 2001), everyday language (Boo, 1998; Papageorgiou & Sakka, 2000; Prieto, Blanco, & Rodriguez, 1989), and instructional strategies (Feltovich, Spiro & Coulson, 1989; Fisher, 1985; Haidar & Abraham, 1991).

A variety of methods has been developed to probe children understanding of natural and technological concepts and to discover the meaning children have for the words they use in explaining things that happen in the world (Osborne & Wittrock, 1983). Most of these methods involve in depth interviews that focus on specific aspects of problems and more general interviews which attempt to discover that a person knows about a topic (Osborne & Gilbert, 1980).

2.1.1 Misconceptions in Solubility Equilibrium

Solubility equilibrium occurs between the undissolved and dissolved solute in a saturated solution at a particular temperature (Silberberg, 2007). When adding soluble ionic compound into water, compounds dissolved into ions. Then, ions produce more solid, and precipitation occurs. At the end of this process, the equilibrium exists. At the equilibrium, the dissolving and precipitation rates are equal. Because of its abstract nature, solubility equilibrium concepts are hardly understood by the students. Therefore, students often hold misconceptions in solubility equilibrium. The studies investigating students' misconceptions of solubility equilibrium were discussed in the following section.

Raviolo (2001) assessed students' conceptual understanding of solubility equilibrium and diagnosed difficulties in relation to previous concepts including dissolution, stoichiometry, chemical equations, the particular nature of matter, ionic compounds, chemical equilibrium characteristics, solubility, the common ion effect, and Le Chatelier's principle. The students were given a figure showing a system in equilibrium between AgCl (a less soluble salt, Ksp = 1.6×10^{-10}) and its ions, surrounded by water molecules. Then students were asked to 1) describe the phenomenon from the moment the salt was added to the water using the previous concepts (macroscopic description), 2) write down the corresponding chemical equation (symbolic representation), and 3) draw situations before equilibrium, at equilibrium and at a new equilibrium after the addition of $AgNO_3$ to the system (microscopic representation). The results revealed that students had trouble when writing the chemical equation (2nd question). It was difficult for the students to relate the microscopic and symbolic levels. Some students could not incorporate the corresponding aggregation states. Some of the students omitted the double arrow. Some confused the chemical equation with the particular experimental situation (e.g., they wrote $AgCl_{(s)} \leftrightarrow 3Cl^{-}_{(aq)} + 3Ag^{+}_{(aq)}$ according to the number of ions in solution drawn in the given figure). Students also encountered difficulties in depicting the particle representations asked in the 3rd question. For example, some students dissolved all the salt or completely precipitated it rather than considering the coexistence of both the precipitate and ions in the equilibrium situation. In applying the Le Chatelier's principle or the common ion effect in question 3, students failed to maintain the solution's neutrality although they stated that solubility of AgCl decreases with the addition of $AgNO_3$.

Akaygun (2009) investigated students' mental models of solubility equilibrium. The study was conducted with 10 high school students, 32 second-semester college general chemistry students, four university chemistry instructors, and two high school chemistry teachers. An open-ended questionnaire on solubility equilibrium was administered to the participants. The mental models of experts and novices were identified and compared in this study. Then, a treatment which is a simulation or screen-captured animation of the same simulation was applied to novices. Novices' mental models on solubility equilibrium were assessed before and after using simulation. The results revealed that novice mental models were found to be similar to expert mental models at the macroscopic level but at the molecular level the novices were less likely to emphasize the dynamic nature of equilibrium and held specific misconceptions. For example, some novice mental models of solubility equilibrium were found to include a chemical reaction between solute and solvent.

Onder and Geban (2006) assessed students' conceptions of solubility equilibrium in their study investigating the effects of conceptual change text oriented and traditional instructions in learning solubility equilibrium. For the assessment of students' conceptions, a multiple-choice test was used. Distracters of each item in the test reflected students' misconceptions about solubility equilibrium. After the treatment, the following misconceptions were detected as common among the students in both groups (Onder, 2006):

- There is no relationship between Ksp and solubility.
- The temperature has no effect on solubility.
- At equilibrium, the concentration of ions will remain constant although common ion is added.
- At equilibrium, there is no precipitation and dissolution.
- Solubility of sparingly soluble salts is affected by change made in pressure and volume.
- At a given temperature, the value of Ksp changes with the amount of solid or ions added.
- At equilibrium addition of salt effects the equilibrium
- At equilibrium the concentrations of the ions produced is equal to the concentration of the salt

- Mass can be used instead of concentration in solubility equilibrium calculation.
- At equilibrium the concentrations of the ions produced is equal to the concentration of the salt.
- At a given temperature, Ksp can change.
- At a given temperature, the value of Ksp changes with the amount of solid or ions added.
- Rate of dissolving increases with time from mixing the solid with solvent until equilibrium establishes.
- As the magnitude of the Ksp increases, the rate of solubility increases
- Ion product (Qi) can be used interchangeably with Ksp.
- The value of Ksp always decreases, as temperature decreases.

Similar to Onder and Geban (2006), Cam (2009) assessed students' understanding of solubility equilibrium conceptions in her study investigating the effects of case-based and traditional instructions in learning solubility equilibrium. Students' understanding of solubility equilibrium was measured using both multiple choice questions and open-ended questions after the treatment. The results revealed that students instructed with case-based instruction demonstrated more scientific conceptions and fewer misconceptions compared to those instructed with traditional instruction. Common misconceptions elicited after the instruction of solubility equilibrium were stated in below. Most of the misconceptions stated below were also uncovered in the study of Onder (2006).

- The temperature has no effect on solubility.
- Before the system reached at equilibrium, there was no precipitation reaction.
- At a given temperature, Ksp can change.
- Ksp and solubility are not related to each other.
- The solubility of solution at equilibrium is determined by only comparing Ksp values.

- The coefficients at solubility equation were used for only balancing equation.
- Ksp is calculated for both saturated and unsaturated solutions.
- Adding common ion does not change the solubility of solution.
- Precipitation happens when the ion product of sparingly soluble salts is equal to or smaller than the solubility product constant.
- The solubility of sparingly soluble salts is affected by change in pressure and volume
- The solubility of solid changes with pressure.
- The rate of dissolving increases with time from mixing the solid with solvent until equilibrium establishes.

Moreover, in their study, O'Sullivan and Crouch (2009) demonstrated that students could not differentiate solution species concentrations for solids with varying thermodynamic solubility product constant. Students had difficulty in calculating Ksp in smaller concentrations. Hawkes (1998) concluded that solubility equilibrium calculations can be omitted from the introductory chemistry course and they can be taught at later chemistry courses because solubility equilibrium calculations in the textbook included errors and their usage for experienced teacher was wrong. Additionally, solubility product calculations were not useful during the instruction, since calculations were not used in real situation. Using computer programs for solubility equilibrium calculations was encouraged in this study.

The studies investigating students' misconceptions in chemistry (e.g., solubility equilibrium) demonstrated the abstract nature of the chemistry as the main source of student misconceptions (Garnett et al., 1995). One of the purposes of science education is to use appropriate strategies in order to eliminate student misconceptions identified in various topics. However, it is not easy to remediate students' misconceptions under traditional classroom environment (Driver & Easly, 1978; Fisher, 1985; Hynd et al., 1994). The strategies emphasizing students' prior understandings and supporting the conditions of conceptual change are promising in eliminating student misconceptions (Niaz, 2002).

There are also other researches in the literature about solubility equilibrium. It was given in the following section.

In order to investigate the perspectives of students on constructivist role-play instruction method, Kavak and Koseoglu (2007) carried out a study. There were 35 tenth grade students in the study. Interviews, observations, and teaching method evaluation form including two open-ended questions were used as instruments. Students participated five role-playing activities about solubility equilibrium during seven-class hour. Content analysis was used to analyze the results. The results of the study showed that role-playing based on constructivist approach helped the understanding the topics. In addition, it was found that role-playing provide conceptual change, meaningful and permanent learning. In addition, results showed that role-playing had some advantages such as, "creating enjoyable learning environment, revealing leadership, providing active participation and social interaction. However, there were some disadvantages of role-playing such as, "the activities were time-consuming, and students personalized the events, object, and concept."

Coleman and Fedosky (2006) investigated the effect of computer simulations on teaching of solubility of salts. The computer program shows the differences in the entropy of solvation. It is suitable for high school and college introductory chemistry courses to illuminate equilibrium concepts qualitatively. The computer program made chemical equilibrium easy to understand for the students' conceptual understanding without any quantitative interpretations. It provides presenting appearances of before and after dissolutions of equal amounts of the two salts in the same amount of water. This animations and applications were discussed by Gil and Paiva (2006). They conducted a study related to using computer simulations to teach salt solubility. They compared solubility of different salts and discovered computer simulations to help the thermodynamic interpretation of the differences. They investigated two questions. First question was why calcium carbonate is much less soluble for the same temperature. Second question was why magnesium sulfate is much more soluble in water than magnesium carbonate. They selected salts and simulations according to some criteria such as familiar salts of very different solubility, salts with similar packing structures, and pairs of salts that essentially require discussion of only configurational disorder or thermal disorder. They discussed first question including comparison of NaCl and $CaCO_3$ about configurational disorder since there was small differences between their dissolution enthalpy changes. It was found that $CaCO_3$ is less soluble than NaCl since dissolution of $CaCO_3$ is slightly exothermic. They also compared dissolutions of $MgCO_3$ and $MgSO_4$. They discussed the changes of configurational disorder. Since dissolution of $MgSO_4$ is highly exothermic, $MgSO_4$ is much more soluble in water than $MgCO_3$. The results showed that discussions and simulations were effective to provide deep understanding of chemical equilibrium since graphical simulations helped to students to see the small particles.

Pereira, Alcalde, Villegas, and Vale (2007) developed the predominance interval diagrams to solve the problem about solubility. They applied the unified treatment to the precipitation-solubility equilibrium. Unified treatment was based on reactions of particle exchange. The problems about solubility were solved this method. The results indicated that predominance interval diagrams were effective and useful for solving problems of solubility. In addition, it provides a new and more meaningful view for the students to solve the solubility equilibrium problems.

In order to see differences between computed Ksp and experimental Ksp, a study was carried out by Clark, and Bonicamp (1998). They investigated which Ksp value will be used. They examined ten general chemistry textbooks for computed Ksp values, and six sources for experimental Ksp values. They rearranged thermodynamic values as Ksp^t and concentration Ksp values as Ksp^c from texbooks. To compare theoretical and experimental values, they converted solubilities to mol\L. They used a computer program (EQUIL) to calculate the solubility from theoretical Ksp. They made a comparison between the theoretical and experimental solubility values. They found that some compounds were eliminated from tables because their values exceed computed solubility values from EQUIL. Three compounds such as silver bromate, and strontium carbonate, which had acceptably standard solubility, were added. They formed the new table including Ksp^t, and Ksp^c values to help the future researchers.

2.2 Constructivism and Conceptual Change

Recently, constructivism has become the most powerful theory about knowing and learning (Tobin, 1993). In this theory, learner is active in constructing knowledge (Wu & Tsai, 2005). Since students connect prior knowledge with new knowledge to be taught, to find out their prior knowledge that affects further learning is important. In addition, to promote learning students' prior knowledge should be taken into account by teachers. Brooks and Brooks (1999) argued that what traditional and constructivist environments should include in Table 2.1 (pp.17).

To provide meaningful learning, constructivist-oriented instruction can be used in the learning environment (Tsai, 1998). Ausubel (1968) explained the students used their prior knowledge in constructing the new knowledge in a meaningful way.

Table 2.1 Differences Between Traditional and Constructivist Classrooms

Traditional Classrooms	Constructivist Classrooms
Curriculum is presented part to whole, with emphasis on basic skills.	Curriculum is presented whole to part with emphasis on big concepts.
Strict adherence to fixed curriculum is highly valued.	Pursuit of student questions is highly valued.
Curricular activities rely heavily on textbooks and workbooks.	Curricular activities rely heavily on primary sources of data and manipulative materials.
Students are viewed as "blank slates" onto which information is etched by the teacher.	Students are viewed as thinkers with emerging theories about the world.
Teachers generally behave in a didactic manner, disseminating information to students.	Teachers generally behave in an interactive manner, mediating the environment for students.
Teachers seek the correct answer to validate student learning.	Teachers seek the students' points of view in order to understand students' present conceptions for use in subsequent lessons.
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing.	Assessment of student learning is interwoven with teaching and occurs through teacher observations of students at work and through student exhibitions and portfolios.
Students primarily work alone.	Students primarily work in groups.

Piaget's theory is clearly constructivist. Piaget's theory describes and explains the development of intellectual structures and knowledge in a systematic way. Instead of being a product of maturation or controlled by external events, the child is a scientist, an explorer, and an active seeker of information. Piaget was concerned about intellectual development and he was mainly interested in how knowledge is constructed within the mind of the individual. Children construct knowledge through their exploratory actions on the environment. Piaget classified knowledge into three as physical knowledge, logical-mathematical knowledge, and social knowledge. Physical knowledge is the knowledge about physical properties of objects and events, and it is acquired through actions of the children on the objects with their senses. Like physical knowledge, logical-mathematical knowledge is acquired from the actions of the children on objects but it is not inherent in objects, rather it is invented by the children. Social knowledge is made by the children through their interactions with other people. Exploration activities should be used to enhance children's construction of knowledge (Wadsworth, 1996).

Piaget viewed intellectual development as processes of adaptation and organization to the environment. Organization and adaptation are viewed by Piaget as complementary processes. Organization refers to the arrangement, combination, recombination, or rearrangement of information and experience into mental structures. Adaptation is a process of adjusting to the environment and it involves the processes of assimilation and accommodation (Wadsworth, 1971; Woolfolk, 1998). Four basic concepts, called as schema, assimilation, accommodation, and equilibration, are necessary in order to understand these processes. Schemata are the mental structures used for the processes of adaptation and organization. The schemata tend to grow and change through assimilation and accommodation. Assimilation is the process of integrating new information into existing schemata. Assimilation occurs all the time and allows for the growth of the schemata. If the new information fits with the existing schemata, assimilation occurs. If there are no schemata into which new information fits, accommodation occurs. Accommodation is the formation of new schemata or revision of existing schemata. Accommodation is followed by the process of assimilation. Equilibration is defined as balance between assimilation and accommodation. The state of imbalance between assimilation and accommodation is mentioned as disequilibrium. Disequilibrium encourages the individuals to seek equilibrium. The process of moving from disequilibrium to equilibrium is called as equilibration (Wadsworth, 1971). There are three factors contributing to equilibration: maturation, experience, and social transmission. As the children grow and mature, their mental structures enable them to deal with new phenomena and assimilate it. Therefore, children become active and achieve the state of equilibrium. The children maintain the state of equilibrium if they are allowed to have experience with concrete objects. The interaction of the children with other people also enables children to achieve higher levels of equilibrium (Pulaski, 1971). Maturation, experience, social transmission, and equilibration are necessary conditions for intellectual development. Intellectual development is divided into four broad stages: sensory-motor, pre-operational, concrete operational and formal operational. In sensory-motor stage, a child's reflexive behaviors gradually evolve into intelligent behavior, the child becomes able to represent objects internally, and the child develops object permanence. In pre-operational stage, language is acquired by the child. Egocentrism, inability to follow transformations, centration, and irreversibility serve as the obstacles to logical thinking of a child in this period. In concrete operational stage, a child makes logical decisions, solves conservation problems, decenters his/her perceptions, attends to transformations, and attains reversibility of operations. A concrete operational child can not solve hypothetical problems, completely verbal, and complex problems but rather can solve problems involving concrete objects and events. In formal operational stage, the child can deal with all kinds of problems, including hypothetical problems, and verbal problems. A formal operational child can organize data, reason scientifically, and generate hypotheses (Wadsworth, 1971). Hypothetical-deductive thinking, scientific-inductive reasoning, and reflective abstraction are the characteristics of an individual who is in formal operational period (Wadsworth, 1996). Hypothetical-deductive thinking means, "Thinking based upon a hypothesis which leads to certain logical deductions" (Pulaski 1971, pp. 66). Inductive reasoning is reasoning from specific observations to general principles, and it is mainly used by scientists. One of the characteristics of scientific reasoning is thinking about a set of variables at one time. Reflective abstraction, or inferential thinking, is thinking about thoughts rather than about the observable things (Pulaski, 1971).

In the constructivist view of learning, knowledge is constructed by learners. Students use their prior knowledge in constructing the new knowledge. That is, students' prior knowledge affects the further learning. Moreover, students come to the classroom with some misconceptions that prevent meaningful learning. In order to remediate students' misconceptions and to learn their prior knowledge that students bring to the classroom, many strategies were developed (Posner et al., 1982). Conceptual change is one of the most effective strategies in the application of constructivist ideas to science instruction (Hewson & Thorley, 1989). Conceptual change model is an outgrowth of constructivist approach in which knowledge acquisition involves active participation of the learners (Tyson, Venville, Harrison, & Treagust, 1997).

Conceptual Change Model was developed by Posner et al. (1982). They described it as "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" (pp. 211).

Piaget only stated that accommodation is necessary for conceptual change, but he could not explain how this should be achieved. Posner et al. (1982) clarified that how assimilation and accommodation should be accomplished. There are four conditions, which are necessary for an accommodation (Posner et al., 1982).

1) There must be *dissatisfaction* with an existing knowledge.
2) A new conception must be *intelligible.*
3) A new conception must be *plausible.*
4) A new conception must appear *fruitful.*

These four conditions form the status of an idea or conception. The degree of learners knowing and ideas is presented as status of conception (Hewson, Beeth, & Thorley, 1998). Intelligibility, plausibility, and fruitfulness raise the status of an idea. Conceptual change is about raising or lowering the status of conceptions. If the new concept has higher status than the current concept, there will be an accommodation. However, if the prior concept retains higher status, new concept will not be accommodated until the status of the old concept is lowered (Duit & Treagust, 2003; Hewson & Thorley, 1989).

Conceptual change is usually not elicited through regular instruction in science (Hynd et al., 1994). Scott, Asoko, and Driver (1991) have identified two main groupings of conceptual change strategies to promote conceptual change. The first grouping of strategies are based on cognitive conflict and the resolution of conflicting perspectives; the second grouping of strategies are built on students' existing ideas and are extended through, for example, analogy or metaphor, to a new domain. According to Limon (2001), presenting anomalous data or contradictory information to induce cognitive conflict is very common in conceptual change strategies. Cognitive conflict has a central role in conceptual change in that presenting conflicting information helps students to activate their prior conceptions concerning the phenomena studied. Presenting anomalous data creates dissatisfaction that is the first step of conceptual change proposed by Posner et al. (1982).

Changing students' misconceptions is a rather difficult task because they are resistant to change under traditional classroom conditions (Driver & Easly, 1978; Fisher, 1985). There are various conceptual change strategies targeting students' understanding of scientific concepts or remediation of misconceptions: cooperative groups (e.g., Bilgin & Geban, 2006), refutational texts (e.g., Hynd et al., 1994), conceptual change texts (e.g., Calik et al., 2007), analogies (e.g., Calik et al., 2009), and combination of conceptual change texts with concept mapping (e.g., Uzuntiryaki & Geban, 2005). Conceptual Change Text is frequently used in educational research and has been found successful in the elimination of misconceptions, in different subject domains, like physics (e.g., Baser & Geban, 2007), chemistry (e.g., Calik et al., 2007), and biology (e.g., Ozkan, Tekkaya, & Geban, 2004) at various grade levels. In conceptual change texts, firstly, common misconceptions in a particular subject matter are determined. Next, students' misconceptions are activated by asking them explicitly to predict what would happen about a given situation. In the following step, the inconsistency between common misconceptions and scientific conception is demonstrated by presenting evidence in a text in which the wrongness of the misconceptions is described. Finally, the correct scientific explanation of the given situation is presented, and students are given the opportunity of using scientific explanations in new situations (Chambers & Andre, 1997; Wang & Andre, 1991).

Conceptual change texts are commonly used for eliminating students' misconceptions in various topics. For example, Cetingul and Geban (2011) conducted a study to examine the effects of conceptual change oriented instruction and traditional instruction on students' understanding of acids and bases concept. The participants of the study included 50 tenth grade students, which were assigned to experimental and control groups. In the experimental group, students were taught acid-base conceptions using conceptual change text while in the control group students were taught the same concepts using traditional instruction. Acid-Base Concept Test was administered to students in both groups as pre- and post-test. Interviews were also conducted with students at the end of the treatment. The results indicated that students in experimental group demonstrated higher performance than those in control group with respect to understanding of acid-base concepts. Moreover, working with conceptual change texts helped students revise their prior knowledge, struggle with their misconceptions and eliminate them.

Calik et al. (2009) used analogies in order to promote conceptual change for solution chemistry concepts in a sample of 44 Grade 9 students. Students were administered two concept test items prior to the instruction. Then, an analogy activity was used as intervention in teaching the solution concepts. During the treatment, students worked in small groups to explore their existing conceptions. The teacher explained the parts of analogy that students failed to understand. Students elaborated their ideas by negotiating them in their own groups. Lastly, in the whole-class discussion the similarities and differences between the analog and target concept were clarified. After the intervention, students were administered the same concept test as post-test. The same test was re-administered as a delayed post-test 10 weeks after the intervention to measure the effect of treatment on students' retention of the scientific concepts in long-term memory. Interviews were conducted with six students to probe student understanding and reasoning of the solution conceptions in depth. The findings revealed a significant difference between pre-test and post-test scores, in favor of the post-test scores, but not a significant difference between the post-test and delayed post-test scores. In addition, using analogy was found helpful in students' acquisition of scientific conceptions. Some students retained alternative conceptions even after the intervention.

Demonstration was used as a conceptual change strategy in the study of Ceylan and Geban (2010). Grade 10 students (N = 61) were assigned to either experimental or control groups. In the experimental group, students were taught chemical reactions and energy conceptions by using conceptual change oriented instruction through demonstrations while those in control group were instructed the same conceptions by traditional instruction. Data were collected using Chemical Reactions and Energy Concepts Test as pre- and post-test. The results indicated that students in the experimental group outperformed those in control group in terms of acquisition of scientific conceptions in chemical reactions and energy. The results also showed that the instruction used in experimental group promoted conceptual change by challenging students' misconceptions emphasizing the intelligibility and usefulness of the scientific conceptions.

The effects of cooperative learning approach over traditional instruction on 10^{th} grade students' conceptual understanding in chemical equilibrium was investigated by Bilgin and Geban (2006). A sample of 87 students of a teacher participated in this study, and they were assigned to either experimental or control groups. Students in experimental group were instructed with the cooperative learning approach by supporting the conditions of conceptual change while those in control group were instructed with the traditional instruction. A concept test was administered as a pre- and post-test to students in both groups. After the treatment, interviews were also conducted with 12 students in both groups to probe students' conceptual understanding in-depth. Results showed that students in the experimental group performed better than those in control group in understanding chemical equilibrium concepts. Using cooperative learning approach facilitated students' acquisition of scientific conceptions and eliminated student misconception. However, the students even in the experimental group retained some of the misconceptions after the instruction.

Moreover, Ozmen (2008) examined the influence of computer-assisted instruction on 11th grade students' conceptual understanding of chemical bonding. A total of 50 students were assigned to experimental and control groups. In the experimental group, computer assisted instruction was used as supplementary to other methods such as power point presentation and regular instruction. Computer software package used in the experimental group included figures, graphs, three-dimensional animations, and problem-solving exercises to supplement to theoretical content knowledge. This software also encouraged student-student interaction. On the other hand, traditional teacher-centered instruction was used in the control group. A test measuring students' understanding in chemical bonding was administered to students in both groups as pre- and post-test. The results revealed that students in experimental group developed a better understanding of chemical bonding compared to those in control group. In addition, computer-assisted instruction was found effective in remediating students' misconceptions in chemical bonding.

In the above-mentioned studies, conceptual change texts, case-based instruction, and role-playing were used for the elimination of student misconceptions and supporting student acquisition of scientific conceptions. In addition to these strategies and methods, inquiry-based approaches including learning cycle model can also be used in eliciting and changing students' misconceptions in various science topics (Colburn & Clough, 1997).

2.3 Learning Cycle Model

Learning cycle has been implemented and investigated by many science educators for about half a century. The learning cycle was initially developed in the 1960s for the Science Curriculum Improvement Study (SCIS). The three phases of the learning cycle were initially called preliminary exploration, invention, and discovery (Karplus & Thier, 1969). Later, the names of these phases have been altered. Three phases of learning cycle were named as: (1) the exploration (or gathering data) phase, (2) the conceptual invention phase, and (3) the conceptual expansion (or expansion of the idea) phase (Abraham & Renner, 1986; Renner, Abraham, Birnie, 1985). Although the names of the phases were stated differently by the researchers, the structure of the learning cycle remains the same. The origins and development of instructional models were given in the following figure.

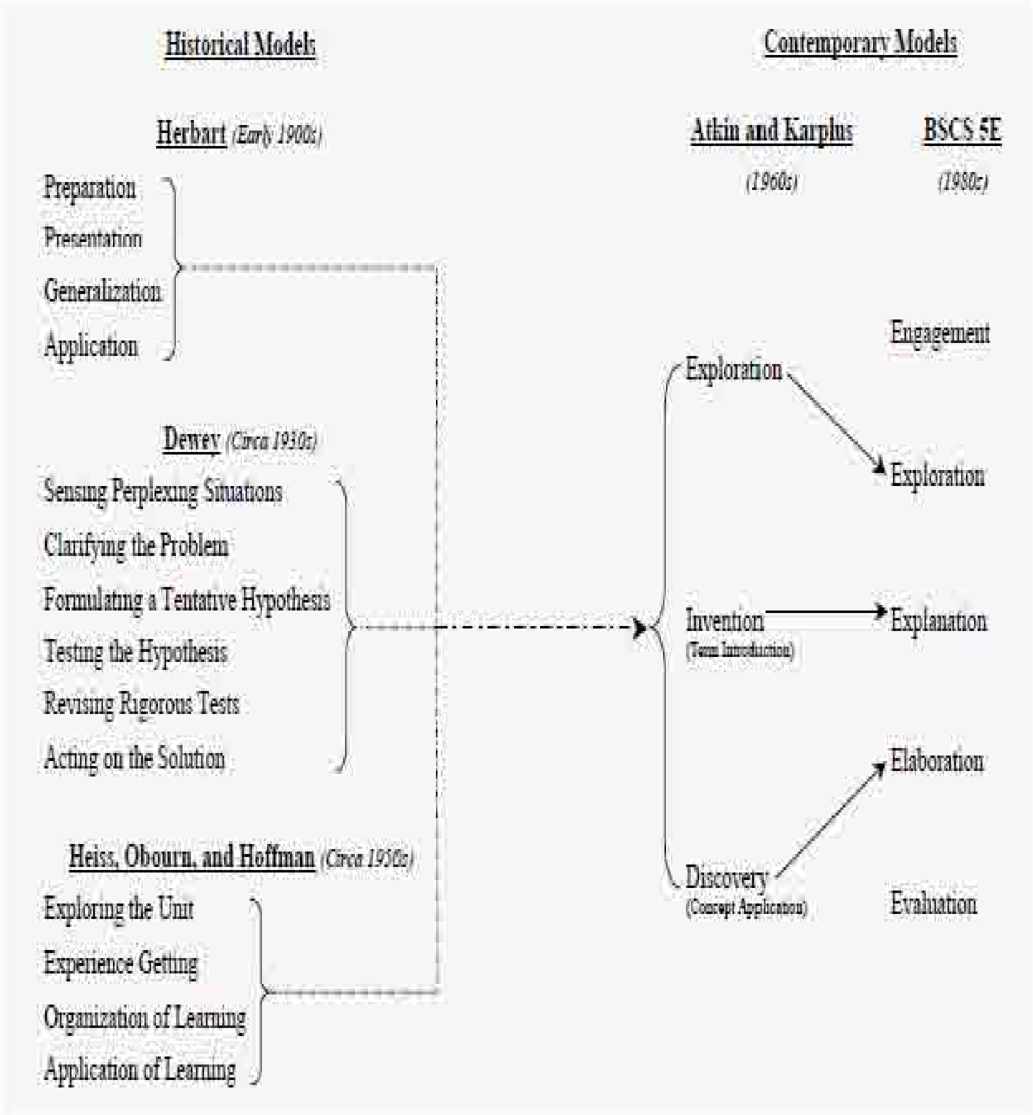


Figure 2.1 Origins and Development of Instructional Models (Bybee et al., 2006, p.13)

Each learning cycle begins with an activity, usually a laboratory experiment, before the introduction of the concept. Through this activity, students are given experiences with the concepts to be learnt. After that, the students are engaged in activities, usually in classroom discussion, for the invention of the concepts from the data. Finally, students are given opportunities, involving extra laboratory experiments, demonstrations, readings, etc. to develop understanding of the newly discovered concept.

The learning cycle method can be contrasted with the traditional method with respect to the sequence of the phases. In traditional method, the students are firstly informed about the concepts intended to be taught through a textbook, a teacher, or a different type of media. After that, verification of the concepts is provided usually by using laboratory. Finally, the students are engaged in practice with the newly acquired concepts. If the phases of the traditional and learning cycle methods are compared, there are similarities among the phases of the two instructional methods. The 'inform' phase of the traditional method appears to be parallel with the 'invention' phase of the learning cycle method; the 'verification' phase of the traditional method seems to be similar to the 'exploration' phase of the learning cycle method; and the 'practice' phase of the traditional method appears to be similar to the 'expansion' phase of the learning cycle method (Abraham & Renner, 1986).

Generally, there are three types of learning cycles, namely descriptive, empirical-abductive and hypothetical-deductive. In descriptive learning cycles, students observe a small part of the world and attempt to discover a pattern and describe it without explaining (exploration). The students report the data they have obtained and they describe the pattern with their teacher; then the teacher introduces a term to refer to the pattern (term introduction). The pattern is discussed and explained in additional contexts (concept application). Descriptive learning cycles raise the question "What?" (Lawson, et al., 1989).

In empirical-abductive learning cycles, the cycle begins with the descriptive and causal question raised by the teacher. The students discover and describe an empirical pattern while they are answering the descriptive question. The students generate alternative hypotheses related to that pattern to answer the causal question (exploration). Then the teacher and/or the students introduce the terms related to the explored pattern and alternative hypotheses (term introduction). The pattern is discussed or explained in other situations (concept application) (Lawson et al., 1989).

In hypothetical-deductive learning cycle, the students are asked to generate alternative hypotheses with regard to the causal question introduced at the beginning of the instruction. Then, students design and conduct experiments to test those hypotheses (exploration). The terms are introduced based on the analysis of the experimental data (term introduction). The newly acquired concept is applied in additional contexts (concept application) (Lawson et al., 1989).

Apart from descriptive, empirical-abductive and hypothetical-deductive learning cycles, there are revised versions of learning cycle. Glasson and Lalik (1993) suggested use of Language-Oriented Learning Cycle. Language-oriented learning cycle is a modified version of learning cycle that reflects a social constructivist perspective. Glasson and Lalik (1993) proposed labels that reflect the reciprocal use of language and action in each phase. The phases of the learning cycle were renamed in language-oriented learning cycle as: exploration, clarification, and elaboration. In exploration phase, students engage in stimulating activities and work in collaborative groups. Students make predictions and explanations, and raise questions. In clarification phase, teacher introduces scientific concepts and designs activities through which students and teacher discuss the meaning of scientific explanations. Students relate scientific explanations to their personal understandings, and represent those concepts meaningfully. Finally, in elaboration phase, students engage in divergent problem solving activities.

Another revised version of learning cycle model, metacognitive learning cycle, was proposed by Blank (2000) in order to give opportunities for teachers and students to formally discuss their science ideas. The phases of the metacognitive learning cycle are concept assessment, concept exploration, concept introduction, and concept application. In the concept assessment phase, students talk about the status of their ideas before the instruction. In the concept exploration phase, students explore new phenomena regarding the concept being investigated. In the concept introduction phase, the teacher and students discuss about the exploratory activity, and introduce the new concept. During the concept introduction phase, students reflect on the status of their ideas. In the concept application phase, students are given opportunities for applying new concept into additional situations and they check the status of their ideas.

The original version of the learning cycle includes three phases namely preliminary exploration, invention and discovery (Karplus & Thier, 1969). Later, more phases have been added to the learning cycle model. Bybee et al. (2004) extended and elaborated the original version of the learning cycle and proposed 5E instructional model. The 5E instructional model has five phases, namely, engagement, exploration, explanation, elaboration, and evaluation. 5E instructional model provides guidance for curriculum developers and helps the classroom teachers improve instructional effectiveness by presenting a systematic approach.

Engagement

In the engagement phase, the students are asked a question in learning task, defined a problem, or shown a discrepant event. The activities presented in this phase hold students mentally and physically active by creating interest and generating curiosity. This phase initiates the process of disequilibrium by activating students' prior knowledge. The role of the teacher is to determine the instructional task and present situations (Bybee et al., 2004).

In this phase teacher

- Creates interest
- Generates curiosity
- Raises questions
- Elicits responses that uncover what the students know or think about the concept or topic (Bybee, Taylor, Gardner, Van Scotteer, Powell, Westbrook, & Landes, 2006, p.34).

In this phase student

- Asks questions such as, "Why did this happen?" "What do I already know about this?" "What can I find out about this?"
- Shows interest in the topic (Bybee et al., 2006, p.33).

Exploration

In the second phase (exploration), concrete and hands-on activities are used to make students explore objects, events, or situations. During the exploration activities, students create relationships, detect patterns, classify variables, and question events. This phase initiates the process of equilibration. The facilitator role of the teacher encourages students work together. The teacher initiates the exploration activity, gives students enough time and opportunities to make them mentally and physically involved in the activities (Bybee et al., 2004).

In this phase teacher

- Encourages the students to work together without direct instruction from the teacher
- Observes and listens to the students as they interact
- Asks probing questions to redirect the students' investigations when necessary
- Provides time for the students to puzzle through problems
- Acts as a consultant for students
- Creates a "need to know" setting (Bybee et al., 2006, p.34).

In this phase student

- Thinks freely, within the limits of the activity
- Tests predictions and hypotheses
- Forms new predictions and hypotheses
- Tries alternatives and discusses them with others
- Records observations and ideas
- Asks related questions
- Suspends judgment (Bybee et al., 2006, p.33).

Explanation

In the third phase (explanation), students are asked to make explanations based on the data obtained from the engagement and exploration activities. Then, the teacher introduces the scientific explanations of the phenomena involved in the learning task. This phase allows both students and teacher use common scientific terms. Explanation phase can be achieved through a variety of ways: (1) oral explanation of the teacher, (2) technology such as reading, video, film, and (3) textbook (Bybee et al., 2004).

In this phase teacher

- Encourages the students to explain concepts and definitions in their own words
- Asks for justification (evidence) and clarification from students
- Formally clarifies definitions, explanations, and new labels when needed
- Uses students' previous experiences as the basis for explaining concepts
- Assesses students' growing understanding (Bybee et al., 2006, p.34).

In this phase student

- Explains possible solutions or answers to others
- Listens critically to others' explanations
- Questions others' explanations
- Listens to and tries to comprehend explanations that the teacher offers
- Refers to previous activities
- Uses recorded observations in explanations
- Assesses own understanding (Bybee et al., 2006, p.33).

Elaboration

In the fourth phase (elaboration), students are involved in additional activities that extend or clarify the concepts, processes, and skills. During this phase, students share their understanding of the subject through their engagement in group discussions and cooperative learning situations. In this phase, students have also opportunity to apply the newly acquired concepts in additional contexts and problems (Bybee et al., 2004). Application activities include designing additional experiments or new research projects, role-playing, debates, and field trips (Colburn & Clough, 1997).

In this phase teacher

- Expects the students to use formal labels, definitions, and explanations provided previously
- Encourages the students to apply or extend the concepts and skills in new situations
- Reminds the students of alternate explanations
- Refers the students to existing data and evidence and asks, "What do you already know?" "Why do you think …?" (Strategies from exploration also apply here.) (Bybee et al., 2006, p.34).

In this phase student

- Applies new labels, definitions, explanations, and skills in new but similar situations
- Uses previous information to ask questions, propose solutions, make decisions, and design experiments
- Draws reasonable conclusions from evidence
- Records observations and explanations
- Checks for understanding among peers (Bybee et al., 2006, p.33).

Evaluation

In the fifth phase (evaluation), students evaluate themselves through formal and informal assessment. Students receive feedback on their conceptual understandings, process skills and behaviors that they acquired during the instruction. Informal assessment can occur at any phase of the learning cycle. Formal assessment is done at the end of the elaboration phase. The teacher can administer test or performance activities to evaluate students' conceptual understandings and skills (Bybee et al., 2004).

In this phase teacher

- Observes the students as they apply new concepts and skills

- Assesses students' knowledge and skills
- Looks for evidence that the students have changed their thinking or behaviors
- Allows students to assess their own learning and group-process skills
- Asks open-ended questions such as, "Why do you think …?" "What evidence do you have?" "What do you know about *x*?" "How would you explain *x*?" (Bybee et al., 2006, p.34).

In this phase student

- Answers open-ended questions by using observations, evidence, and previously accepted explanations
- Demonstrates an understanding or knowledge of the concept or skill
- Evaluates his or her own progress and knowledge
- Asks related questions that would encourage future investigations (Bybee et al., 2006, p.33).

There is a lot of methods used 5E learning cycle model phases (Aggul Yalcin, 2010). These methods were given the following table.

Table 2.2 The Methods used in the 5e Learning Cycle Phases

Phases	Example Methods
Engagement	Question and Answer, Demonstartion, Video, Predict- Observe-Explain, Reading interesting story, Brain storming
Exploration	Inquiry, Small group negotiation, Role-playing, Field trip, Experiment, Preparing poster
Explanation	Concept map, Role-playing, Question and Answer, Teacher presentation, Student presentation, Discussion
Elaboration	Analogy, Question and Answer, Brain storming, Concept map, Problem solving, Relating the words
Evaluation	Concept map, Drawing, Interview, Performance assessment, rubric

Eisenkraft (2003) expanded the 5E model to a 7E model to ensure instructors do not ignore important aspects of learning from their lessons. The proposed 7E model expands the *engagement* phase of the 5E model into two components: *elicitation* and *engagement*. In a similar way, 7E model expands the *elaboration* and *evaluation* phases of the 5E model into three components: *elaboration, evaluation,* and *extension.* The reason of the emergence of 7E model is to increase the significance of eliciting students' prior knowledge and transfer of learning. Students' abilities to apply their knowledge in new situations are enhanced through learning cycle.

2.4 Research on Learning Cycle Model

Several studies have been conducted in the area of learning cycle. The nature of the studies changes from descriptive to experimental. Lawson et al. (1989) and Abraham (2003) reviewed and synthesized a considerable number of studies concerning the learning cycle approach. It was supported that learning cycle instructional method has many advantages over traditional instruction in terms of students' attitudes towards science, conceptual understanding, process skills, thinking skills, motivation, and reasoning ability.

Colburn and Clough (1997) provided teachers guidelines about the implementation of learning cycle in science teaching by altering the inform (lecture)-verify (lab)-practice cycle. These guidelines can be summarized as follows:

- Do the lab activity first
- Discuss the lab activity before the introduction of the new concept
- Have students communicate their lab findings
- Administer tests including questions that require students to use or reflect upon their experience in the laboratory
- Begin changing your role during the activity by eliciting what students are thinking
- Have students develop procedures about how to answer a lab question
- Continue changing your role during the activity by allowing students to think independently

- Ensure students to apply their new knowledge in additional situations

In order to understand why the learning cycle is effective, three variables were investigated: sequence of the phases, necessity of each phase, and the form in which students acquired data. Renner et al. (1985) changed the form of the exploration and extension steps of the learning cycle and examined whether the form variables affect physics students' content achievement and their attitudes towards the learning procedures. The findings indicated that the form in which the phases of the learning cycle are experienced does not affect the level of students' content achievement. The content understandings are more permanent when students engage in regular forms of the learning cycle. Most of the students showed positive attitudes towards the regular-form learning cycle.

Abraham and Renner (1986) altered the sequence of the three phases of two high school learning cycles in chemistry and compared with the normal learning cycle sequence with respect to content achievement and student attitudes. The results revealed that (a) the sequence of the phases of the learning cycle is important, (b) the normal learning cycle format is optimum for content achievement, and (c) the students prefer sequences where the invention comes later in the sequence.

Renner, Abraham, and Birnie (1988) investigated whether or not each learning cycle phase is necessary in physics students' conceptual learning. The data regarding the necessity of each phase of the learning cycle revealed that (a) the exploration phase alone is inefficient to provide maximum concept learning, (b) explaining a concept before the exploration phase adds little or no conceptual understanding, (c) exploration phase needs to be followed with term introduction phase, (d) all phases of the learning cycle are necessary, but any phase of the learning cycle can be substituted for if the remaining phases produce a thorough laboratory experience with the concept and integrate its language with that experience, and (e) students believe that all phases are necessary.

Abraham (1989) conducted experiments with 11^{th} and 12^{th} grade chemistry students in order to examine three variables of instructional strategies (sequence, necessity, and form). In an experiment designed to investigate the necessity variable, six chemistry classes were exposed to learning cycle teaching method on the topic of physical and chemical change. The three phases of instruction were alternated in order to make each class to be instructed with one of the six possible sequences of the three phases. After each phase of the instruction, the equivalent test administered to each group. The results revealed that instructional strategies consisting of all three phases achieved better than those involving one or two phases. Another experiment was designed to investigate the sequence variable. Three groups of high school chemistry students were instructed with learning cycle method on the topic of heat laws. The position of the invention phase was different in each group. The findings indicated that the instructional sequences that have invention as the second phase resulted in higher content achievement than other sequences. Moreover, form variable was investigated in another experiment. Most commonly used instructional forms include laboratory/discussion, demonstration, lecture, and reading. Four high school chemistry classes were taught with learning cycle method on the topic of simple chemical reactions. The learning cycle activities were designed considering one of the instructional form in each group. The results revealed that students taught with the laboratory/discussion form scored higher in tests than those in the lecture and reading groups. The students exposed to the demonstration form scored moderately in tests.

There are some studies combining the learning cycle with other instructional methods. Odom and Kelly (1998) combined the learning cycle and concept mapping methodologies. When combined, the learning cycle provides students concepts relevant to the new learning based on the concrete experiences; and concept mapping makes students to link between the concepts. The combination of concept mapping and learning cycle results in higher science achievement. Odom and Kelly (2001) compared the effect of concept mapping, the learning cycle, expository instruction, and a combination of concept mapping/learning cycle with respect to high school biology students' conceptual understanding of diffusion and osmosis. As a result, concept mapping/learning cycle and concept mapping treatment groups achieved higher understanding of diffusion and osmosis than expository treatment group. No significant difference was found among the learning cycle and other groups.

Learning cycle research has been conducted with pre-service teachers as well as high school and elementary school students because teachers play a key role in developing students' understandings of science concepts and process skills. Various researchers studied on pre-service elementary teachers' understanding of the learning cycle. Hanuscin and Lee (2007) designed science methods course activities for each of the five phases of learning cycle in order to teach the learning cycle to pre-service elementary teachers. Lindgren and Bleicher (2005) studied with 83 pre-service elementary teachers who were taught with learning cycle teaching strategy in their science methods course. Changes in pre-service elementary teachers' understanding of learning cycle and the factors affecting understanding the learning cycle were examined. The results showed that there was a significant improvement in participants' understanding of the learning cycle. Multiple exposures to the learning cycle, discussion, and journal writing were found necessary for pre-service elementary teachers to understand the learning cycle. Like Lindgren and Bleicher (2005), Settlage (2000) examined the factors influencing teachers' ability to understand the learning cycle. The findings indicated that science teaching outcome expectancy contributed to the understanding of the learning cycle but personal science teaching efficacy and attitudes towards science could not explain understanding of the learning cycle. Another study examining pre-service elementary teachers' understandings of the learning cycle was conducted by Marek, Laubach, and Pedersen (2003). It was found that participants demonstrated differing levels of understandings of each phase of the learning cycle after completing two elementary school science methods course. Understandings of the exploration and concept introduction phases were greater than that of concept application phase.

The learning cycle and traditional methods were compared in order to understand the effect of learning cycle instruction on students' subject matter knowledge and reasoning abilities. Ates (2005) investigated the effectiveness of learning cycle and traditional methods when teaching direct current circuits to university students. The findings revealed that learning cycle method resulted in better understanding of the direct circuit concepts than traditional method. The learning cycle was found equally effective for both males and females when prior knowledge of the students was controlled.

Like Ates (2005), Musheno and Lawson (1999) supported the effectiveness of the learning cycle in science teaching in their study. There is a difference between these two studies with respect to the application of learning cycle. Ates (2005) applied learning cycle in science instruction by using hands-on laboratories and interactive discussions but Musheno and Lawson (1999) applied learning cycle to science text.

Learning cycle instruction was found very effective not only on developing students' subject matter knowledge but also on improving reasoning ability (Johnson & Lawson, 1998; Lawson, 2001). The effects of the learning cycle on some variables, e.g., science process skills, logical thinking skills, and attitudes were investigated by various researchers. Westbrook and Rogers (1994) examined the development of 9th grade physical science students' scientific reasoning, science process skills, and logical thinking by making variations in the form of the expansion phase of the learning cycle. Their study showed that using laboratory exercises alone is not sufficient to stimulate students to reason at a formal operational level and to think of scientifically. Students' science process skills and logical thinking can be enhanced when they are given the opportunity to design and conduct experiments or to generate and test hypotheses. Lavoie (1999) investigated the effects of adding a prediction-discussion phase at the beginning of a three-phase learning cycle; including exploration, term introduction, and concept application. The prediction/discussion-based learning cycle instruction was found effective on developing students' science process skills, logical thinking skills, conceptual understandings, and scientific attitudes compared to traditional learning cycle instruction. Cavallo and Laubach (2001) investigated the variable 'attitude' by comparing high paradigmatic and low paradigmatic learning cycle classrooms and found that students in the high paradigmatic learning cycle classes demonstrated positive attitudes towards science and their science classroom environments. Like Cavallo and Laubach (2001), Yilmaz and Huyuguzel Cavas (2006) investigated the effect of learning cycle method on 6^{th} grade students' attitudes. They compared 4E (exploration, explanation, expansion and evaluation) with traditional method and demonstrated the effect of learning cycle method on students' attitudes towards science and understanding of electricity concepts. This study is also similar to Ates's (2005) study in that both of them investigated the influence of learning cycle on students' conceptual understanding regarding the electricity unit.

There are some studies in which learning cycle method is used for eliminating students' misconceptions. Balci et al., (2006) investigated the effects of 5E learning cycle method, conceptual change text instruction method and traditional method on 8^{th} grade students' understanding of biology concepts. 5E learning cycle and conceptual change text instruction methods were found equally effective on remediation of students' misconceptions, so they led to better conceptual understanding compared to traditional method.

Ceylan and Geban (2009) examined the effects of 5E learning cycle method and traditional instruction on 10th grade students' conceptual understanding related to the state of matter and solubility. The participants of this study were 119 students of a teacher. Students were assigned to either experimental or control groups. In the experimental group 5E learning cycle method was used in teaching state of matter and solubility concepts while in control group traditional instruction was used in teaching the same concepts. A test including both multiple-choice and open-ended questions was administered to all students as a pre- and post-test. The findings indicated a significant different between the two groups with respect to understanding of state of matter and solubility concepts, in favor of the experimental group. Moreover, 5E learning cycle method helped students overcome their misconceptions about state of matter and solubility.

Yilmaz, Tekkaya, and Sungur (2011) investigated the effects of prediction/discussion-based learning cycle (conceptual change text and traditional instructions on students' conceptual understanding in genetics. A pre-test post-test non-equivalent control group design was used in the study. Students taught by the same teacher were assigned to prediction/discussion-based learning cycle class (N = 30), conceptual change text class (N = 25) and traditional class (N = 26). A test measuring students' conceptions about genetics was administered to all students' as pre-test, post-test and delayed post-test. The results revealed that students in both prediction/discussion-based learning cycle and conceptual change text classes demonstrated higher levels of scientific understanding and retention of genetic conceptions than students in traditional class. In addition, prediction/discussion-based learning cycle and conceptual change text instructions helped students overcome misconceptions of genetics.

Turgut and Gurbuz (2011) examined the comparative effects of 5E model and traditional instruction on eighth grade students' understanding of heat and temperature concepts and their attitudes towards science and technology. The participants included 37 eighth grade students attending to two intact classes taught by the same teacher. One class was randomly assigned as experimental group and instructed by 5E model, while the other was assigned as control group and taught by traditional instruction. The data were collected using a three-tier Heat and Temperature Misconception Test and the Attitude Scale towards Science and Technology. The results revealed that 5E model was more effective than traditional instruction in eliminating students' misconceptions and providing a permanent conceptual change. However, there was not any statistically significant difference in the mean scores of students' attitudes towards science and technology across the two groups.

Demircioglu, Ozmen, and Demircioglu (2004) investigated the effectiveness of 5E learning cycle model over traditional instruction on 10^{th} grade students' conceptual understanding in factors affecting solubility equilibrium. There were 46 students assigned to either experimental or control groups. In the experimental group, 5E learning cycle was used while in the control group traditional instruction was used. A concept test including both multiple-choice and open-ended items were administered to all students as pre- and post-test. After the treatment, semi-structured interviews were conducted with five students in experimental group. Post-test analysis revealed that students in experimental group performed significantly better than those in control group. There were striking differences in the proportions of correct responses for several post-test items between the groups in favor of the experimental group. In the interviews, students stated that 5E learning cycle activities helped them learn the factors affecting solubility equilibrium in an effective and a permanent way. Some students taught that the activities provided in 5E learning cycle classes helped them change their misconceptions.

2.5 Attitude

Attitude towards science is one of the most important affective variables in science learning as well as cognitive variables. The affective domain includes constructs, such as attitudes, values, beliefs, opinions, interests, and motivation. Therefore, science learning cannot be explained only by examining cognitive factors, learners' attitudes should also be considered. Attitude is commonly defined as a predisposition to respond positively or negatively to things, people, places, events, or ideas (Simpson, Koballa, Oliver, & Crawley, 1994, pp. 212). This definition suggests that attitudes have three major components: cognitive, affective, and behavioral. Some confusion can emerge between the terms 'scientific attitudes' and 'attitudes towards science'. Scientific attitudes refer to ways in which scientists believe and conduct their work, whereas attitudes towards science refer to whether a person likes or dislikes science. 'I enjoy science courses', and 'Everyone should learn about science' reflect attitudes towards science as an example (Koballa & Glynn, 2004; Simpson et al., 1994).

Several studies in science education have investigated the effect of gender (Liu, Hu, Jiannong, & Adey, 2010; Ozyalcin Oskay, Erdem, & Yilmaz, 2009; Usak, Prokop, Ozden, Ozel, Bilen, & Erdogan, 2009), age (George, 2000; Prokop, Tuncer, & Chuda, 2007), instructional strategies (Adesoji & Raimi, 2004; Baser & Geban, 2007; Siribunnam & Tayraukham, 2009), grade level (Greenfield, 1997; George, 2000; Pehlivan & Koseoglu, 2011; Stefan & Ciomos, 2010), achievement level (Greenfield, 1997; Pehlivan & Koseoglu, 2011), peer group (Koballa & Crawley, 1985; Simpson & Oliver, 1990; Tsivitanidou, Zacharia, & Hovardas, 2011), and parents involvement (George & Kaplan, 1998; Haladayna & Shauhnessy, 1982; Papanastasiou, 2002) on students' attitudes towards different school subject.

A common intuitive belief among the individuals is "attitude and achievement are positively related." Many studies were conducted to verify this assumption. Indeed, several of them found that there was a positive low up to moderate correlation between attitude and achievement (e.g, Kose, Sahin, Ergun, & Gezer, 2010; Ozyalcin Oskay et al., 2009; Salta, & Tzougraki, 2004). However, some studies found that there a significant relationship between students' achievement and attitude (e.g., Hough & Piper, 1982; Mitchell & Simpson, 1982).

There are some contradictory results about gender issues in the researches. Ozyalcin Oskay et al. (2009) conducted a study to explore undergraduate students' attitudes towards chemistry course with respect to taking General Chemistry Laboratory lesson and gender. Moreover, the relationship between students' attitudes towards chemistry course and their achievement were investigated. Total of 99 undergraduate students from education faculty participated in this study. The results showed that students who took General Chemistry Laboratory lesson had positive attitudes toward science. Female students had better attitudess toward chemistry than males. In addition, it is found that there was low correlation between attitude towards chemistry and achievement in chemistry courses. On the other hand, Ozden (2008) carried a study to investigate university student attitudes towards chemistry. The data were obtained from 627 prospective teachers (science, elementary, and mathematics teachers) four different Education Faculties of Adıyaman, İnönü, Anadolu and Gazi University in Turkey. The results indicated that males have more positive attitude towards chemistry compared to females. In addition, it is found that prospective science teachers had more positive attitude towards chemistry. Kan and Akbas (2006) investigated students' level of attitude and self-efficacy towards chemistry, and how the chemistry achievement was predicted by these variables. The study involved 1000 students studying at the 1st, 2nd and the 3rd grade of 10 high schools in Mersin. The results revealed that attitude towards chemistry is an important predictor of chemistry achievement. Second grades students had more positive attitude towards chemistry and self-efficacy. Moreover, it is found that there was no significant difference between attitudes of female and male.

Instructional strategies based on the learning cycle approach that emphasizes active learning affect students' attitudes positively. For example, Sasmaz Oren and Tezcan (2009) investigated the effect of the learning cycle approach on learners' attitudes towards science in 7th grade elementary science classes. The results showed that the learning cycle approach affected students' attitudes towards science more positively than the traditional chemistry instruction. In another study, Altun Yalcin et al. (2010) conducted a study to investigate the effect of 5E Instructional Model on the first year science undergraduates' attitudes towards physics laboratory and development of scientific process skills. The results revealed that the 5E learning cycle approach produced significantly higher positive attitudes towards physics laboratory and scientific process skills than the traditionally designed instruction. There are similar results in the literature such as Ergin, Kanli, and Unsal (2008), and Nuhoglu and Yalcin (2006). However, there were some researches that could not found an improvement in students' attitudes through the implementation of learning cycle approach in the literature (Gonen, Kocakaya, & Inan, 2006; Koseoglu & Tumay, 2010).

In conclusion, there were different relationships between attitudes towards science and science achievement. Several studies detected that there was a positive correlation between attitude and achievement (e.g., Altun Yalcin et al., 2010; Ozden, 2008; Sasmaz Oren & Tezcan, 2009). Therefore, instruction based on the 5E learning cycle is taken into consideration of students' attitudes towards chemistry in this study.

2.6 Motivation and Self-regulation

Motivation is an internal state that arouses, directs, and maintains behavior (Woolfolk, 1998). It is also defined as "the process whereby goal-directed activity is instigated and sustained" (Pintrich & Schunk, 2002, p.5). Motivation has three components: a) beliefs about the importance, interest, and utility of learning task (value components), b) beliefs about one's ability or skill to perform a learning task (expectancy components), and c) feelings about the self or emotional reactions to a learning task (affective component) (Pintrich, 2003; Pintrich, Smith, Garcia & McKeachie, 1991, 1991).

The value component of motivation includes intrinsic goal orientation, extrinsic goal orientation and task value (Pintrich, 2003). Individuals always have some reasons or purposes for their engagement in learning tasks. Goal orientation is defined as "behavioral intentions that determine how students approach and engage in learning activities" (Meece, Blumenfeld, & Hoyle, 1988, pp.514). Goal orientation could be either specific (e.g., a midterm exam) or general (e.g., a course) Students pursuing *intrinsic goal orientation* engage in activities for reasons such as challenge, curiosity and mastery, while those adopting *extrinsic goal orientation* engage in tasks for reasons such as grades, rewards, performance, evaluation by others, and competition (Pintrich et al., 1991). Besides individuals' goals to achieve a task, their perceptions of the importance, interest, and utility about the learning task have an influence on their achievement behaviors. There are three components of *task value*: a) individual's belief about the importance of a task, b) individual's personal interest in a task (intrinsic interest), and c) individual's perception about the utility of the task for future goals (Eccles & Wigfield, 1995).

The expectancy component contains control of learning beliefs and self-efficacy for learning and performance. *Control of learning* refers to individuals' perceptions about their efforts to learn will result in adaptive outcomes. Students believe that their learning outcomes depend on their effort exerted on a task rather than the external factors (e.g., teacher). Such a belief makes students feel that they can control their learning by studying more strategically (Pintrich et al., 1991). *Self-efficacy* is known as beliefs about one's own abilities to perform a task successfully. Self-efficacy beliefs contribute to motivation and there is a closer link between self-efficacy and intrinsic interest. Self-efficacy beliefs influence goal setting, the effort needed to master a task, the persistence to cope with threatening situation, and the resistance to failure. High self-efficacious people set themselves challenging goals and exert a persistent effort to deal with stressful situations. In case of failure, they attribute failure to insufficient effort or deficient knowledge and heighten their effort rather than avoiding. There are four general ways for the development of sense of self-efficacy, namely, mastery experience, vicarious experience, verbal persuasion, and emotional state. Mastery experience is known as the most effective source of self-efficacy. Successes raise people's beliefs that they have the capabilities to master given task while failures diminish them. People rely on not only mastery experience but also vicarious experiences in developing expectations about their own capabilities. Observing people similar to oneself succeed by persistent effort influence judgments of one's own capabilities to master comparable activities. Verbal persuasion is widely used because of its ease. People who are persuaded verbally that they have adequate ability to master the given task tend to exert grater effort and maintain it. People's interpretations about their emotional state influence their judgments of their personal efficacy. Positive emotional state strengthens sense of self-efficacy while opposite diminishes it (Bandura, 1994).

Test anxiety is one of the affective components of motivation. Test anxiety has two components: a cognitive (or worry) component and an emotional component. The cognitive component is described as individuals' negative thought that lower performance, while the emotionality component is described as affective and physiological arousal aspects of anxiety. Individuals' anxiety could be adjusted to optimum level by training them in the use of effective learning strategies and test-taking skills (Pintrich et al., 1991).

Self-motivational beliefs act as an energizing agent for an individual's self-regulatory behaviors and influence the implementation of self-regulatory knowledge and skills appropriately through the enhancement of learning motivation and the quality of the selection and use of learning strategies (Torrano Montalvo & Gonzales Torres, 2004). Self-regulation is described as "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, pp. 14). There are three cyclical phases of self-regulatory processes, namely, forethought, performance or volitional control, and self-reflection. The forethought phase involves processes and beliefs that come before efforts to learn; the performance or volitional control phase refers to processes that occur during performance efforts and influence attention and action; and the self-reflection phase includes processes that occur after each learning effort and affect a person's response to that action. Personal, behavioral, and environmental factors have an influence on the development of these processes.

Learning strategies are tactics used by self-regulated learners to facilitate the acquisition of knowledge and skills. By employing learning strategies, self-regulated learners take the major responsibility for their own learning and guide their own learning process rather than having the learning process supplied by the instruction. Learning strategies are categorized as cognitive and metacognitive strategies (rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation), and support strategies (time and study environment, effort regulation, peer learning, and help seeking) (Pintrich et al., 1991).

Rehearsal strategies simply refers to recite or name items from a list to be learned. These strategies are useful for activation of information stored in working memory rather than acquisition of new information in long-term memory. These strategies assist learners in the encoding and retrieval of information but do not assist them in developing connections among the information and integrating the information with the previous knowledge. *Elaboration strategies* are used to establish connections between new information and previous knowledge. Elaboration strategies assist learners store information into long-term memory by building associations among the information. Paraphrasing, creating analogies, and generative note-taking are examples of elaboration strategies. *Organization strategies* are used to structure information in memory and to store new information in memory within an appropriate structure. Organization strategies assist individuals in selecting appropriate information and establish connections among the information to be learned. Clustering and outlining are examples of organization strategies. *Critical thinking* is described as the extent to which individuals apply previously acquired knowledge to new situations in solving problems, making a decision, and making critical evaluations with respect to higher standards (Pintrich et al., 1991; Weinsten & Mayer, cited in Pintrich, 2002).

Metacognition refers to "knowledge of one's knowledge, processes, and cognitive and affective states; and the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states" (Papaleontiou-Louca, 2003, pp. 10). The components of metacognition are knowledge of cognition and regulation of cognition. The subcomponents of knowledge of cognition are declarative knowledge, procedural knowledge and conditional knowledge while the subcomponents of regulation of cognition are planning, information management, monitoring, debugging, and evaluation (Schraw

& Dennison, 1994). The regulation of cognition component of the metacognition can be referred as *metacognitive self-regulation* (Pintrich et al., 1991). Metacognitive strategies are sequential processes because they are used for controlling cognitive activities and ensuring that a cognitive goal has been met. These processes help individuals in planning and monitoring, and regulating their learning and thinking (Pintrich, 2002). Planning activities (e.g., goal setting, task analysis, etc.) activate prior knowledge and thereby makes easier the comprehension of the learning task, monitoring activities help the individuals integrate new information with the prior knowledge, and regulating activities help individuals in controlling and correcting their behavior as they work on task (Pintrich et al., 1991). An example of metacognitive strategy would be 'individuals re-read the text they don't understand'.

Self-regulated learners can use management strategies effectively as well as cognitive and metacognitive strategies. *Time management* includes scheduling, planning, and managing one's study time in an effective and realistic way. *Study environment management* involves organizing the setting where an individual does her class work. Self-regulated learners can achieve their pre-determined goals in the face of difficulties or distractions by controlling their effort. *Effort management* can improve performance by regulating the continuous use of learning strategies. *Peer learning* has been found to be positively related to the achievement. The dialogical interaction with peers can help individuals learn deeply by acquiring them multiple viewpoints. Self-regulated learners ask for support of both their peers and instructors when they do not know something. Several studies consistently reveal that help seeking facilitates students' learning (Pintrich et al., 1991).

The research on the relationship between self-efficacy and self-regulation revealed that higher levels of self-efficacy were associated with higher levels of self-regulation (Iverach & Fisher, 2008; Pintrich & De Groot, 1990; Pintrich, Roeser, & De Groot, 1993). Individuals who believed that they were capable of accomplishing classroom tasks were more likely to use cognitive and metacognitive strategies. Both mathematical and verbal self-efficacy beliefs were found to be correlated with the strategy use (Zimmerman & Martinez-Pons, 1990). Verbal self-efficacy was associated with the use of organizing and transforming, reviewing notes, and seeking peer assistance strategies while mathematical self-efficacy was associated with the strategy of reviewing notes. Both verbal and mathematical self-efficacy beliefs were found to be negatively correlated with seeking adult assistance.

The relationships among these motivational constructs and achievement have been studied extensively. Pintrich and De Groot (1990) reported that self-efficacy, intrinsic interest, and self-regulation were positively related to students' academic performance. Relevant literature indicated that self-efficacy beliefs have an effect on academic achievement either directly or indirectly through mediating the influence of other variables (e.g., mental ability, previous knowledge) that predict academic achievement (Pajares & Schunk, 2001; Wolters & Pintrich, 1998). Uredi and Uredi (2005) examined relationships among motivational beliefs, self-regulation, and mathematics performance of 550 Grade 8 students. Significant positive correlations were detected among mathematics achievement, motivational constructs, and self-regulation. Self-regulation was found to be a significant predictor of student achievement with high-achieving students demonstrating a greater use of self-regulatory strategies than low-achieving students do.

Ceylan (2008) investigated the comparative effects of 5E learning cycle model and traditional instruction on 10^{th} grade students' perceived motivation and use of learning strategies. The participants were 119 students from two intact classes instructed by the same chemistry teacher. One class was assigned as experimental group and taught the state of matter and solubility concepts using 5E learning cycle model while the other class was assigned as control group and taught the same concepts using traditional instruction. Motivated Strategies for Learning Questionnaire (MSLQ) was administered to all students in both groups as pre- and post-test. The findings indicated that students taught by 5E learning cycle model were more curious, willing to mastery the subject and challenged the chemistry tasks compared to students taught by traditional instruction. Students in 5E learning cycle class tended to perceive chemistry more interesting, more important, and more useful course than those in control class. Instruction based on 5E learning cycle model positively affected students' intrinsic goal orientation, extrinsic goal orientation, and task value, but it doesn't have effect on control of learning beliefs, self-efficacy for learning and performance, and test anxiety. In addition, 5E learning cycle model was found effective on students' use of elaboration and organization strategies compared to traditional instruction. On the other hand, there was no significant difference between the two groups with respect to rehearsal, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning, and help seeking strategies. Moreover, the findings indicated non-significant difference differences between males and females with respect to perceived motivation and use of learning strategies.

Saygin (2009) examined the effects of learning cycle model and traditional instruction on high school students' understanding of nucleic acids and protein synthesis, their perceived motivation and learning strategies. The sample included 105 11^{th} students attending two intact classes of the same teacher. One class was assigned as experimental group and taught by 3E learning cycle model while the other class was assigned as control group and taught by traditional instruction. A concept test and MSLQ were administered to students in both groups as pre- and post-test. The results indicated a significant difference between the two groups with respect to understanding of nucleic acids and protein synthesis, in favor of the experimental group. The results also showed that learning cycle model was more effective than traditional instruction in eliminating student misconceptions on nucleic acids and protein synthesis. Moreover, students in learning cycle class had higher levels of intrinsic goal orientation, control of learning beliefs, self-efficacy for learning and performance, and metacognitive self-regulation and help seeking strategies.

Yilmaz (2007) investigated the comparative effects of prediction/discussion-based learning cycle, conceptual change text, and traditional instructions on 8^{th} grade students' perceived motivation and use of learning strategies. A total of 81 students from three classes of the same teacher participated in this study. Two classes were assigned as experimental groups and the other class was assigned as control group. One of the experimental group was instructed genetics concepts by prediction/discussion-based learning cycle instruction, the other experimental group was instructed the same concepts by conceptual change text instruction, and the control group was taught the same concepts by traditional instruction. MSLQ was administered to all students as pre- and post-test. The findings indicated that the only difference among the groups was the use of elaboration strategies. Students in prediction/discussion-based learning cycle class appeared to use elaboration strategies more than those in conceptual change text group. However, results indicated no statistically significant differences among the groups with respect to students' perceived motivation.

Sungur and Tekkaya (2006) examined the influence of an instructional approach based on constructivism and traditional instruction on 10th grade students' perceived motivation and use of learning strategies. The participants included 61 tenth grade students attending two intact classes of the same teacher. One class was assigned as experimental group and instructed the human respiratory system and excretory system concepts using problem-based learning (PBL) approach. The other class was assigned as control group and instructed the same concepts using traditional approach. MSLQ was administered to the students in both groups as pre- and post-test. The findings demonstrated that the instruction based on constructivism (PBL approach) enhanced students' intrinsic goal orientation, task value, use of elaboration strategies, critical thinking, metacognitive self-regulation, effort regulation and peer learning compared to traditional instruction. On the other hand, there was no significant differences between the two groups with respect to extrinsic goal orientation, control of learning beliefs, self-efficacy for learning and performance, text anxiety, and using the strategies of rehearsal, organization, time and study environment and help seeking. Regarding the gender effect on perceived motivation and use of learning strategies (Sungur, 2004), there was no significant difference between males and females with respect to perceived intrinsic goal orientation and control of learning beliefs, and perceived use of rehearsal, critical thinking, metacognitive self-regulation, time and study environment management, effort regulation, peer learning and help seeking strategies. Boys' perceived extrinsic goal orientation and test anxiety were higher than that of girls; but girls perceived task value and self-efficacy for learning and performance; and use of elaboration and organization strategies more than that of boys.

In the light of literature mentioned above, it can be concluded that motivation and self-regulation are two important constructs influencing students' learning in various topics (Pintrich & De Groot, 1990; Uredi & Uredi, 2005). That means, development of students' motivational beliefs and use of learning strategies are critical in the development of scientific conceptions. Previous research demonstrated that learning cycle model (Ceylan, 2008; Saygin, 2009; Yilmaz, 2007) and instructional approaches based on constructivism (Sungur & Tekkaya, 2006) are effective in developing students' perceived motivation and use of learning strategies. Therefore, in the current study, the comparative effects of 5E learning cycle model and traditional instruction on students' perceived motivation and use of learning strategies were investigated.

2.7 Summary of the Findings of the Reviewed Studies

Students have some ideas, interpretations, and concepts that are not congruent with the scientifically accepted ones (Driver et al., 1985). These kinds of ideas are often referred to as misconceptions (Nakhleh, 1992). Students have misconceptions in various chemistry concepts (Garnett et al., 1995) including solubility equilibrium (Akaygun, 2009; Cam, 2009; Hawkes, 1998; Onder, 2006; Onder & Geban, 2006; O'Sullivan & Crouch, 2009; Raviolo, 2001).

Abstract nature of the chemistry is the main source of student misconceptions (Garnett et al., 1995). It is not easy to remediate students' misconceptions under traditional classroom environment (Driver & Easly, 1978; Fisher, 1985; Hynd et al., 1994). The strategies emphasizing students' prior understandings and supporting the conditions of conceptual change are promising in eliminating student misconceptions (Niaz, 2002). There are various conceptual change strategies targeting students' understanding of scientific concepts or remediation of misconceptions: cooperative groups (e.g., Bilgin & Geban, 2006), refutational texts (e.g., Hynd et al., 1994), conceptual change texts (e.g., Calik et al., 2007), analogies (e.g., Calik et al., 2009), and combination of conceptual change texts with concept mapping (e.g., Uzuntiryaki & Geban, 2005).

Learning cycle is an instructional method based on constructivism. It emphasizes active participation of the students to the learning environment. The studies comparing learning cycle instruction with traditional instruction were reviewed and synthesized (Lawson et al., 1989; Abraham, 2003). The findings revealed that learning cycle instructional method was superior to traditional method in terms of conceptual understanding, attitude towards science and reasoning ability.

Three variables (sequence of the phases, necessity of each phase, and the form in which students acquired data) have been investigated extensively within the framework of learning cycle research (Abraham, 1989; Abraham & Renner, 1986; Renner et al., 1985; Renner et al., 1988). Some studies described the implementation of learning cycle in science classrooms (Colburn & Clough, 1997). In some studies, learning cycle was combined with other instructional methods (Odom & Kelly, 1998).

Learning cycle research has been conducted with elementary school students (Balci et al., 2006; Yilmaz & Huyuguzel Cavas, 2006), middle school students (Turgut & Gurbuz, 2011; Yilmaz et al., 2011), high school students (Abraham, 1989; Abraham & Renner, 1986; Ceylan & Geban, 2009; Demircioglu et al., 2004; Saygin, 2009; Westbrook & Rogers, 1994) and pre-service teachers (Ates, 2005; Hanuscin & Lee, 2007; Lindgren & Bleicher, 2005; Marek et al., 2003; Settlage, 2000).

Learning cycle instruction was found very effective on developing students' subject matter knowledge (Ates, 2005; Ceylan & Geban, 2009; Demircioglu et al., 2004; Musheno & Lawson, 1999; Saygin, 2009; Turgut & Gurbuz, 2011; Yilmaz et al., 2011), reasoning ability (Johnson & Lawson, 1998; Lawson, 2001), attitudes (Altun Yalcin et al., 2010; Cavallo & Laubach, 2001; Ceylan, 2008; Ergin et al., 2008; Nuhoglu & Yalcin, 2006; Sasmaz Oren & Tezcan, 2009; Yilmaz & Huyuguzel Cavas, 2006), science process skills and logical thinking skills (Westbrook & Rogers, 1994; Lavoie, 1999), and perceived motivation (Ceylan, 2008; Saygin, 2009) and perceived use of learning strategies (Ceylan, 2008; Saygin, 2009; Yilmaz, 2007). Learning cycle method can be used effectively for eliminating students' misconceptions (Balci et al., 2006; Ceylan & Geban, 2009; Demiricioglu et al., 2004; Saygin, 2009; Turgut & Gurbuz, 2011; Yilmaz et al., 2011).

The learning cycle is a teaching model used for designing curriculum materials and instructional strategies in science. Many strategies can be used within the phases of the learning cycle including laboratory experiments, demonstrations, group work, simulations, field trips, analogies, and models (Marek, Gerber, & Cavallo, 1998), all of which makes learning cycle highly constructivist. Since learning cycle instruction is applied as step by step, it is easy to use and it has many advantages compared to traditional instruction, especially for concrete operational students. Learning cycle method works well in high school science teaching as well as in elementary science teaching because most of the high school students have not yet attained formal operational level (Abraham, 1989). Learning cycle is very effective in reducing the performance difference between concrete operational and formal operational students (Ward & Herron, 1980).

In the light of the summary of the reviewed studies, this study aims to investigate the effect of 5E learning cycle instruction over traditional chemistry instruction on 11^{th} grade students' understanding of solubility equilibrium concepts, attitudes towards chemistry, and perceived motivation and use of learning strategies. In addition, the effect of gender on these dependent variables was also investigated.

CHAPTER 3

PROBLEMS AND HYPOTHESES

This chapter includes main research problems, sub problems, and hypotheses.

3.1 The Main Problems

There were three main research problems of the study:

1. What is the effect of instruction based on 5E learning cycle model compared to the traditional instruction and gender on the 11th grade students' understanding in solubility equilibrium concept and their attitudes towards chemistry as a school subject?

2. What is the effect of instruction based on 5E learning cycle model compared to traditional instruction and gender on students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety)?

3. What is the effect of instruction based on 5E learning cycle model compared to traditional instruction and gender on students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking)?

3.2 Sub-Problems

1. Is there a significant mean difference between the effects of instruction based on 5E learning cycle model and traditionally designed chemistry instruction on students' understanding of solubility equilibrium concept and attitude towards chemistry as a school subject when their science process skill scores is controlled as a covariate?

2. Is there a significant mean difference between males and females with respect to students' understanding of solubility equilibrium concept and attitude towards chemistry as a school subject when their science process skill scores is controlled as a covariate?

3. Is there any significant interaction between treatment and gender with respect to students' understanding of solubility equilibrium and attitudes toward chemistry as a school subject concept when their science process skill scores is controlled as a covariate?

4. Is there a significant mean difference between the effects of instruction 5E learning cycle model and traditionally designed chemistry instruction on students' retention in solubility equilibrium concept when their science process skill scores is controlled as a covariate?

5. Is there a significant mean difference between the groups exposed to instruction based on 5E learning cycle model and traditionally designed chemistry instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

6. Is there a significant mean difference between males and females with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety)?

7. Is there any significant interaction between treatment and gender with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety)?

8. Is there a significant mean difference between the groups exposed to instruction based on 5E learning cycle model and traditionally designed chemistry instruction with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking)?

9. Is there a significant mean difference between males and females with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self - Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking)?

10. Is there any significant interaction between treatment and gender with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking)?

3.3 Hypotheses

Ho1: There is no significant mean difference between the effects of instruction based on 5E learning cycle model and traditionally designed chemistry instruction on students' understanding of solubility equilibrium concept and attitude towards chemistry as a school subject when their science process skill scores is controlled as a covariate

Ho2: There is no significant mean difference between males and females with respect to students' understanding of solubility equilibrium concept and attitude towards chemistry as a school subject when their science process skill scores is controlled as a covariate.

Ho3: There is no significant interaction between treatment and gender with respect to students' understanding of solubility equilibrium and attitude towards chemistry as a school subject concept when their science process skill scores is controlled as a covariate.

$H_0$4: There is no significant mean difference between the effects of instruction 5E learning cycle model and traditionally designed chemistry instruction on students' retention in solubility equilibrium concept when their science process skill scores is controlled as a covariate.

$H_0$5: There is no significant mean difference between the groups exposed to instruction based on 5E learning cycle model and traditionally designed chemistry instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety).

$H_0$6: There is no significant mean difference between males and females with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal

Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety).

$H_0$7: There is no significant interaction between treatment and gender with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety).

$H_0$8: There is no significant mean difference between the groups exposed to instruction based on 5E learning cycle model and traditionally designed chemistry instruction with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking).

$H_0$9: There is no significant mean difference between males and females with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self -Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking).

$H_0$10: There is no significant interaction between treatment and gender with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking).

CHAPTER 4

METHOD

In this chapter, design of the study, population and subjects, description of variables, instruments, procedure, treatment, treatment fidelity and verification, ethical concerns, methods that were used to analyze the data, power analysis, assumptions, and limitations of the study are explained briefly.

4.1 The Experimental Design of the Study

Non-equivalent control group design, a type of quasi-experimental design, was used in this study (Gay & Airasian, 2000). Students were not randomly assigned to experimental and control groups because it is unlikely to assign each subject to experimental and control groups in the Turkish school system. Two experienced chemistry teachers were participated in this study. One class of each teacher was randomly assigned as the experimental group and the other class of each teacher was assigned as the control group. In total, there were two experimental and two control groups from a high school.

Instruction based on the 5E learning cycle was used in the experimental groups and traditionally designed chemistry instruction was used in the control groups. The teachers were informed about the aim of the study and instruction based on the 5E learning cycle model before the treatment. They taught three 45-minute sessions per week for each group and the treatment was carried out over seven weeks.

Solution Concept Test and Science Process Skills Test were administered to students in both groups before the treatment as a pre-test. Attitude Scale towards Chemistry and Motivated Strategies for Learning Questionnaire were given to students in both groups before and after the treatment. Moreover, Solubility Equilibrium Concept Test (SECT) was administered to students in both groups after the treatment as a post-test to compare the effects of instructions on students' understanding of solubility equilibrium concepts. Furthermore, SECT was administered as a retention test two months later. Table 4.1 shows the design of the study.

Table 4.1 Research Design of the Study

Groups	Pre-test	Treatment	Post-test	Retention Test
Experimental Groups (EG)	SCT ASTC SPST MSLQ	5EIM	SECT ASTC MSLQ	SERT
Control Groups (CG)	SCT ASTC SPST MSLQ	TDCI	SECT ASTC MSLQ	SERT

The meanings of abbreviations in the table are presented below.

SCT: Solution Concept Test

SECT: Solubility Equilibrium Concept Test

SERT: Solubility Equilibrium Retention Test

ASTC: Attitude Scale towards Chemistry

SPST: Science Process Skill Test

MSLQ: Motivated Strategies for Learning Questionnaire

5EIM: Instruction based 5E Learning Cycle Model

TDCI: Traditionally Designed Chemistry Instruction

4.2 Population and Subjects

The target population of the study consisted of all eleventh grade public high school students in Ankara. However, since it is not easy to conduct an experimental study on such a large population, an accessible population was chosen as all eleventh grade students in Çankaya district. There are 19 public high schools and approximately 2000 eleventh grade students who are taught chemistry in Çankaya district. One Anatolian high school was selected from the accessible population randomly. A convenience sampling technique was used to choose a sample from the accessible population since it would be extremely difficult to select a random sample of individuals. Four classes taught by the two-chemistry teacher were selected. One class from each teacher was randomly assigned as the experimental group; the other class was randomly assigned as the control group. In total, there were four groups in this study in which two of them were defined as control groups and two of them were defined as experimental groups.

A total of 109 eleventh grade students (56 male and 53 female) attending to an Anatolian High School in Ankara during the 2009-2010 spring semester were participated in this study. There were 53 students (29 female and 24 male) in the experimental group and 56 students (24 female and 32 male) in the control group. The ages of the students ranged from 16 to 17. Experimental groups were taught by 5E Learning Cycle instruction and the control groups were taught by traditionally designed chemistry instruction. Both groups received regular instruction on the solubility equilibrium concept.

4.3 Variables

4.3.1 Independent Variables

The independent variables of this study were the type of instruction (5E learning cycle instruction or traditional instruction), gender, and science process skills test scores (SPST). Among these variables, types of instruction and gender were used as group membership and SPST scores was used as covariate.

4.3.2 Dependent Variables

The dependent variables of this study were students' understanding of solubility equilibrium concepts scores obtained from the administration of Solubility Equilibrium Concept Test (SECT) as a post-test and retention test, and students' attitudes toward chemistry scores, which was measured by the Attitude Scale towards Chemistry. In addition, the other dependent variables were students' intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety, rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning, and help seeking scores as measured by the MSLQ.

4.4 Instruments

Solution Concept Test (SCT), Solubility Equilibrium Concept Test (SECT), Science Process Skill Test (SPST), Attitude Scale towards Chemistry (ASTC), and Motivated Strategies for Learning Questionnaire (MSLQ) were used as instruments. In addition, semi-structured interview schedule and classroom observation checklist were used for the collection of the qualitative data.

4.4.1 Solubility Equilibrium Concept Test (SECT)

This instrument was used to assess students' understanding of solubility equilibrium concepts. The researchers developed this instrument by taking into account the high school chemistry curriculum. In test development process; first, the instructional objectives of this unit were defined by considering the national curriculum (see Appendix B). Second, possible misconceptions about solubility equilibrium were investigated from related literature (Cam, 2009; Raviolo, 2001; Onder, 2006). These misconceptions were included in the alternatives of each item. Common misconceptions and the corresponding items addressed by the SECT were given in Table 4. 2. In total, there were 23 multiple-choice items in this test.

After the preparation of this test, it was examined by one-chemistry professor, one associate professor, and two research assistants in chemistry education, a specialist in chemistry education, and three high school chemistry teachers. Their recommendations were taken into account to revise the test.

This test was administered to students in both groups just after the treatment as a post-test and two months later as a retention test to compare the effects of instruction on students' understanding of solubility equilibrium concepts. This test was administered in both groups and took 45 minutes.

Table 4.2 Common Misconceptions and Corresponding Items Addressed by the SECT

Misconception	Item No
At equilibrium, the concentrations of the ions produced is equal to the concentration of the salt.	1(D), 14(A), 18(D)
Believing that coefficients in solubility equilibrium equations have no other meaning then equating the solubility reaction.	1(A, B, E)
Solubility equilibrium equations are written as sum of the concentration of different substances whose concentration are more than 1.	1(A, B, E)
At equilibrium, there is no precipitation and dissolution or dissolution stops.	2(B, D), 11(E), 12(A, B, C, D), 14(B, D), 18(B)

Table 4.2 Common Misconceptions and Corresponding Items Addressed by the SECT (Contunied)

Misconception	Item No
Mass can be used instead of concentration in Ksp calculations.	15(D)
The value of Ksp always decreases as temperature decreases and the concentrations of ions decrease.	21(B, D)
Before the system reaches equilibrium, there was no precipitation reaction.	2(C), 18(E)
Believing that solubility of sparingly soluble salts is effected by change made in pressure and volume.	8(A, B, D), 10(A, B, E), 20(A, C, E)
Believing that in all situations one can compare solubility of salts at equilibrium by just looking at Ksp values.	3(C, E), 13(E)
Compounds in solid form should be included while writing Ksp equations.	4(B, E), 15(B)
At equilibrium, the concentrations of ions will remain constant although common ion is added.	5(C), 11(E), 20(C)
Amount (moles) can be used instead concentration (molarity) in Ksp calculation.	6(A) , 15(C)
At equilibrium, addition of salt increases the concentrations of ions.	7(B)
Believing that there is no relation between Ksp and solubility.	8(C), 17(A)
Temperature has no affect on solubility.	9(D, E), 21(C)
At a given temperature, Ksp can change with the amount of solid or ions added.	8(A, B, D), 12(A, B, C), 20(A, C,E)
If system is at equilibrium no other solute that doesn't contain common ion can dissolve and solubility doesn't change.	12(A, B, C)
Believing that solubility of sparingly soluble salts is effected by change made in pressure.	19(A, B, C)
Believing that ion product (Qi) can be used interchangeably with Ksp.	16(A, D, E)
Believing that large Ksp implies very fast dissolution.	22(A, C, E)
The rate of dissolving increases with time until equilibrium establishes.	23(E)
The rate of dissolving remains constant until equilibrium establishes.	23(B)
The rate of precipitation remains constant until equilibrium establishes.	23(C)

A pilot test was conducted to evaluate the reliability aspects of this test scores. There were 233 students in the pilot study. Cronbach - alpha reliability of the test was calculated as 0.78. A Turkish teacher's and chemistry teachers' opinions were used as an evidence for face validity because they evaluated the test items in terms of appropriateness of language and grammatical aspects. The professor and associate professor in chemistry education evaluated the test items according to their appropriateness with the related test specifications, which were used as content-related evidence.

4.4.2 Solution Concept Test (SCT)

The test was developed by Onder (2006). This test contains 20 multiple-choice questions related to solution concepts (see Appendix D). The test was administered to students in both groups before the treatment as a pre-test to evaluate students' prior knowledge in solution and solubility concepts. The test was investigated by faculty members in chemistry and science education, and by chemistry teachers to provide content validity. The mean proportion correct and mean biserial values were obtained as 0.645 and 0.468, respectively. The reliability of the test was found to be 0.607. This test was administered in groups and took 45 minutes.

4.4.3 Attitude Scale toward Chemistry (ASTC)

This test was developed to measure students' attitudes towards chemistry as a school subject by Geban, Ertepinar, Yilmaz, Altin, and Sahbaz (1994). This instrument includes 15 items in a likert type scale (fully agree, agree, undecided, partially agree, and fully disagree) in Turkish (see Appendix E). There are both positive and negative statements. This test was given to students in both groups before and after the treatment. Total possible ASTC scores range is from 15 to 75. While lower scores show negative attitudes towards chemistry, higher scores show positive attitudes towards chemistry. The reliability of the test was found previously to be .83 (Geban et. al., 1994).

4.4.4 Science Process Skills Test (SPST)

This test was originally developed by Okey, Wise, and Burns (1982). It was adapted into Turkish by Geban, Askar, and Ozkan (1992). This test contains 36 four-alternative multiple-choice questions. The reliability of the test was found to be 0.85. This test measures intellectual abilities of students related to identifying variables, identifying and stating hypotheses, creating operational definition, designing investigations, and graphing and interpreting data. Total possible score of the SPST is 36. This test (see Appendix F) was given to all students in the study before the treatment to determine whether there is a significant contribution of science process skills to the variation in students' understanding of solubility equilibrium concepts. This is a standard test; therefore, there is no need to collect evidence for validity.

4.4.5 Motivated Strategies for Learning Questionnaire (MSLQ)

It is an 81-item-questionnaire developed to measure students' motivational orientations and learning strategies for a college course (Pintrich, et al., 1991). Students responded to items on each subscale on a seven point scale ranging from always "not at all true of me" to "very true of me." A response of "not at all true of me'' was assigned a value of 1, "very true of me" was 7.

MSLQ includes two section; motivation and learning strategies. There are 31 items in the motivation part. This part assesses the students' goals and value beliefs for a course, and their anxiety about tests in a course. There are six sub-scales in the motivation part. These are intrinsic goal orientation (IGO), extrinsic goal orientation (EGO), task value (TV), control of learning beliefs (CLB), self-efficacy for learning and performance (SELP), test anxiety (TA).

In the learning strategies section, there are 50 items concerning students' use of different cognitive and metacognitive strategies. In addition, there are 19 items related to students' management of different resources. There are nine sub-scales including rehearsal (R), elaboration (E), organization (O), critical thinking (CT), metacognitive self-regulation (MSR), time and study environmental management

(TSE), effort regulation (ER), peer learning (PL), help seeking (HS). MSLQ was originally developed in English.

Confirmatory factor analysis was conducted to calculate fit statistics ($\chi 2$/df, GFI, AGFI and RMR) for motivation section in MSLQ. In order to indicate a good fit between observed and reproduced correlation matrices, the $\chi 2$/df ratio must be less than 5. In addition, to fit the model, acceptable values are GFI or AGFI is 0.9 or greater and an RMR is 0.05 or less (Hayduk, 1987). The results of confirmatory factor analysis showed that $\chi 2$/df ratio, GFI, and RMR are 3.49, 0.77, and 0.07, respectively. These results are not within acceptable limits. However, these values were accepted as reasonable by Pintrich et al. (1991) since course characteristics, teacher demands, and individual student characteristics may affect the motivational attitudes.

The MSLQ was translated and adapted into Turkish for a biology course by Sungur (2004). A pilot study included 319 tenth and 169 eleventh grade students and confirmatory factor analysis was conducted for the 31 motivation items. Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety are six latent factors. $\chi 2$/df, GFI, and RMR were calculated as 5.3, 0.77, and 0.11, respectively by Sungur (2004). These indices values were accepted as reasonable by considering the results of the English version. It was given the fit indices of English and Turkish version of MSLQ for motivation section in Table 4.3.

Table 4.3 Comparison of Fit Indices For English Version, and Turkish Version by Sungur (2004) of MSLQ's Motivation Section (31 Items)

	N(sample size)	$\chi 2$/df	GFI	RMR
ENG	380	3.49	0.77	0.07
TUR	488	5.3	0.77	0.11

Ceylan (2009) adapted MSLQ for chemistry course from Turkish biology course adaptation of Sungur (2004). In this current study, Turkish chemistry version of MSLQ was used (see Appendix G). The test was piloted on 159 tenth grade students in an Anatolian High School and it was given to students at one time. To calculate the reliability coefficients (Cronbach alphas) of English version, Turkish version for biology and chemistry, SPSS was used. Cronbach alpha values were given in Table 4.4 for the motivation subscales.

Table 4.4 Reliability Coefficients of MSLQ's Motivation Subscale

	N(sample size)	IGO	EGO	TV	CLB	SELP	TA
ENG	380	0.74	0.62	0.90	0.68	0.93	0.80
TUR(Sungur's)	488	0.73	0.54	0.87	0.62	0.89	0.62
TUR(Ceylan's)	159	0.71	0.56	0.84	0.63	0.86	0.68

For learning strategies section in MSLQ for English and Turkish version, confirmatory factor analysis was also carried out. The results of confirmatory factor analysis for English version showed that $\chi2/df$ ratio, GFI, and RMR are 2.26, 0.78, and 0.08, respectively (Pintrich et al., 1991). On the other hand, it was found that $\chi2/df=4.5$, GFI=0.71, and RMR=0.08 at the results of confirmatory factor analysis for Turkish version by Sungur (2004). Since fit indices of English and Turkish version were similar, no modifications were made the fit indices of English and Turkish version of MSLQ for learning strategies subscales are reported in Table 4.5.

Table 4.5 Comparison of Fit Indices For English Version, and Turkish Version (Sungur, 2004) of MSLQ's Learning Strategies Subscale (50 items)

	N(sample size)	$\chi2/df$	GFI	RMR
ENG	380	2.26	0.78	0.08
TUR	488	4.5	0.71	0.08

Reliability coefficients (Cronbach alpha) were given in Table 4.6 for MSLQ's learning strategies section.

Table 4.6 Reliability Coefficients of MSLQ's Learning Strategies Subscale

	N	R	E	O	CT	MSR	TSE	ER	PL	HS
ENG	380	0.69	0.76	0.64	0.80	0.79	0.76	0.69	0.76	0.52
TUR(Sungur's)	488	0.73	0.78	0.71	0.81	0.81	0.73	0.62	0.61	0.57
TUR(Ceylan's)	159	0.71	0.71	0.66	0.82	0.79	0.74	0.70	0.66	0.55

To investigate the effect of instruction based on 5E learning cycle model on eleventh grade students' motivation and learning strategies, the Turkish version of MSLQ adapted for use in chemistry courses (Ceylan, 2009) was used in the present study.

4.4.6 Semi-Structured Interviews

A semi-structured interview schedule was conducted with 12 students in both groups after the treatment to investigate the nature of and reasons for students' misconceptions in solubility equilibrium concepts. Students in both groups were categorized as high achievers, middle achievers and low achievers according to post-solubility equilibrium concept test scores on the SECT, and six students from each group were chosen randomly based on their achievement level. By comparing the answers of experimental (24 Male and 29 female Students) and control group (32 Male and 24 female students) students, the treatment effectiveness on remediation of students' misconceptions about solubility equilibrium was analyzed in-depth. Interview schedule was constructed by the researchers, and it included two parts (see Appendix H). In the first part, students were asked conceptual questions related to solubility equilibrium concepts. Second part included seven questions related to the differences between traditional and 5E learning cycle instruction, changes in the teacher, and general questions. The questions in the second part were only administered to the students in the experimental group. Before conducting the interview, a pilot study was carried out with six eleventh grade high school students to check the effectiveness of the interview questions in gaining information about students' misconceptions about solubility equilibrium concepts. The recommendations of the professors and colleagues were also taken into consideration, and some revisions were done on the interview schedule. A tape recorder was used during interview process in order to record the data. Each interview process took approximately 30-40 minutes.

4.4.7 The Classroom Observations

Observations in both control and experimental group classrooms were conducted by the researcher. An observation checklist with respect to lesson plans was prepared before the treatment. This checklist consisted of 16 items with 3 points Likert type scale including yes\ no\ partially (see Appendix I). The checklist was examined by a specialist in chemistry education and three high school chemistry teachers from different schools. The researcher observed all classrooms and scored whether the steps in the checklist were observed or not. It was decided by the researcher whether the treatments were applied properly or not after the observation.

4.5 Procedure

The aim of the study was to investigate the effect of the 5E learning cycle instruction on students' understanding of solubility equilibrium concepts. First, a detailed review of the literature was conducted. Keywords, such as learning cycle, 5E learning cycle, science education, chemistry education, solubility equilibrium, conceptual change approach, hands-on activities, laboratory activities, attitude, motivation, science process skill, MSLQ, metacognition, self-efficacy, self-regulation were determined. Then, Educational Resources Information Center (ERIC), Social Science Citation Index (SSCI), Dissertation Abstracts International, and the Internet were searched by using these keywords. Finally, literature was examined in detail and the instruments were developed by the researcher.

4.6 Treatment

This study was conducted over seven weeks during the spring semester of 2009-2010 academic year. A total of 109 students from four 11^{th} grade classes participated in the study. Classes were randomly assigned to control and experimental treatments. Experimental group students were instructed using the 5E learning cycle model whereas control group students were instructed with traditionally designed chemistry instruction. Both groups were instructed by the two-chemistry teacher throughout the treatment. Each chemistry teacher taught one control and one experimental class.

The 5E learning cycle instruction was defined by creating a list that showed each step of instruction. The objectives of this lesson were determined by the researcher. Detailed lesson plans were prepared by integrating these two procedures (see Appendix J).These lesson plans were examined by experts in chemistry, chemistry education, and chemistry teachers. Revisions were made with respect to their recommendations. The last version of lesson plan served as an instructional guideline that was used in the experimental groups. The same procedures were conducted for the traditionally designed chemistry instruction. Pilot study was conducted in a public high school. After the minor revisions on the pilot study, the actual study was carried out. The teachers were trained with respect to these lesson plans and instruction based on 5E learning cycle model, how to implement the lesson plan in the experimental groups, and which steps of 5E learning cycle model were represented by the activities. Furthermore, the teachers were informed about possible students' misconceptions about solubility equilibrium. As it was said before, there were two teachers in this study; therefore, the main aim of the training was to eliminate the differences that might arise from differences in implementation. Permission was granted from the teachers to observe the control and experimental groups.

Same subject matter and textbook were used by both groups. The classroom instruction consisted of three 45-minutes sessions each week. Solubility equilibrium topics were covered as a part of the regular curriculum.

Before the treatment, the Solution Concept Test, Attitude Scale towards Chemistry, Science Process Skill Test, and Motivated Strategies for Learning Questionnaire were administered to both groups as a pre-test. The Solution Concept Test was used in order to examine students' level of understanding about solution concepts before the treatment. The aim of using Attitude Scale towards Chemistry as a pre-test was to measure students' attitudes towards chemistry as a school subject. Science Process Skill Test and Motivated Strategies for Learning Questionnaire were administered to assess students' level of science process skills and students' motivational constructs, respectively. The Solubility Equilibrium Concept Test, Motivated Strategies for Learning Questionnaire, and Attitude Scale towards Chemistry were administered as post- tests to examine the effect of the treatment. Two months after the treatment the SECT was administered again to both groups to assess their retention on solubility equilibrium concepts (SERT).

The 5E learning cycle model consisted of five steps including engagement, exploration, explanation, elaboration, and evaluation. Each lesson in the experimental group started with a question asked by the teacher (Engage). The aim of these questions was to activate students' prior conceptions or misconceptions about the concepts and to engage students in the lesson. Generally, after this question, different answers emerged and a disagreement among students occurred. The teacher guided this discussion until students were aware of where their knowledge failed to explain the situation. In the exploration phase, activities were designed for students to acquire concrete experiences of the concepts. Generally, demonstrations, hands-on activities, and laboratory activities were used in this phase. To attract students' attention, these activities were conducted by teachers. In the explanation phase, teachers presented scientifically content explanations for the students. After the discussion, the teacher explained and connected early phases concepts. The aim of the elaboration phase was to provide students' further experiences to elaborate the concepts, process, or skills. The activities in this step are similar to exploration phase but completely based on new situation. In the evaluation phase, students received feedback from the teachers about their understanding and skills. For example, in a week, teacher asked these questions "Have you ever been Alanya and Burdur?", "Have you ever seen Damlatas cave, and Insuyu cave?", "How these caves were formed?". These questions were discussed by students in the engagement phase. In the exploration phase, teacher demonstrated the experiment about equilibrium. Students were given observations sheet to fill the results of the experiment. In the explanation phase, teacher reminded chemical equilibrium. Writing of Ksp and equilibrium equation were explained and given activity sheets. Students were answered these questions in the whiteboard. After this activity, students were given the activity sheet related formation of Damlatas and Insuyu caves becase teacher asked the questions these subject in the first phase. These formations were discussed and explained by the teacher and students. Teacher continued the solubility equilibirum expalanations, which are related with the types of solubility. In the elaboration phase, the teacher tells the hard water leaves the scaly residues in the sanitary installations and asked the students "Could you explain the reason why?." After the discussion, teacher distributed hard water and teacher asked "What are the advanages and disadventages of hard water?." After students gave their answers, activity sheet about the advanatages and disadvantages of hard water were distributed to them. In the final phase, teacher was given conceptual change texts about subject to evaluate the students. After students were answered these texts, teacher gave the answers them.

In the experimental classes, groups of 4-5 students were formed. Students were engaged in activities aiming to increase their attention, and curiosity and to elicit their misconceptions related to solubility equilibrium. Then, students were given opportunity to explore new phenomena. Both the teacher and the students engaged in a discussion based on the previous exploratory activity and the teacher introduced the scientific explanation of the new concept. At the end, students were given opportunities to apply the new concepts to additional situations and their acquisitions of the scientific concepts were evaluated both formally and informally.

In the control groups, traditionally designed instruction was used. Lecture, and discussion were used to teach solubility equilibrium concepts and problems were asked. Before the lesson, students read the topic from their textbook. During the lesson teacher explained the topic without consideration of students' misconceptions, and wrote content and formulas to the board. Students took the notes from the board to their notebooks. Teacher did not ask question to the students in order to check if they understood or not. Then, teacher asked algorithmic and conceptual questions related to the topic. Adequate time was given to respond to the questions. If the question was conceptual, a discussion session followed. During this session, teacher gave directions to find the correct answer. That is, students took the correct answers from their teacher and memorized them. If the question was algorithmic, two problems were solved by the teacher on the board. Then, similar questions were asked to provide student understanding. In this questioning process, a question was written on the board and the teacher gave two or three minutes to solve the problem. The teacher often selected faster or eager students to solve the problem on the board. Most of the students were passive listeners and only took notes. In general, the same students answered the questions. There was limited teacher-student interaction. For example, at the beginning of the lesson the teacher asked "what is the solubility?", "what are the factors affecting the solubility?." Mostly by using rote knowledge, students answered these questions. At the end of the lesson, worksheets including problems were given to the students. In next week, the teacher solved these problems on the board.

4.7 Treatment Fidelity and Treatment Verification

Treatment fidelity is an attempt by the researcher to ensure that no other factor except the treatment is responsible for the difference in the dependent variable before study is conducted (Borrelli, Sepinwall, Bellg, Breger, DeFrancesco, Sharp, Ernst, Czajkowski, Levesque, Ogedegbe, Resnick, & Orvig, 2005; Detrich, 1999; Hennessey & Rumrill, 2003). To do this, the instruction based on the 5E learning cycle model was defined by creating a list that shows each steps of this instruction and then the objectives of this lesson were determined. Detailed lesson plans for the instruction based on 5E learning cycle model were prepared. These lesson plans were examined by a chemistry professor, an associate professor, two research assistants in chemistry education, a specialist in chemistry education, and three high school chemistry teachers. Revisions were made with respect to their recommendations. Moreover, the last version of lesson plans served as a guideline for the instruction used in experimental groups. Furthermore, in the last step, the teachers were trained with respect to these lesson plans. As it was said before, there were two teachers in this study; therefore, the main aim of the training was to eliminate the differences that may arise from the different implementer factor. Moreover, the researcher observed the control and experimental groups. These procedures are defined as treatment fidelity.

Treatment verification enables the researcher to ensure that the treatment was implemented as defined in the study (Shaver, 1983). Observations in both control and experimental groups were conducted by researcher. An observation checklist with respect to lesson plans was prepared before the treatment. This checklist was examined by a specialist in chemistry education and two high school chemistry teachers from different schools. The researcher observed the classrooms and decided whether the steps in the checklist were completed or not. After the observation, the researcher with the help of experts decided whether the treatments were applied properly or not. The minimum criterion for accepting the treatment implemented as intended was at least 75% of the items, above the average. This procedure is defined as treatment verification.

4.8 Ethical Concerns

In this research, there were no ethical problems. Some issues such as the protection of students from harm, the ensuring of confidentiality of research data, and the question of deception of subjects were addressed in the study. This study did not cause any physical or psychological harm or danger. In addition, students were given a consent form that involved the information about potential harm of the instruction used in the experiment. The data were not accessed by anyone except researcher. Additionally, the subjects' names were removed from instruments by assigning a number to each student. Students' names were not stated in the study. All students had a chance to withdraw or not to participate in the study. All students in the study were assured that any data collected from or about them were held in confidence. The researcher avoided deceiving any subject in the study.

4.9 Analysis of Data

Data obtained from this study were entered in a SPSS data file after data collection. Descriptive and inferential statistics were conducted.

4.9.1 Descriptive Statistics

Mean, range, minimum and maximum values, standard deviation, skewness, kurtosis, and frequency tables were presented to describe the data for the both groups.

4.9.2 Inferential Statistics

To check the equality of experimental and control groups, independent t-tests were conducted at the beginning of the study with respect to students' pre-test scores on solution concept test, attitude scale towards chemistry, and science process skill test. Since there were significant differences between control and experimental groups with respect to students' science process skills, SPST were assigned as a covariate. Moreover, two different MANOVA were executed to determine whether there was a significant difference between control and experimental group with respect to students' motivation and learning strategies.

After the treatment, two-way MANCOVA was used to determine the effectiveness of instruction based on the 5E learning cycle model and traditional instruction, and gender difference on students' understanding of solubility equilibrium concepts and attitude by controlling the effect of students' science process skills as a covariate. In addition, in order to determine the effect of two different instructional methods on students' retention related to solubility equilibrium concepts by controlling the effect of students' science process skills as a covariate, ANCOVA was carried out. Moreover, MANOVA was conducted in order to examine the effect of two different instructional methods on students' motivation to the chemistry as a school subject including intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety. Furthermore, another MANOVA was executed to determine effectiveness of two instructional methods on students' use of learning strategies including rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning, and help seeking.

4.10 Power Analysis

Before conducting statistical procedures, the power, which is the probability of rejecting a false null hypothesis (1-β), and the sample size (n) are needed to discuss (Hinkle, Wiersma, & Jurs, 2003). Alpha (α), which is the probability of rejecting true null hypothesis, was set to 0.05 for the present study. Moreover, β, which is the probability of failing to reject a false null haypothesis, was set to 0.20. In addition, the power of the study (1- β), which is the probability of rejecting a false null hypothesis, was set to the value of 0.80 at the beginning of the study (Cohen, Cohen, West, & Aiken, 2003). k_a (the number of covariates) = 1, and k_b (the number of fixed factors) = 1. Then, L value was found as 7.85 from table presented Cohen et al. (2003, p.651). Required sample size was determined by using the "$n= L/f^2+ k_a + k_b+1$" formula (Cohen et al., 2003). By applying the values of $L=7.85$, $f^2= 0.15$, $k_a = 1$, and $k_b = 1$ to the n formula, sample size is found as 55. Sample size was 109 eleventh grade students in the current study. k_c (the number of independent variables) for the study is gender and teaching method. L value was calculated for the 109 participants as 15.90 by using same formula ($109= L\backslash 0.15+ 2 + 1 \rightarrow L= 15.90$). Then by using the table of Cohen et al. (2003, p.651), the calculated power was found as between 0.95 (15.44 of L value) and 0.99 (21.40 of L value). The calculated power was more close 0.95 value.

4.11 Assumptions of the Study

1. There were no interaction between students in the experimental group and the control group during treatment.
2. Teachers were not biased during the treatment.
3. The results of the study were not affected by characteristics of two chemistry teachers who implemented the treatments.

4. All instruments were administered under standard conditions in experimental and control groups.
5. The students answered the tests truthfully, honestly and seriously.

4.12 Limitations of the Study

1. The study was limited to the topic of solubility equilibrium.
2. The findings of the study are limited to the 109 eleventh grade students from one school in Ankara.
3. The independence of observation assumption of the MANOVA may not be met properly since treatments and instrumentation were applied at the same time.
4. Already formed groups were used and the subjects in the groups were not assigned randomly in this study.

CHAPTER 5

RESULTS AND CONCLUSION

In this chapter, hypotheses of the study were analyzed statistically and the results were presented. In addition, results of interviews and observations were given. The results were divided into five sections. In the first section, statistical analyses of pre-test scores on the SCT, ASTC, SPST, and MSLQ were displayed. The second section included statistical analyses of post-test and retention test scores. In the third section, analyses of students' responses to interviews were presented. The fourth section explains the analyses of students' ideas about the 5E learning cycle model. In the fifth section, the results of classroom observation were presented. Finally, the results of this study were summarized.

5.1 Statistical Analysis of Pre-test Scores

Prior to the treatment, independent t-tests were conducted to determine whether there was a statistically significant mean difference between experimental and control groups with respect to students' pre-test scores on Solution Concept Test, Attitude Scale towards Chemistry Test, and Science Process Skill Test. Two separate MANOVA were executed to determine whether there was a statistically significant mean difference between experimental and control groups with respect to students' perceived motivation and learning strategies. Statistical analyses were performed at 0.05 significance level using PASW (Predictive Analytics Software) Statistics 18.

5.1.1 Statistical Analysis of the pre-SCT, pre-ASTC, and pre-SPST scores

Descriptive statistics of experimental and control group students' pre-SCT, pre-ASTC, and pre-SPST scores were given in Table 5.1.

Table 5.1 Descriptive Statistics related to the pre-SCT, pre-ASTC, and SPST Scores of Students in Experimental (EG) and Control Group (CG)

Test	N		Mean		Std Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Pre-SCT	56	53	11.07	12.00	3.56	3.32	-.369	-.536	-1.008	-.597
Pre-ASTC	56	53	48.16	49.66	10.43	10.7	-.745	-1.286	.002	2.498
SPST	56	53	29.75	26.58	2.29	2.10	-.055	.201	-.986	-.643

The mean of the experimental and control groups with respect to the pre-SCT were 12.00 and 11.07, respectively. A better understanding of solution concept is represented by higher scores. The experimental group students had a higher mean score than the control group students in terms of prior knowledge on the solution concept.

Experimental group students' mean scores in the pre-ASTC were 49.66 while control group students' mean scores in pre-ASTC were 48.16. Students in the experimental group had more positive attitude towards chemistry than those in control group prior to the study.

As shown in Table 5.1, the experimental group students' SPST mean scores were 26.58 while control group students' SPST mean scores were 29.75. Students in the control group showed better abilities in science problem solving than those in the experimental group before the treatment.

Before interpreting, the independent t-test outputs, normality, independence of observations, and equality of variance assumptions were checked. Normal distribution, skewness, and kurtosis values ranged between -2 and +2. All skewness and kurtosis values ranged between -2 and +2, except for the kurtosis value of the pre-ASTC. However, this violation was very small. Therefore, all distributions were normal. Since the students answered the tests independently, the independence of observation assumption was assumed to be met. Levene's test results, shown in Table 5.2, revealed that the population variances for the two groups were equal.

Table 5.2 Levene's Test of Equality of Variances

	F	*p*
pre-SCT	.343	.560
pre-ASTC	.249	.475
SPST	.697	.406

Having met the assumptions, independent t-test outputs were interpreted to determine whether there was a significant mean difference between experimental and control group with respect to pre-SCT, pre-ASTC, and SPST. The results of independent t-tests were displayed in Table 5.3.

Table 5.3 Independent t-Tests Results with respect to pre-SCT, pre-ASTC, SPST

	t	*df*	*p*
pre-SCT	1.402	107	.164
pre-ASTC	.740	107	.461
SPST	-7.497	107	.000

According to this analysis, there were no significant mean differences between the EG (M= 12.00, SD= 3.32) and the CG (M= 11.07, SD= 3.56) with respect to students' previous solution concept understanding as measured by pre-SCT, t (107) = 1.402, p > 0.05. Moreover, results showed that there was no significant mean difference between EG (M= 49.66, SD= 10.70) and CG (M= 48.16, SD= 10.43) with respect to students' previous attitude towards chemistry as a school subject measured by pre-ASTC, t (107) = .740, p > 0.05. On the other hand, there was a significant mean difference between EG (M=26.58, SD= 2.10) and CG (M= 29.75, SD= 2.29) with respect to students' science process skills measured by SPST in favor of the control group, t (107) = -7.497, p < 0.05. Therefore, to control preexisting differences SPST was assigned as a covariate in the statistical analyses of post-SECT and SERT scores.

5.1.2 Statistical Analysis of the pre-MSLQ scores for Motivation Section

Prior to treatment, a MANOVA was conducted to investigate whether there was a significant mean difference between EG and CG group in terms of the motivational collective dependent variables of students' Intrinsic Goal Orientation (IGO), Extrinsic Goal Orientation (EGO), Task Value (TV), Control of Learning Beliefs (CLB), Self-Efficacy for Learning and Performance (SELP), and Test Anxiety (TA) for groups. Table 5.4 displays descriptive statistics for the motivational dependent variables for experimental and control groups.

Table 5.4 Descriptive Statistics of IGO, EGO, TV, CLB, SELP, and TA for EG and CG

	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
IGO	56	53	18.07	19.81	4.87	3.99	-.020	-.065	-1.142	-.519
EGO	56	53	19.43	18.77	4.60	5.34	-.319	-.151	-.223	-.737
TV	56	53	26.73	27.74	6.18	4.92	-.214	-.037	-.484	-1.039
CLB	56	53	21.73	22.26	4.07	3.46	-.439	-.298	-.106	-.458
SELP	56	53	38.57	39.28	8.763	8.66	-.352	-.747	-.271	.675
TA	56	53	18.52	19.91	6.442	6.75	-.446	-.117	.252	-.311

Before interpreting the MANOVA outputs for motivation section, the assumptions were checked, as reported in the following sections.

5.1.2.1 Assumptions of Multivariate Analysis of Variance

5.1.2.1.1 Sample Size

The sample size was large enough to execute MANOVA because the number in each cell was greater the number of dependent variables (Pallant, 2007).

5.1.2.1.2 Normality and Outliers

Skewness and kurtosis values for the dependent variables, which were presented in Table 5.4, were checked for univariate normality assumption. Since the values varied between -2 and +2 in the experimental and the control group, this assumption was met. In addition, histograms with a normal curve were tested to check normality.

Mahalanobis value was calculated to test for multivariate outliers. Moreover, this value was compared to the critical value for six dependent variables given in the Chi-square table (Pallant, 2007). The critical value with six dependent variables was found to be 22.46 from the table. The maximum Mahalanobis distance of the sample was found as 20.955. Since this value was smaller than the critical value, there were no multivariate outliers in the data. That is, there was no need to remove any value from the data. Moreover, the multivariate normality assumption was met by considering the maximum Mahalanobis distance of the sample.

5.1.2.1.3 Linearity

Presence of a straight-line relationship between each pair of the dependent variables is called as linearity assumption. By generating a matrix of scatterplots between each pair of the dependent variables, this assumption was checked (Pallant, 2007). Since the matrix of scatterplots did not demonstrate any obvious of non-linearity, the linearity assumption was verified.

5.1.2.1.4 Multicollinearity and Singularity

If the correlations among the dependent variables are moderate, a MANOVA runs well. When correlations of dependent variables are high, multicollinearity occurs. To check whether multicollinearity exists, correlations among dependent variables are computed. If the correlations are around .8 or .9, there is a problem with multicollinearity. When the correlations of dependent variables are too low, singularity occurs (Pallant, 2007). Table 5.5 shows that the dependent variables were moderately correlated. Therefore, these assumptions were satisfied.

Table 5.5 Correlations among Dependent Variables

	IGO	EGO	TV	CBL	SELP	TA
IGO	---					
EGO	-.155	---				
TV	.488**	-.020	---			
CBL	.417**	.038	.285**	---		
SELP	.528**	-.095	.538**	.339**	---	
TA	-.229*	.439**	-.088	-.139	-.252	---

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

5.1.2.1.5 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances. Box's Test results revealed that the covariance matrices of the dependent variables were equal across groups, F (21, 41834) = 1.240, p = .205. That is, the homogeneity of variance-covariance matrices assumption was not violated with a Box's M significance value of 0.205.

Table 5.6 Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices	
Box's M	27.713
F	1.240
df1	21
df2	41834
Sig.	.205

To check the homogeneity of variance assumption, the Levene's test results were examined. The results in Table 5.7 showed that each dependent variable except IGO has the same variance across groups. Since skewness and kurtosis values are normal and F value of IGO was not large, it can be accepted there was no violation of this assumption (George & Mallery, 2003).

Table 5.7 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
IGO	4.036	1	107	.047
EGO	1.896	1	107	.171
TV	1.980	1	107	.162
CLB	.819	1	107	.368
SELP	.164	1	107	.686
TA	.345	1	107	.558

After verifying the assumptions, a Multivariate Analysis of Variance (MANOVA) was conducted.

5.1.2.2 Multivariate Analysis of Variance

Prior to treatment, a MANOVA was executed to check whether there was a significant mean difference between experimental and control group with respect to IGO, EGO, TV, CLB, SELP, and TA. The results of MANOVA were given in Table 5.8.

Table 5.8 MANOVA Results with respect to Collective Dependent Variables of IGO, EGO, TV, CLB, SELP, and TA

Source	Wilk's Lambda	F	Sig. (p)
Treatment	0.92	1.39	0.225

The results of MANOVA revealed that there was no significant mean difference between experimental and control groups' students in terms of collective dependent variables of IGO, EGO, TV, CLB, SELP, and TA, $F (6, 102) = 1.39$, $p=.225$; Wilks' Lambda = .92. In other words, before the treatment students' motivations in chemistry were not different in experimental and control group.

5.1.3 Statistical Analysis of the pre-MSLQ scores for Learning Strategies Section

A MANOVA was carried out to determine whether there was a significant mean difference between EG and CG group in terms of collective dependent variables of Rehearsal (R), Elaboration (E), Organization (O), Critical Thinking (CT), Metacognitive Self-Regulation (MSR), Time and Study Environment (TSE), Effort Regulation (ER), Peer Learning (PL), and Help Seeking (HS) before the instruction. Table 5.9 displays descriptive statistics of learning strategies dependent variables for experimental and control groups.

Table 5.9 Descriptive Statistics of R, E, O, CT, MSR, TSE, ER, PL, and, HS for EG and CG

	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
R	56	53	16.95	17.89	4.81	5.14	.440	.132	-.210	-.170
E	56	53	25.91	26.58	6.22	5.08	-.234	-.134	-.298	-.581
O	56	53	17.27	18.58	4.56	4.62	-.210	-.066	-1.132	-.758
CT	56	53	19.09	20.26	5.83	5.03	-.003	-.199	-.701	-.575
MSR	56	53	51.04	54.53	10.10	8.68	.328	.193	.378	-.297
TSE	56	53	36.63	38.17	7.53	6.78	.219	-.179	.201	.121
ER	56	53	18.46	19.31	5.12	4.12	-.457	-.101	.073	-.418
PL	56	53	10.93	11.19	3.38	3.09	.625	-.147	.110	-.400
HS	56	53	18.80	19.42	4.66	4.53	-.737	-.689	.913	.615

Before interpreting MANOVA outputs for learning strategies section, the assumptions were checked.

5.1.3.1 Assumptions of Multivariate Analysis of Variance

5.1.3.1.1 Sample Size

The sample size was large enough to execute MANOVA because the number in each cell was greater the number of dependent variables (Pallant, 2007).

5.1.3.1.2 Normality and Outliers

Skewness and kurtosis values for the dependent variables, which are presented in Table 5.4, were checked for univariate normality assumption. Since the values varied between -2 and +2 in the experimental and the control groups, this assumption was met. In addition, histograms with a normal curve were tested to check normality.

Mahalanobis value was calculated to test for multivariate outliers. Moreover, this value was compared to the critical value for nine dependent variables given in the Chi-square table (Pallant, 2007). The critical value with nine dependent variables was found to be 27.88 from the table. The maximum Mahalanobis distance of the sample was found as 26.269. Since this value was smaller than the critical value, there were no multivariate outliers in the data. That is, there was no need to remove any value from the data.

5.1.3.1.3 Linearity

Presence of a straight-line relationship between each pair of the dependent variables is called as linearity assumption. By generating a matrix of scatterplots between each pair of the dependent variables, this assumption was checked (Pallant, 2007). Since the matrix of scatterplots did not demonstrate any obvious of non-linearity, the linearity assumption was verified.

5.1.3.1.4 Multicollinearity and Singularity

If the correlations among the dependent variables are moderate, a MANOVA runs well. When correlations of dependent variables are high, multicollinearity occurs. To check whether multicollinearity exists, correlations among dependent variables were computed. If the correlations are around .8 or .9, there is a problem with multicollinearity. When the correlations of dependent variables are too low, singularity occurs (Pallant, 2007). Table 5.10 shows that the dependent variables were moderately correlated. Therefore, these assumptions were satisfied.

Table 5.10 Correlations among Dependent Variables

	R	E	O	CT	MSR	TSE	ER	PL	HS
R	---								
E	.371**	---							
O	.432**	.421**	---						
CT	.086**	.488**	.321**	---					
MSR	.511**	.491**	.392**	.426**	---				
TSE	.461**	.378**	.354**	.166	.533**	---			
ER	.337**	.237*	.378**	.279**	.527**	.628**	---		
PL	.324**	.398**	.321**	.441**	.389**	.155	.237*	---	
HS	.369**	.258**	.344**	.274**	.246**	.152	.260**	.256**	---

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

5.1.3.1.5 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances. Box's M Test results in Table 5.11 revealed that the covariance matrices of the dependent variables were equal across groups, F (45, 37372) = 1.208, p = .161. That is, homogeneity of variance-covariance matrices assumption was not violated with a Box's M significance value of 0.161.

Table 5.11 Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices	
Box's M	59.660
F	1.208
df1	45
df2	37372
Sig.	.161

To check homogeneity of variance assumption the Levene's test results were examined. The results in Table 5.12 showed that each dependent variable has the same variance across groups.

Table 5.12 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
R	.208	1	107	.649
E	1.624	1	107	.205
O	.033	1	107	.857
CT	1.201	1	107	.276
MSR	.767	1	107	.383
TSE	.169	1	107	.682
ER	1.489	1	107	.225
PL	.737	1	107	.392
HS	.009	1	107	.926

After verifiying the assumptions, Multivariate Analysis of Variance (MANOVA) was conducted.

5.1.3.2 Multivariate Analysis of Variance

Prior to treatment, MANOVA was executed to check whether there was a significant mean difference between experimental and control group with respect to R, E, O, CT, MSR, TSE, ER, PL, and HS. The results of MANOVA were given in Table 5.13.

Table 5.13 MANOVA Results with respect to Collective Dependent Variables R, E, O, CT, MSR, TSE, ER, PL, and HS

Source	Wilk's Lambda	F	Sig. (p)
Treatment	0.95	0.61	0.79

The results of MANOVA in Table 5.13 revealed that there was no significant mean difference between experimental and control groups' students in terms of collective dependent variables of R, E, O, CT, MSR, TSE, ER, PL, and HS, F (9, 99) = .61, p=.79; Wilks' Lambda = .95; partial eta squared = .052. In other words, before the treatment students' learning strategies in chemistry were not different in experimental and control group.

5.2 Statistical Analyses of Post-test Scores

Statistical analyses of post-SECT, post-ASTC, and post-MSLQ scores were conducted to test the hypotheses given in Chapter 3.

5.2.1 Statistical Analyses of the post-SECT and post-ASTC Scores

Ho1: There is no significant mean difference between the effects of instruction based on the 5E learning cycle model and traditionally designed chemistry instruction on students' understanding of solubility equilibrium concept, and students' attitudes towards chemistry as a school subject when their science process skill is controlled as a covariate.

Ho2: There is no significant mean difference between males and females with respect to students' understanding of solubility equilibrium concept and students' attitudes towards chemistry as a school subject when their science process skill is controlled as a covariate.

Ho3: There is no significant interaction between treatment and gender with respect to students' understanding of solubility equilibrium and attitudes towards chemistry as a school subject concept when their science process skill is controlled as a covariate.

These hypotheses were tested by two-way MANCOVA where independent variables were treatment and gender. Understanding of solubility equilibrium concept (SECT) and students' attitudes towards chemistry as a school subject (ASTC) were dependent variables. Students' science process skills (SPST) scores were assigned as a covariate. Descriptive statistics for the dependent variables across the experimental and control groups were displayed in Table 5.14.

Table 5.14 Descriptive Statistics in terms of SECT and post-ASTC across Experimental and Control Groups

	Mean		Std. Dev.		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG
SECT	10.66	15.19	3.28	3.36	.294	-.005	-.419	-.174
ASTC	46.50	52.30	9.11	9.30	-.699	.237	1.799	-.363

Descriptive statistics for the dependent variables across gender were given in Table 5.15.

Table 5.15 Descriptive Statistics in terms of SECT and post-ASTC across Gender

	Mean		Std. Dev.		Skewness		Kurtosis	
	Male	Female	Male	Female	Male	Female	Male	Female
SECT	12.16	13.60	3.69	4.23	-.268	.267	-.754	-.811
ASTC	47.23	51.53	10.34	8.32	-.186	.245	1.315	-.396

5.2.1.1 Assumptions of Multivariate Analysis of Covariance

5.2.1.1.1 Sample Size

The sample size was large enough to execute MANCOVA because the number in each cell was greater the number of dependent variables (Pallant, 2007).

5.2.1.1.2 Normality and Outliers

Skewness and kurtosis values for the dependent variables, which are presented in Table 5.14, were checked for univariate normality assumption. Since the values varied between -2 and +2 in the experimental and the control group, this assumption was met. In addition, histograms with a normal curve were tested to check normality.

Mahalanobis value was calculated to test for multivariate outliers. Moreover, this value was compared to the critical value for two dependent variables given in the Chi-square table (Pallant, 2007). The critical value with two dependent variables was found to be 13.82 from the table. The maximum Mahalanobis distance of the sample was found as 13.55. Since this value was smaller than the critical value, there were no multivariate outliers in the data. That is, there was no need to remove any value from the data.

5.2.1.1.3 Linearity

Presence of a straight-line relationship between each pair of the dependent variables is called as linearity assumption. By generating a matrix of scatterplots between each pair of the dependent variables, this assumption was checked (Pallant, 2007). Since the matrix of scatterplots did not demonstrate any obvious of non-linearity, linearity assumption was verified.

5.2.1.1.4 Multicollinearity and Singularity

If the correlations among the dependent variables are moderate, a MANCOVA runs well. When correlations of dependent variables are high, multicollinearity occurs. To check whether multicollinearity exists, correlations among dependent variables were computed. If the correlations are around .8 or .9, there is a problem with multicollinearity. When the correlations of dependent variables are too low, singularity occurs (Pallant, 2007). Table 5.16 shows that the dependent variables were moderately correlated. Therefore, these assumptions were satisfied.

Table 5.16 Correlations among Dependent Variables

	SECT	ASTC
SECT	---	
ASTC	.171	---

5.2.1.1.5 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances. Box's Test results revealed that the covariance matrices of the dependent variables were equal across groups, F (9, 100597) = 1.531, p = .130. That is, homogeneity of variance-covariance matrices assumption was not violated with a Box's M significance value of 0.130.

Table 5.17 Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices	
Box's M	14.281
F	1.531
df1	9
df2	100597
Sig.	.130

To check homogeneity of variance assumption the Levene's test results were examined. The results in Table 5.18 showed that each dependent variable has the same variance across groups.

Table 5.18 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
SECT	1.793	3	105	.153
ASTC	1.191	3	105	.317

5.2.1.1.6 Homogeneity of Regression Slopes

Multiple Regression Correlation (MRC) analysis was conducted to check assumption of homogeneity regression slopes. This analysis was carried out both dependent variables, Post - SECT and Post – ASTC. Set A, Set B, and Set C was determined for this analysis. Set A was covariate (Pre-SPST), and Set B was Treatment, Gender, and Treatment*Gender. Set C included Pre-SPST*Treatment, Pre-SPST*Gender, Pre-SPST*Treatment*Gender. All interaction terms were formed by multiplying all variables in Set A and Set B. The results of MRC analyses were given in Table 5.19 and Table 5.20. According to these tables, there was no significant interaction between covariate and group membership for the Post-SECT

(0.820) and Post-ASTC (0.347). Therefore, assumption of homogeneity regression slopes was met.

Table 5.19 MRC Analysis indicating Homogeneity of Regression Assumption For The post-SPST

Change Statistics for the post-SPST					
Model	R^2 Change	F Change	df1	df2	Sig. F Change
Set A (Covariate)	0.058	6.564	1	107	0.012
Set B (Grup Membership)	0.287	15.167	3	104	0.000
Set C (Set A X Set B)	0.006	0.307	3	101	0.820

Table 5.20 MRC Analysis indicating Homogeneity of Regression Assumption For the post-ASTC

Change Statistics for the post-ASCT					
Model	R^2 Change	F Change	df1	df2	Sig. F Change
Set A (Covariate)	0.105	12.493	1	107	0.001
Set B (Grup Membership)	0.085	3.633	3	104	0.015
Set C (Set A X Set B)	0.026	1.114	3	101	0.347

5.2.1.1.7 Linear Relationship between Dependent Variables and Covariate

The correlation between dependent variables and covariate should be significant in order to meet this assumption. By calculating the correlations between dependent variables and covariate, this assumption was checked. The correlations between post-SECT and SPST ($p = .012$), and post-ASTC and SPST ($p = .001$) were significant.

5.2.1.2 Multivariate Analysis of Covariance

After verifying the assumptions, a Multivariate Analysis of Covariance (MANCOVA) outputs were interpreted.

Table 5.21 MANCOVA Results with respect to Collective Dependent Variables

Source	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Sig. (p)	Eta-Squared	Observed Power
Treatment	.729	19.112	2	103	.000	.271	1.000
Gender	.925	4.153	2	103	.018	.075	.721
SPST	.934	3.645	2	103	.030	.066	.661
Treatment* Gender	.988	.650	2	103	.524	.012	0.156

The results revealed that there was a significant mean difference between experimental and control groups with respect to understanding of solubility equilibrium concepts and attitude towards chemistry as a school subject when the effect of SPST mean score was controlled ($F(2,103) = 19.112$, Wilk's Lambda = .0.729, $p < 0.05$). The difference between the groups occurred as a result of treatment was large since eta-squared value was calculated as 0.271 (Green & Salkind, 2008). In other words, 27% of the multivariate variance of the dependent variables was related to the treatment. Moreover, the result showed that the difference between experimental and control group arose from the treatment effect because the observed power value was found to be 1.00. The size of difference between the groups arise from the treatment effect had practical importance. In addition, the results indicated that there was a significant mean difference between males and females with respect to understanding of solubility equilibrium concepts and attitude towards chemistry as a school subject when the effect of SPST mean score was controlled ($F (2,103) = 4.153$, Wilk's Lambda = .0. 925, $p < 0.05$). The difference between males and females was large since eta-squared value was calculated as 0.075 (Green & Salkind, 2008). In other words, 7.5 % of the multivariate variance of the dependent variables was related to the gender. Furthermore, Table 5.21 indicated that there was no interaction between treatment and gender ($F (2,103) = .650$ Wilk's Lambda = .0. 988, $p > 0.05$). On the other hand, students' science process skills ($F (2,103) = 3.645$, Wilks' Lambda = .934, $p < 0.05$) significantly contributed to students' understanding of solubility equilibrium concepts and attitude towards chemistry.

In order to determine whether the effect of treatment and gender were significant on each dependent variable, multiple univariate ANCOVAs were carried out. Table 5.22 displays the results of univariate ANCOVAs.

Table 5.22 Univariate ANCOVA Results with respect to Dependent Variables

Source	Dependent Variable	df1	F	Sig. (p)	Eta Squared	Power
Treatment	post-SECT	1	37.720	.000	.266	1.000
	post-ASTC	1	.902	.345	.009	.156
Gender	post-SECT	1	1.332	.251	.013	.208
	post-ASTC	1	7.069	.009	.064	.750
Treatment*	post-SECT	1	.266	.607	.003	.080
Gender	post-ASTC	1	1.044	.309	.010	.173

Table 5.22 shows that there was a statistically significant mean difference between the experimental and control groups in the favor of the experimental group with respect to post-SECT when SPST was controlled as a covariate. Moreover, the results indicated that there was a statistically significant mean difference between males and females in favor of female with respect to post-ASTC when SPST was controlled as a covariate.

5.2.2 Statistical Analysis of the retention-SECT (SERT)

$H_0$4: There is no significant mean difference between the effects of instruction based on 5E learning cycle model and traditionally designed chemistry instruction on students' retention in solubility equilibrium concepts when their science process skill is controlled as a covariate.

This hypothesis was tested by analysis of covariance (ANCOVA) where independent variable was treatment, and Retention of solubility equilibrium concept (SERT) was dependent variable. Students' science process skills (SPST) were assigned as a covariate. Descriptive statistics for the dependent variable across the experimental and control groups were displayed in Table 5.23.

Table 5.23 Descriptive Statistics in terms of SERT across Experimental and Control Groups

	Mean		Std. Dev.		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG
SERT	9.18	14.96	3.105	3.069	-.332	-.469	-.706	.005

Prior to the interpretation of the outputs, assumptions of ANCOVA were checked.

5.2.2.1 Assumptions of Analysis of Covariance

5.2.2.1.1 Normality

Skewness and kurtosis values for the dependent variable, which were presented in Table 5.21, were checked for univariate normality assumption. Since the values varied between -2 and +2 in the experimental and the control groups, this assumption was met. In addition, histograms with a normal curve were tested to check normality.

5.2.2.1.2 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Levene's Test of Equality of Error Variances. The results in Table 5.24 showed that the dependent variable has the same variance across groups ($F_{(1,107)} = .258$, $p > 0.05$).

Table 5.24 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
SERT	.258	1	107	.612

5.2.2.1.3 Linear relationship between dependent variable and covariate

The correlation between the dependent variable and covariate should be significant in order to meet this assumption. By calculating the correlation between dependent variable and covariate, this assumption was checked. The correlations between SERT and SPST (p = .000) was significant.

5.2.2.1.4 Homogeneity of Regression Slopes

Multiple Regression Correlation (MRC) analysis was conducted to check assumption of homogeneity regression slopes. This analysis was carried out dependent variables, SERT. Set A, Set B, and Set C were determined for this analysis. Set A was covariate (Pre-SPST), and Set B was Treatment. Set C included Pre-SPST*Treatment. All interaction terms were formed by multiplying all variables in Set A and Set B. The results of MRC analyses were given in Table 5.25. According to the table, there was no significant interaction between covariate and group membership for the SERT (0.878). Therefore, assumption of homogeneity regression slopes was met.

Table 5.25 MRC Analysis indicating Homogeneity of Regression Assumption for the SERT

Change Statistics for the SERT					
Model	R^2 Change	F Change	df1	df2	Sig. F Change
Set A (Covariate)	0.116	14.083	1	107	0.000
Set B (Grup Membership)	0.361	73.297	1	106	0.000
Set C (Set A X Set B)	0.000	0.024	1	105	0.878

By checking the significance of the interaction between the treatment and covariate, homogeneity of the regression slopes assumption was checked. No custom interaction was found between the treatment and SPST (F (1,105) = .024, p = .878).

5.2.2.2 Analysis of Covariance

Provided having met assumptions, an ANCOVA outputs were interpreted. The result of the ANCOVA was given in Table 5.26.

Table 5.26 ANCOVA Summary

Source	*df*	SS	MS	*F*	*Eta Squared*	*p*
SPST	1	11.318	11.318	1.189	.011	.278
Treatment	1	697.583	697.583	73.297	.409	.000
Error	106	1008.821	9.517			

The results indicated that there was a significant mean difference between scores of students taught by instruction based on the 5E learning cycle model and traditional instruction in students' retention test scores when their science process skill was controlled as a covariate (F (1,106) = 73.297, p = .000, partial eta squared = .409). Students in the experimental group scored significantly higher than those in control group (X_{EG} = 14.96, X_{CG} = 9.18). The difference between experimental and control group was large since eta-squared value was calculated as 0.409 (Green & Salkind, 2008). In other words, 41% of the variance of the dependent variable was related with the treatment.

5.2.3 Statistical Analysis of the post-MSLQ for Motivation Section

$H_0$5: There is no significant mean difference between the groups exposed to instruction based on the 5E learning cycle model and traditionally designed chemistry instruction with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety).

$H_0$6: There is no significant mean difference between males and females with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal

Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety).

$H_0 7$: There is no significant interaction between treatment and gender with respect to students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety).

After the treatment, a two-way MANOVA was executed to test hypothesis 5, hypothesis 6, and hypothesis 7. Dependent variables were students' Intrinsic Goal Orientation (IGO), Extrinsic Goal Orientation (EGO), Task Value (TV), Control of Learning Beliefs (CLB), Self-Efficacy for Learning and Performance (SELP), and Test Anxiety (TA) and independent variables were treatment and gender. Table 5.27 displays descriptive statistics of motivational dependent variables for experimental and control groups.

Table 5.27 Descriptive Statistics of IGO, EGO, TV, CLB, SELP, and TA for EG and CG

	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
IGO	56	53	17.02	18.92	4.14	3.91	-.123	.331	.806	.144
EGO	56	53	20.64	18.55	4.36	4.66	-.122	-.162	-.371	-.496
TV	56	53	26.02	30.40	6.31	5.87	-.384	-.029	-.815	-.477
CLB	56	53	21.38	22.08	3.76	3.22	-.253	.177	-1.192	-.553
SELP	56	53	35.54	40.74	8.60	9.47	.020	-.221	-1.180	-.240
TA	56	53	21.46	21.66	5.86	5.29	-.794	.018	-.097	-.864

As seen from Table 5.27, the students of experimental group had highest mean scores on IGO, TV, CLB, SELP, and TA whereas the students of control group only had highest mean scores on EGO.

Descriptive statistics for the dependent variables across gender were given in Table 5.28.

Table 5.28 Descriptive Statistics of IGO, EGO, TV, CLB, SELP, and TA for Males and Females

	N		Mean		Std. Dev		Skewness		Kurtosis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
IGO	56	53	17.59	18.32	4.07	4.18	-.106	.153	1.702	-.375
EGO	56	53	20.04	19.19	4.68	4.54	-.302	-.056	-.127	-.518
TV	56	53	27.50	28.83	6.72	6.16	-.210	-.270	-.206	-.475
CLB	56	53	21.64	21.79	3.65	3.39	-.291	.075	-.895	-.768
SELP	56	53	37.02	39.17	9.22	9.47	.044	-.111	-.769	-.517
TA	56	53	21.61	21.51	5.38	5.82	-.350	-.563	-.008	-.614

Before interpreting the MANOVA outputs for motivation section, the assumptions were checked.

5.2.3.1 Assumptions of Multivariate Analysis of Variance

5.2.3.1.1 Sample Size

The sample size was large enough to execute MANOVA because the number in each cell was greater the number of dependent variables (Pallant, 2007).

5.2.3.1.2 Normality and Outliers

Skewness and kurtosis values for the dependent variables, which were presented in Table 5.27, were checked for univariate normality assumption. Since the values vary between -2 and +2 in the experimental and the control group, this assumption was met. In addition, histograms with a normal curve were tested to check normality.

Mahalanobis value was calculated to test for multivariate outliers. Moreover, this value was compared to the critical value for six dependent variables given in the Chi-square table (Pallant, 2007). The critical value with six dependent variables was found to be 22.46 from the table. The maximum Mahalanobis distance of the sample was found as 21.64. Since this value was smaller than the critical value, there were no multivariate outliers in the data. That is, there was no need to remove any value from the data.

5.2.3.1.3 Linearity

Presence of a straight-line relationship between each pair of the dependent variables is called as linearity assumption. By generating a matrix of scatterplots between each pair of the dependent variables, this assumption was checked (Pallant, 2007). Since the matrix of scatterplots did not demonstrate any obvious of non-linearity, the linearity assumption was verified.

5.2.3.1.4 Multicollinearity and Singularity

If the correlations among the dependent variables are moderate, a MANOVA runs well. When correlations of dependent variables are high, multicollinearity occurs. To check whether multicollinearity exists, correlations among dependent variables are computed. If the correlations are around .8 or .9, there is a problem with multicollinearity. When the correlations of dependent variables are too low, singularity occurs (Pallant, 2007). Table 5.29 shows that the dependent variables were moderately correlated, these assumptions were satisfied.

Table 5.29 Correlations among Dependent Variables

	IGO	EGO	TV	CBL	SELP	TA
IGO	---					
EGO	.020	---				
TV	.626**	.071	---			
CBL	.493**	.274**	.510**	---		
SELP	.521**	.060	.610**	.509**	---	
TA	-.071	.284**	.100	.066	-.203*	---

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

5.2.3.1.5 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances. Box's Test results revealed that the covariance matrices of the dependent variables were equal across groups, F (63, 23228) = 1.166, p = .173. That is, homogeneity of variance-covariance matrices assumption was not violated with a Box's M significance value of 0.173.

Table 5.30 Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices	
Box's M	82.148
F	1.166
df1	63
df2	23228
Sig.	.173

To check homogeneity of variance assumption the Levene's test results were examined. The results in Table 5.31 showed that each dependent variable has the same variance across groups.

Table 5.31 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
IGO	.718	3	105	.543
EGO	.771	3	105	.513
TV	.512	3	105	.675
CLB	2.173	3	105	.096
SELP	.583	3	105	.627
TA	.470	3	105	.704

Having meting the assumptions, MANOVA outputs were interpreted.

5.2.3.2 Multivariate Analysis of Variance

After the treatment, a two-way MANOVA was executed to check whether there was a significant mean difference between the experimental and control groups with respect to IGO, EGO, TV, CLB, SELP, and TA. The results of MANOVA were given in Table 5.32.

Table 5.32 MANOVA Results with respect to Collective Dependent Variables of IGO, EGO, TV, CLB, SELP, and TA

Source	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Sig. (p)	Eta-Squared	Observed Power
Treatment	.808	3.97	6	100	.001	.192	.964
Gender	.983	.283	6	100	.944	.017	.124
Treatment* Gender	.965	.598	6	100	.731	.035	.229

The results of MANOVA revealed that there was a significant mean difference between experimental and control groups' students in terms of collective dependent variables of IGO, EGO, TV, CLB, SELP, and TA ($F\ (6, 100) = 3.97$, Wilks' Lambda = .808; $p < 0.05$). The difference between experimental and control group was large since eta-squared value was calculated as 0.192 (Green & Salkind, 2008). In other words, 19% of the multivariate variance of the dependent variables that reflect students' motivation was related to the treatment. Moreover, results show that the difference between the experimental and control groups arose from the treatment effect because the observed power value was found to be .964. The size of difference between the experimental and control groups have practical importance. In addition, the results indicated that there was no significant mean difference between males and females with respect to the dependent variables about motivation ($F\ (6,100) = .283$, Wilk's Lambda = .0. 983, $p > 0.05$). Moreover, there was no significant interaction between treatment and gender ($F\ (6,100) = .598$ Wilk's Lambda = .0. 965, $p > 0.05$).

In order to determine whether the effect of treatment was significant on each dependent variable, multiple univariate ANOVAs were carried out. Table 5.33 displays the results of the univariate ANOVAs.

Table 5.33 Univariate ANOVA Results with respect to Dependent Variables

Source	Dependent Variable	df	F	Sig. (p)	Eta-Squared	Observed Power
Treatment	IGO	1	5.543	.020	.050	.645
	EGO	1	5.323	.023	.048	.628
	TV	1	13.005	.000	.110	.947
	CLB	1	1.059	.306	.010	.175
	SELP	1	8.154	.005	.072	.808
	TA	1	.033	.856	.000	.054

There was a significant mean difference between experimental and control group with respect to dependent variables of intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy for learning and performance because these dependent variables were significant ($p < 0.05$). As seen from Table 5.27, students in the experimental group had higher scores than those in the control group with respect to IGO, TV, and SELP whereas students in the control group had higher scores than those in the experimental group with respect to EGO. Mean scores of EG and CG students were IGO: 18.92 and 17.02; TV: 30.40 and 26.02; SELP: 40.74 and 35.54; EGO: 18.55 and 20.64, respectively.

Table 5.34 displays the percentages of agreement with the selected items in the IGO (item 1, 24), TV (item 26, 27), SELP (item 5, 31), and EGO (item 13, 30) across experimental and control groups.

In general, students in the experimental group had higher scores than those in the control group with respect to IGO items in Table 5.34. In other words, it could be said that the experimental group students participated in the chemistry lesson more because they were more curious about chemistry. For example, in item 1, the statement; "In a chemistry class, I prefer course material that really challenges me so I can learn new things" was rated as 5, 6, and 7 by 35.8 % of experimental group students while 16.1 % of control group students agreed with this statement.

Moreover, the percentage of agreement with item 24, "When I have the opportunity in chemistry lesson, I choose course assignments that I can learn from even if they don't guarantee a good grade", was 64.2 in the experimental group while it was 39.3 in the control group.

Table 5.34 Percentages of Responses to Selected Items of the IGO, the TV, the SELP, and the EGO Scale

Scale	Item No	Groups	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
IGO	1	CG	21.4	8.9	25.0	28.6	5.4	8.9	1.8
		EG	9.4	11.3	9.4	34.0	20.8	7.5	7.5
	24	CG	3.6	7.1	23.2	26.8	21.4	14.3	3.6
		EG	3.8	0	9.4	22.6	30.2	18.9	15.1
TV	26	CG	17.9	5.4	21.4	16.1	19.6	14.3	5.4
		EG	1.9	7.5	20.8	11.3	24.5	17.0	17.0
	27	CG	5.4	1.8	10.7	21.4	17.9	19.6	23.2
		EG	0	0	1.9	11.3	24.5	34.0	28.3
SELP	5	CG	8.9	5.4	14.3	25.0	25.0	10.7	10.7
		EG	3.8	1.9	13.2	20.8	13.2	30.2	17.0
	31	CG	3.6	1.8	25.0	16.1	17.9	26.8	8.9
		EG	0	1.9	5.7	17.0	28.3	20.8	26.4
EGO	13	CG	1.8	0	1.8	10.7	14.3	26.8	44.6
		EG	0	1.9	3.8	5.7	26.4	26.4	35.8
	30	CG	8.9	7.1	17.9	8.9	25.0	25.0	7.1
		EG	0	7.5	20.8	26.4	18.9	11.3	15.1

When the mean scores of task value were examined, it can be said that students in the experimental group perceived chemistry as more interesting, more important, and more useful. For instance, 58.8 % of students in the experimental group agreed with item 26 stating, "I like subject matter of chemistry course," while 39.3 % of the students in the control group agreed with the statement. In addition, item 27, statement of "Understanding the subject matter of chemistry course is very important to me", was rated as 5, 6, and 7 by 86.8 % of students in the experimental group and 60.7 % of students in the control group.

Students in the experimental group had higher scores with respect to self-efficacy for learning and performance. That is they were more confident than those in the control group in accomplishing a task. For example, the statement "I will receive an excellent grade in the chemistry lesson" (item 5) was rated as 5, 6, and 7 by 60.4 % of students in the experimental group and 46.4 % of students in the control group. In addition, item 31, stating that, "Considering the difficulty of chemistry course, the teacher, and my skills, I think I will do well in chemistry class", was agreed by 75.5 % of students in the experimental group and by 53.6 % of students in the control group.

The students in the control group had higher mean scores compared to students in experimental group with respect to extrinsic goal orientation. The percentages of items that rated as 5, 6, and 7 were examined. However, it was found that experimental group students had higher percentages of agreement in item 13 than the control group students. That is, the statement, "If I can, I want to get better grades in chemistry class than most of the other students" was agreed upon by 88.6 % of the students in experimental group whereas the percentage of students in the control group that agree this statement was 85.7 %. In addition, item 31 stating, "I want to do well in chemistry class because it is important to show my ability to my family, friends, employer, or others" was agreed by 45.3 % of the students in experimental group and 57.1 % of students in the control group.

In summary, the results showed that instruction based on the 5E learning cycle model improved the students' intrinsic goal orientation, task value, and self-efficacy for learning and performance. In contrast, as can be seen from Table 5.30, the results of MSLQ scores indicated that there was no significant mean difference between experimental and control group with respect to control of learning beliefs and task anxiety.

5.2.4 Statistical Analysis of the post-MSLQ for Learning Strategies Section

$H_0$8: There is no significant mean difference between the groups exposed to instruction based on the 5E learning cycle model and traditionally designed chemistry instruction with respect to the students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, & Help Seeking).

$H_0$9: There is no significant mean difference between males and females with respect to the students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self -Regulation, Time and Study Environment, Effort Regulation, Peer Learning, & Help Seeking).

$H_0$10: There is no interaction between treatment and gender with respect to students' perceived use of learning strategies (Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning, Help Seeking).

After the treatment, a two-way MANOVA was executed to evaluate hypothesis 8, hypothesis 9, and hypothesis 10. Dependent variables were students' Rehearsal (R), Elaboration (E), Organization (O), Critical Thinking (CT), Metacognitive Self-Regulation (MSR), Time and Study Environment (TSE), Effort Regulation (ER), Peer Learning (PL), and Help Seeking (HS). Independent variables were treatment and gender. Table 5.35 displays descriptive statistics of the dependent variables for the experimental and control groups.

Table 5.35 Descriptive Statistics of R, E, O, CT, MSR, TSE, ER, PL, and, HS for EG and CG

	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
R	56	53	14.3	18.49	5.64	5.64	-.293	.194	-.142	-.733
E	56	53	23.32	28.26	8.09	6.60	-.871	.433	-.014	-.410
O	56	53	14.52	18.49	5.54	4.55	-.076	.330	-.217	-.695
CT	56	53	17.64	22.02	6.78	6.18	-.350	.334	-.532	-.532
MSR	56	53	48.23	55.53	13.25	10.29	-.936	.547	.432	-.597
TSE	56	53	34.54	40.19	9.91	8.47	-.562	.403	.123	-.738
ER	56	53	17.41	18.79	5.77	3.98	-.615	.359	.337	-.702
PL	56	53	9.82	12.83	4.16	3.52	.006	.171	-.665	-.605
HS	56	53	17.82	19.13	4.45	4.17	.091	-.227	-1.072	-.217

As seen from Table 5.35, the students in the experimental group had highest mean scores on R, E, O, CT, MSR, TSE, ER, PL, and HS than those in the control group.

Descriptive statistics for the dependent variables across gender were given in Table 5.36.

Table 5.36 Descriptive Statistics of R, E, O, CT, MSR, TSE, ER, PL, and HS for Males and Females

	N		Mean		Std. Dev		Skewness		Kurtosis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
R	56	53	15.79	16.92	5.59	6.42	-.122	-.063	.529	-.483
E	56	53	25.18	26.30	7.91	7.66	-.555	-.530	.713	.942
O	56	53	15.00	17.98	5.12	5.38	-.064	-.318	.484	-.120
CT	56	53	19.91	19.62	7.20	6.48	-.230	-.021	-.094	.059
MSR	56	53	50.18	53.47	11.45	13.22	-.771	-.659	2.174	.651
TSE	56	53	35.86	38.79	9.94	9.12	.106	-.803	.386	1.259
ER	56	53	18.11	18.06	4.79	5.27	-.428	-.623	1.462	.392
PL	56	53	10.68	11.92	3.95	4.26	-.064	-.213	-.365	-.340
HS	56	53	17.48	19.49	4.48	3.99	.266	-.397	-.443	-.764

Before interpreting MANOVA outputs for learning strategies section, the assumptions were checked.

5.2.4.1 Assumptions of Multivariate Analysis of Variance

5.2.4.1.1 Sample Size

The sample size was large enough to execute MANOVA because the number in each cell was greater the number of dependent variables (Pallant, 2007).

5.2.4.1.2 Normality and Outliers

Skewness and kurtosis values for the dependent variables, which are presented in Table 5.35, were checked for univariate normality assumption. In this study, all skewness and kurtosis values ranged between -2 and +2, except kurtosis value of MSR. However, this violation is very small. Therefore, it can be said that this assumption was met. In addition, histograms with a normal curve were tested to check normality.

Mahalanobis value was calculated to test multivariate outliers. Moreover, this value was compared to the critical value for nine dependent variables given in the Chi-square table (Pallant, 2007). The critical value with nine dependent variables was found to be 27.88 from the table. The maximum Mahalanobis distance of the sample was found as 26.92. Since this value was smaller than the critical value, there were no multivariate outliers in the data. That is, there was no need to remove any value from the data. Moreover, the multivariate normality assumption was met by considering the maximum Mahalanobis distance of the sample.

5.2.4.1.3 Linearity

Presence of a straight-line relationship between each pair of the dependent variables is called as linearity assumption. By generating a matrix of scatterplots between each pair of the dependent variables, this assumption was checked (Pallant, 2007). Since the matrix of scatterplots did not demonstrate any obvious of non-linearity, the linearity assumption was verified.

5.2.4.1.4 Multicollinearity and Singularity

If the correlations among the dependent variables are moderate, a MANOVA runs well. When correlations of dependent variables are high, multicollinearity occurs. To check whether multicollinearity exists, correlations among dependent variables are computed. If the correlations are around .8 or .9, there is a problem with multicollinearity. When the correlations of dependent variables are too low, singularity occurs (Pallant, 2007). Table 5.37 shows that the dependent variables were moderately correlated. Therefore, these assumptions were satisfied.

Table 5.37 Correlations among Dependent Variables

	R	E	O	CT	MSR	TSE	ER	PL	HS
R	---								
E	.643**	---							
O	.749**	.657**	---						
CT	.686**	.741**	.667**	---					
MSR	.771**	.785**	.763**	.743**	---				
TSE	.475**	.572**	.547**	.471**	.673**	---			
ER	.459**	.618**	.406**	.412**	.640**	.645**	---		
PL	.550**	.566**	.548**	.618**	.603**	.449**	.352**	---	
HS	.494**	.430**	.455**	.349	.502**	.349**	.467**	.519**	---

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

5.2.4.1.5 Homogeneity of Variance-Covariance Matrices

The assumption of homogeneity of variance-covariance matrices was checked by using Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances. Box's Test results revealed that the covariance matrices of the dependent variables were equal across groups, $F(135, 21747) = 1.168$, $p = .090$. That is, the homogeneity of variance-covariance matrices assumption was not violated with a Box's M significance value of 0.090.

Table 5.38 Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices	
Box's M	187.241
F	1.168
df1	135
df2	21747
Sig.	.090

To check the homogeneity of variance assumption, the Levene's test results were examined. The results in Table 5.39 showed that each dependent variable has the same variance across groups.

Table 5.39 Levene's Test of Equality of Error Variances

	F	df1	df2	*p*
R	.629	3	105	.598
E	.382	3	105	.766
O	1.356	3	105	.260
CT	.176	3	105	.912
MSR	1.359	3	105	.259
TSE	.332	3	105	.802
ER	1.720	3	105	.167
PL	.780	3	105	.507
HS	2.189	3	105	.094

Having meting the assumptions, a MANOVA outputs were interpreted.

5.2.4.2 Multivariate Analysis of Variance

After the treatment, a two-way MANOVA was executed to check whether there was a significant mean difference between the experimental and control groups with respect to R, E, O, CT, MSR, TSE, ER, PL, and HS. The results of MANOVA were given in Table 5.40.

Table 5.40 MANOVA Results with respect to Collective Dependent Variables of R, E, O, CT, MSR, TSE, ER, PL, and HS

Source	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Sig. (p)	Eta-Squared	Observed Power
Treatment	.791	2.854	9	97	.005	.209	.950
Gender	.785	2.947	9	97	.004	.215	.957
Treatment* Gender	.846	1.967	9	97	.081	-	-

The results of MANOVA revealed that there was a significant mean difference between the experimental and control groups students in terms of the collective dependent variables of R, E, O, CT, MSR, TSE, ER, PL, and HS (F (9, 97)

= 2.854, Wilks' Lambda = .791; $p < 0.05$). The difference between experimental and control group was large since eta-squared value was calculated as 0.209 (Green & Salkind, 2008). In other words, 21% of the multivariate variance of the dependent variables, which reflect students' learning strategies, was related to the treatment. Moreover, the results show that the difference between experimental and control group arose from the treatment effect because the observed power value was found to be .950. The size of difference between experimental and control group has practical importance. In addition, the results indicated that there was a significant mean difference between males and females in favor of females on the collective dependent variables (F (9, 97) = 2.947, Wilk's Lambda = .985, $p < 0.05$). The difference between males and females was large since eta-squared value was calculated as 0.215 (Green & Salkind, 2008) and power was found to be .957. Moreover, there was no interaction between treatment and gender (F (9,97) = 1.967 Wilk's Lambda = .846, $p > 0.05$).

In order to determine whether the effect of treatment were significant on each dependent variable, multiple univariate ANOVAs were carried out. Table 5.41 displays the results of the univariate ANOVAs.

There was a significant mean difference between experimental and control group with respect to the dependent variables of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning. These dependent variables were significant ($p < 0.05$). As seen from Table 5.35, students of the experimental group had higher scores than the control group with respect to all dependent variables. Mean scores of EG and CG students were R: 18.49 and 14.30; E: 28.26 and 23.32; O: 18.49 and 14.52; CT: 22.02 and 17.64; MSR: 55.53 and 48.23; TSE: 40.19 and 34.54; and PL: 12.83 and 9.82. Moreover, as seen from Table 5.41, it was found that there was a significant mean difference ($p < 0.05$) between males and females with respect to the dependent variables of organization and help seeking. Table 5.36 displays that females had higher mean scores more than males with respect to organization and help seeking. In addition, results showed that there was no significant interaction between treatment and gender with respect to the dependent variables of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning ($p>0.05$).

Table 5.41 Univariate ANOVA Results with respect to Dependent Variables

Source	Dependent Variable	df	F	Sig. (p)	Eta-Squared	Observed Power
Treatment	R	1	14.678	.000	.123	.967
	E	1	11.412	.001	.098	.917
	O	1	15.066	.000	.125	.970
	CT	1	12.493	.001	.106	.938
	MSR	1	9.375	.003	.082	.859
	TSE	1	9.020	.003	.079	.845
	ER	1	2.102	.150	.020	.301
	PL	1	15.266	.000	.127	.972
	HS	1	1.839	.178	.017	.269
Gender	R	1	.407	.525	.004	.097
	E	1	.139	.710	.001	.066
	O	1	7.289	.008	.065	.763
	CT	1	.452	.503	.004	.102
	MSR	1	1.183	.279	.011	.190
	TSE	1	1.617	.206	.015	.243
	ER	1	.050	.823	.000	.056
	PL	1	1.504	.223	.014	.229
	HS	1	5.407	.022	.049	.635
Treatment* Gender	R	1	2.779	.099	.026	.379
	E	1	.039	.844	.000	.054
	O	1	1.442	.232	.014	.221
	CT	1	.991	.322	.009	.167
	MSR	1	.622	.432	.006	.122
	TSE	1	.747	.390	.007	.137
	ER	1	.000	.992	.000	.050
	PL	1	.652	.421	.006	.126
	HS	1	1.298	.257	.012	.204

Table 5.42 displays the percentages of agreement with the selected items in rehearsal (item 39, 59), elaboration (item 53, 64), organization (item 49, 63), critical thinking (item 51, 66), metacognitive self-regulation (item 55, 61), time and study environment (item 43, 70), and peer learning (item 34, 50) across the experimental and control groups.

As seen in Table 5.42, students in the experimental group had higher scores than students in the control group with respect to rehearsal, elaboration, and organization. In other words, the experimental group' students perceived using rehearsal strategies, elaboration strategies, and organization strategies more than the control group' students. For example, in item 39, the statement "When I study for chemistry class, I practice saying the material to myself over and over" was rated as 5, 6, and 7 by 67.9 % of experimental group students while only 34.6 % of the control group students agreed with the statement. Similarly, the percentage of agreement with item 59, "I memorize the keywords to remind me of important concepts in chemistry class" 58.6 % of the experimental group agreed with this statement while only 30.4 % of the students in the control group agreed with it. Moreover, item 53, "When I study for chemistry class, I pull together information from different sources such as lectures, readings, and discussions" was agreed to by 64.1 % of the students in the experimental group while only 46.4 % of the control group students agreed with it. Item 64 stated, "When I study for chemistry class, I write brief summaries of the main ideas from the readings and the concepts from the lectures" was agreed to by 68.0 % of students in experimental group and by 42.9 % of the control group students. In addition, in item 49, the statement of "I make simple charts, diagrams, or tables to help me organize course material" was agreed to by 39.7 % of experimental group students while 25.1 % of the control group students agreed with it. The percentage of agreement with item 63, "When I study for a chemistry course, I go over my class notes and make an outline of important concepts" was agreed by 54.8 % of the experimental group while the corresponding percentage of students in control group was 33.9 %.

Table 5.42 Percentages of Responses to Selected Items of the R, E, O, CT, MSR, TSE, and PL Scale

Scale	Item No	Groups	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
R	39	CG	17.9	3.6	14.3	19.6	23.2	12.5	8.9
		EG	1.9	3.8	13.2	13.2	26.4	13.2	28.3
	59	CG	23.2	7.1	23.2	16.1	10.7	17.9	1.8
		EG	3.8	7.5	18.9	11.3	34.0	5.7	18.9
E	53	CG	12.5	7.1	17.9	16.1	33.9	12.5	0
		EG	1.9	1.9	15.1	17.0	22.6	24.5	17.0
	64	CG	17.9	7.1	12.5	19.6	23.2	17.9	1.8
		EG	0	5.7	5.7	20.8	32.1	17.0	18.9
O	49	CG	28.6	21.4	14.3	10.7	17.9	5.4	1.8
		EG	5.7	11.3	18.9	24.5	13.2	20.8	5.7
	63	CG	21.4	5.4	14.3	25.0	14.3	8.9	10.7
		EG	0	7.5	11.3	26.4	18.9	15.1	20.8
CT	51	CG	23.2	8.9	17.9	19.6	21.4	5.4	3.6
		EG	5.7	11.3	15.1	20.8	22.6	13.2	11.3
	66	CG	16.1	14.3	12.5	21.4	19.6	12.5	3.6
		EG	1.9	5.7	22.6	20.8	22.6	9.4	17.0
MSR	55	CG	25.0	10.7	17.9	21.4	14.3	7.1	3.6
		EG	3.8	11.3	15.1	17.0	26.4	15.1	11.3
	61	CG	12.5	3.6	12.5	23.2	14.3	25.0	8.9
		EG	0	1.9	7.5	20.8	30.2	22.6	17.0
TSE	43	CG	17.9	5.4	12.5	19.6	23.2	12.5	8.9
		EG	1.9	0	13.2	18.9	26.4	18.9	20.8
	70	CG	17.9	5.4	19.6	23.2	16.1	12.5	5.4
		EG	0	5.7	18.9	15.1	24.5	5.7	30.2
PL	34	CG	21.4	8.9	25.0	10.7	21.4	5.4	7.1
		EG	3.8	11.3	15.1	24.5	20.8	11.3	13.2
	50	CG	17.9	14.3	14.3	17.9	19.6	12.5	3.6
		EG	3.8	5.7	22.6	11.3	24.5	18.9	13.2

Students of experimental group had higher scores with respect to critical thinking. In order to solve problems, reach decisions, or make critical evaluations with respect to standards of excellence, they tended to apply previous knowledge. For instance, item 51, "I treat the chemistry course material as a starting point and try to develop my own ideas about it" was rated as 5, 6, and 7 indicating agreement by 47.1 % of students in the experimental group while only 30.4 % of control group students agreed with it. Similarly, the statement of "I try to play around with ideas of my own related to what I am learning in chemistry course" (item 66) was agreed to by 49 % of students in the experimental group and 35.7 % of the control group students.

When considering the mean scores of metacognitive self-regulatory strategies and time and study environment strategies, students in the experimental group appeared to use these strategies more than the students in the control group. For example, 52.8 % of experimental group students agreed with item 55, rating it as 5, 6, and 7. The item stating, "I ask myself questions to make sure I understand the material I have been studying in the chemistry class" was agreed to by 25 % of students in the control group. Similarly, item 61 stating, "I try think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for chemistry" was agreed to by 69.8 % of the experimental group students and by 48.2 % of the control group students. Moreover, item 43, "I make good use of my study time for chemistry course" was agreed to by 81.2 % of the students in the experimental group and only 66.1 % of the control group students. Item 70, "I make sure I keep up with the weekly readings and assignments for the chemistry course" was agreed to by 60.4 % of the students in the experimental group and by 34 % of the control group students.

Students of the experimental group had higher scores with respect to peer learning. The experimental group students tended to make more collaborate more with peers compared to students in the control group. For instance, the item 34, "When studying for chemistry course, I often try to explain the material to a classmate or a friend" was rated 5, 6, and 7 indicating agreement by 45.3 % of the students in the experimental group while only 33.9 % of control group students agreed with the statement. In addition, the statement, "I try to work with other students from this class to complete the course assignments" (item 70) was agreed to by 28.3% of the students in the experimental group whereas only 17.8 % of control group students agreed with the statement.

To sum up, the results showed that instruction based on 5E learning cycle model improved the students' rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning strategies. In contrast, as can be seen from Table 5.41, the results of MSLQ scores indicated that there was no significant mean difference between the experimental and the control groups with respect to effort learning, and help seeking.

5.2.5 Students' Misconceptions on Solubility Equilibrium Concept

SECT was administered to the experimental and control group after instruction. This test was prepared to identify students' misconceptions about the solubility equilibrium. The results of SECT showed that instruction based on the 5E learning cycle model eliminated students' misconception on the solubility equilibrium concept and developed the students' motivation to learn chemistry and learning strategies. In the following section, students' misconceptions on solubility equilibrium measured via SECT and interviews were analyzed briefly.

5.2.5.1 Analysis of Students' Responses to SECT

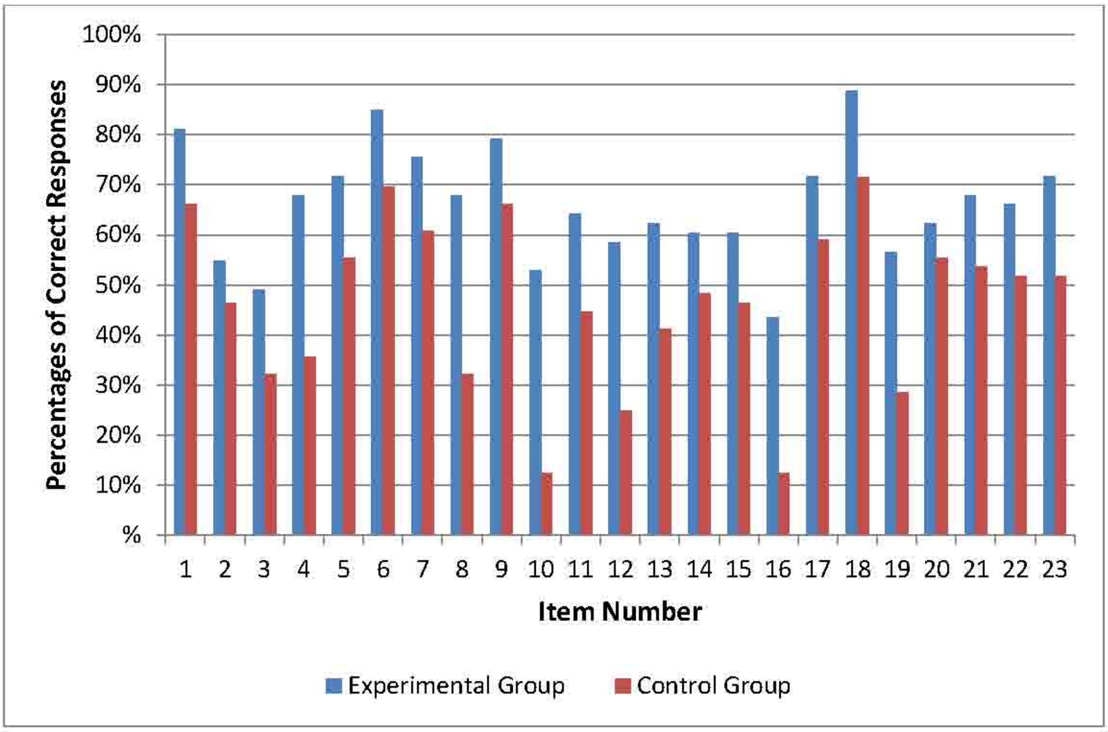


Figure 5.1 Comparison of the Percentages of Students' Correct Responses on post-SECT across Experimental and Control Groups

Students' responses on post-SECT were examined. There was a difference in responses between students in the experimental and control group with respect to SECT. The percentages of students' correct answers on post-SECT for each item were presented in Figure 5.1. In addition, the largest differences between experimental and control group were found in the items 4, 5, 8, 10, 11, 12, 13, and 19. Therefore, student responses to these items were discussed in this section.

Table 5.43 Frequencies and Percentages of Students' Selection of Alternatives for Item 4

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	6	10.7	6	11.3
B	8	14.3	4	7.5
C	11	19.6	0	0
D*	20	35.7	36	67.9
E	11	19.6	7	13.2
Total	56	100	53	100

(*) Correct Alternative

Item 4 was prepared to investigate whether the students were aware of the fact that compounds in solid form should not be included while writing Ksp equations. The percentage of 67.9 of the experimental group students answered this question correctly whereas 35.7 % of control group students answered this question by selecting alternative D. The common misconception in both group [EG (20.7 %) and CG (33.9%)] was that compounds in solid form should be included while writing Ksp equations by selecting alternatives B and E. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 4 in the post-SECT were displayed in Table 5.43.

Table 5.44 Frequencies and Percentages of Students' Selection of Alternatives for Item 5

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A*	31	55.4	38	71.7
B	3	5.4	8	15.1
C	18	32.1	7	13.2
D	0	0	0	0
E	4	7.1	0	0
Total	56	100	53	100

(*) Correct Alternative

Item 5 was related to the effect of a common ion on the solubility equilibrium system. The percentage of 71.7 of the experimental group students answered this question correctly whereas 55.4 % of control group students answered this question by selecting alternative A. The common misconception in both group [EG (13.2 %) and CG (32.1 %)] was that at equilibrium the concentrations of ions will remain constant although a common ion is added by selecting alternative C. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 5 in the post-SECT were given in Table 5.44.

Table 5.45 Frequencies and Percentages of Students' Selection of Alternatives for Item 8

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	32	57.1	5	9.4
B	0	0	0	0
C	3	5.4	8	15.1
D	3	5.4	4	7.5
E*	18	32.1	36	67.9
Total	56	100	53	100

(*) Correct Alternative

In item 8, students were asked to describe what happened to the solubility and Ksp of a compound when the same compound was added at a given temperature. According to post-SECT results, the proportion of the correct responses was 67.9 % for the experimental group and 32.1 % for the control group. The common misconception in both groups [EG (16.9 %) and CG (62.5 %)] was that at a given temperature, Ksp can change with the amount of solid or ions added by selecting alternatives A, B, and D. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 8 in the post-SECT were presented in Table 5.45.

Table 5.46 Frequencies and Percentages of Students' Selection of Alternatives for Item 10

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	16	28.6	4	7.5
B	2	3.6	2	3.8
C	3	5.4	1	1.9
D*	7	12.5	28	52.8
E	28	50.0	18	34.0
Total	56	100	53	100

(*) Correct Alternative

Item 10 was related to the effect of volume on solubility equilibrium. Students were expected to find the ion concentration after the volume increases at a given temperature. While 52.8 % of students in experimental group gave the correct answer for this question, 12.8 % of students in the control group answered correctly after instruction. The common misconception in both group EG [(45.3 %) and CG (82.2%)] was that at a given temperature, solubility of sparingly soluble salts is effected by the change made in volume by selecting alternatives A, B, and E. In other words, students in the both groups still had this misconception. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 10 in the post-SECT were presented in Table 5.46.

Table 5.47 Frequencies and Percentages of Students' Selection of Alternatives for Item 11

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	6	10.7	2	3.8
B	1	1.8	5	9.4
C*	25	44.6	34	64.2
D	10	17.9	6	11.3
E	14	25.0	6	11.3
Total	56	100	53	100

(*) Correct Alternative

In item 11, students were asked to find the concentration of ions after adding common ions. The percentage of the students who selected the correct answer in experimental group was 64.2 while the percentage of the students who selected the correct answer in control group was 44.6 after the instruction. Some of the students had two misconceptions: at equilibrium, there is no precipitation and dissolution or dissolution stops; and at equilibrium, the concentrations of ions will remain constant although a common ion is added (11.3 % for experimental group and 25 % for control group). The frequencies and percentages of experimental, and control group students' selection of alternatives for item 11 in the post-SECT were presented in Table 5.47.

Table 5.48 Frequencies and Percentages of Students' Selection of Alternatives for Item 12

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	3	5.4	2	3.8
B	35	62.5	8	15.1
C	1	1.8	0	0
D	3	5.4	12	22.6
E*	14	25.0	31	58.5
Total	56	100	53	100

(*) Correct Alternative

Item 12 was prepared to investigate whether the students were aware of the fact that at a given temperature Ksp does not change with the amount of solid or ions added. The percentage of 58.5 of the experimental group students answered this question correctly whereas 25 % of the control group students answered this question by selecting alternative E. The two common misconception in both group EG (18.9 %) and CG (69.7 %) were that at a given temperature, Ksp can change with the amount of solid or ions added and if system is at equilibrium, no other solute that doesn't contain a common ion can dissolve and solubility doesn't change, as indicated by selecting alternatives A, B and C. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 12 in the post-SECT were displayed in Table 5.48.

Table 5.49 Frequencies and Percentages of Students' Selection of Alternatives for Item 13

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	3	5.4	4	7.5
B*	23	41.1	33	62.5
C	5	8.9	7	13.2
D	2	3.6	2	3.8
E	23	41.1	7	13.2
Total	56	100	53	100

(*) Correct Alternative

In item 13, students were asked to choose the correct relationship between Ksp of compound. In the experimental group, 62.5 % of the students and in the control group 41.1 % of the students gave the correct answer after the treatment. The common misconception in both groups [EG (13.2 %) and CG (41.1 %)] was that in all situations one can compare solubility of salts at equilibrium by just looking at the Ksp values, as indicated by selecting alternative E. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 13 in the post-SECT were displayed in Table 5.49.

Table 5.50 Frequencies and Percentages of Students' Selection of Alternatives for Item 19

	Control Group		Experimental Group	
Alternatives	Frequency	Percentage	Frequency	Percentage
A	18	32.1	4	7.5
B	11	19.6	2	3.8
C	8	14.3	1	1.9
D	3	5.4	16	30.2
E*	16	28.6	30	56.6
Total	56	100	53	100

(*) Correct Alternative

Item 19 was mainly about the effect of pressure on solubility. Students were asked to find the concentrations of ions and Ksp when the pressure increases. According to the results of post-SECT, the percentage of students giving the correct answer was 56.6 % and 28.6 % for experimental and control group, respectively. The common misconception in both group EG (13.2 %) and CG (66 %) was that solubility of sparingly soluble salts is effected by the change made in pressure, as indicated by selecting alternatives A, B, and C. The frequencies and percentages of experimental, and control group students' selection of alternatives for item 19 in the post-SECT were displayed in Table 5.50.

5.3 Analyses of Students' Responses to Interview

In order to obtain detailed information about students' reasoning and misconceptions concerning solubility equilibrium concepts, semi-structured interviews were carried out with 12 eleventh grade students in both groups (6 experimental group students and 6 control group students). Students were selected voluntarily and stratified by their achievement level, high, medium, and low according to results of post solubility equilibrium test. Two students were high achievers, two students were medium achievers, and two students were low achievers representing both groups. Interview results showed that the experimental group students, instructed using the 5E learning cycle model, demonstrated higher conceptual and scientific understanding of solubility equilibrium concepts when compared to control group students. Students responses to the interview questions were analyzed by coding. Moreover, five themes were found; writing a dissolution equation and Ksp, drawing a graphic, reading the graphic, identifying factors affecting solubility equilibrium, and using examples from daily life. The distributions of the number (percentages) of the students in experimental and control groups across codes were given in Table 5.51 and each category is explained in the following part.

Table 5.51 The Distribution of the Number (Percentages) of Students in Experimental and Control Groups across the Codes identified from Interviews (NA: No answer, I: Incorrect, M: Misconception, PC: Partially correct, C: Correct)

	Experimental Group					Control Group				
	NA	I	M	PC	C	NA	I	M	PC	C
Writing of dissolution equation and Ksp	0	0	0	0	6 (100%)	0	1 (16.6%)	0	2 (33.3%)	2 (33.3%)
Drawing a graphic	0	1 (16.6%)	0	0	5 (83.3%)	0	0	5 (83.3%)	1 (16.6%)	0
Reading the graphic	0	0	1 (16.6%)	0	5 (83.3%)	0	1 (16.6%)	4 (66.6%)	0	1 (16.6%)
Indentifiying factors affecting solubility equilibrium										
Temperature	0	0	0	0	6 (100%)	0	0	4 (66.6%)	0	2 (33.3%)
Nature of solute or solvent	1 (16.6%)	0	0	0	5 (83.3%)	1 (16.6%)	2 (33.3%)	0	0	03 (50%)
Common ion	0	0	1 (16.6%)	0	5 (83.3%)	0	0	5 (83.3%)	0	1 (16.6%)
Uncommon ion	0	0	0	2 (33.3%)	4 (66.6%)	1 (16.6%)	2 (33.3%)	0	3 (50%)	0
Pressure	0	0	1 (16.6%)	0	5 (83.3%)	0	0	4 (66.6%)	0	2 (33.3%)
Using examples from daily life	0	0	0	0	6 (100%)	3 (50%)	3 (50%)	0	0	0

5.3.1 Writing a Dissolution Equation and Ksp

The students in both the experimental and control groups were asked to write the dissolution equation and Ksp of $Ca_3(PO_4)_2$. If both dissolution equation and Ksp were written correctly, the answer was accepted as correct. If either dissolution equation or Ksp were written correctly, the answer was accepted as partially correct. If both dissolution equation and Ksp were written incorrectly, the answer was accepted as incorrect. All students in the experimental group (six students) and two students in the control group answered the question correctly. For example, the writing of the dissolution equation and Ksp of $Ca_3(PO_4)_2$ of four students in the experimental group and a student in the control group was as given below.

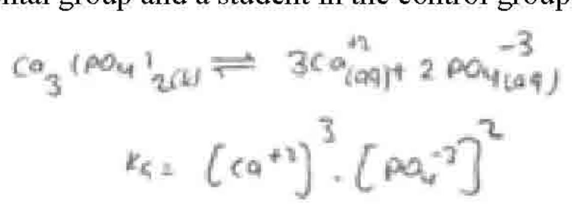


Figure 5.2 A Student Writing the Correct Dissolution Equation and Ksp in the Experimental Group

Since two students in the control group wrote the Ksp correctly but they did not write the dissolution equation correctly, their answer was accepted as partially correct. For example, a student in the control group wrote the dissolution equation without the arrow and phase. The other student in the control group wrote the dissolution equation of $Ca_3(PO_4)_2$, with the phases of ions as liquid. The statement of "when writing the dissolution equation, liquid was written as the phase" is a misconception. Figure 5.3 and figure 5.4 showed partially correct answers of the students in the control group.

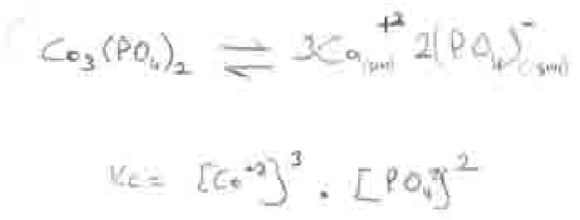


Figure 5.3 A Student Writing the Partially Correct Dissolution Equation and Ksp in The Control Group

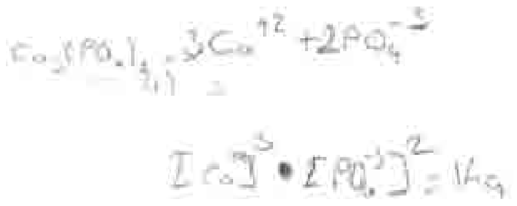


Figure 5.4 A Student Writing the Partially Correct Dissolution Equation and Ksp in The Control Group

A student in the control group wrote both dissolution equation and Ksp incorrectly. Student answer was given following figure 5.5.

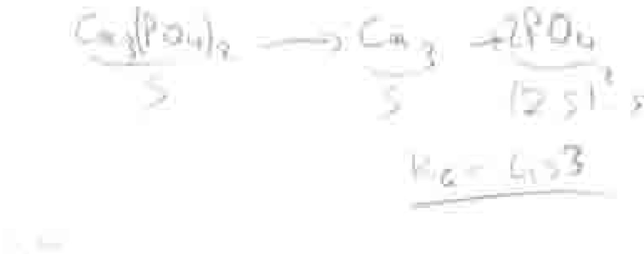


Figure 5.5 A Student Writing the Incorrect Dissolution Equation and Ksp in The Control Group

After writing the dissolution equation and Ksp, students in both experimental and control groups were asked the reason for not considering $Ca_3(PO_4)_2$ while writing Ksp. Five students in the control group gave the similar reason. For example, a student in the control group explained the reason as "it is a rule, we do not know the reason. Our teacher said that reactants are not included when writing a dissolution equation." Six students in the experimental group and one student in the control group explained the reason correctly. For example, a student in the experimental group answered the question correctly as "we do not write the $Ca_3(PO_4)_2$ in the dissolution equation because it is solid. Solids are not written in the dissolution equation."

Students in both groups asked, "Can we write Ksp for all solutions (saturated and unsaturated solutions)." All students in the experimental group and one student in the control group answered the question correctly. For example, a student in the experimental group explained correctly that "we can write Ksp only for a saturated solution because in the saturated solution, dissolved substances solved and they are at equilibrium." Five of the students in the control group answered the question with a misconception. For example, a student in the control group answered with the misconception "we can not do such a distinction, that is, we can write Ksp for all saturated and unsaturated solutions."

Experimental and control group students were asked the following question: "Saturated $Ca_3(PO_4)_2$ is in equilibrium with solid matter. At equilibrium, which $Ca_3(PO_4)_2$ solid, Ca^{+2}, and PO_4^{-3} ions are found in the environment? Explain." All students in the experimental group and four students in the control group answered the question correctly. For example, a student in the experimental group answered correctly as "a solid and two ions are found because dissolution and precipitation always continue." Two students in the control group answered with a misconception. For example, a student in the control group explained that "there are ions not solid since solid finished in the environment." Students in both groups were asked probing questions. It was found that there were misconceptions of the students in the control group (four students) and the experimental group (three students). They thought that "before the system reaches equilibrium there was no precipitation reaction. "In addition, a student in the control group had another misconception. The student thought that "at equilibrium, there is no precipitation and dissolution or dissolution stops."

5.3.2 Drawing Graphic

The students in the experimental and control groups were asked to draw a graphic showing dissolution and precipitation rates. Whereas most of the students in the experimental group could draw the graphic correctly, none of the students in the control group could draw it correctly, while some were partially correctly. Most of the students in the control group in the control group drew it with a misconception. One student in the experimental group drew it incorrectly.

In the experimental group, five students drew the graphic correctly. For example, a student in experimental group drew it as below.

Figure 5.6 A Student Drawing in the Experimental Group (Correct Drawing)

A student in the experimental group drew it incorrectly. She drew incorrectly both graphics about dissolution and precipitation. The drawings are given following Figure 5.6.

Figure 5.7 A Student Drawing in the Experimental Group (Incorrect Drawing)

In the control group, a student drew a partially correct answer. That is, the precipitation graphic was draw correctly but the dissolution graphic was draw incorrectly. Therefore, it was accepted as partially correct. The drawings are given below.

Figure 5.8 A Student Drawing in the Control Group (Partially Correct Drawing)

Five students in the control group drew the graphics with misconception. All students believed that the rate of dissolving increases with time until equilibrium is established. For example, a student drawing is given below.

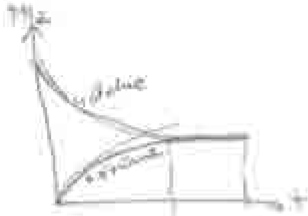
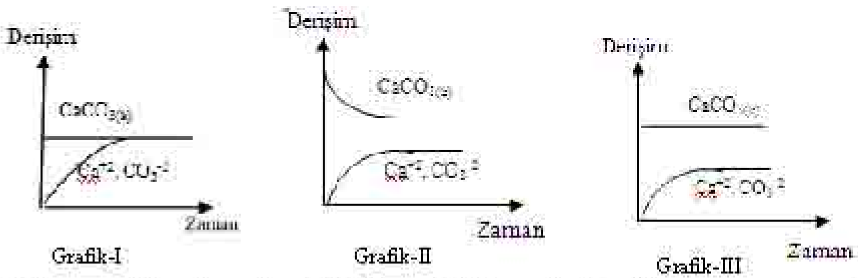


Figure 5.9 A Student Drawing in the Control Group (Misconception Drawing)

5.3.3 Reading Graphic

The students in both experimental and control group were asked the following question.



"The graphics showing $CaCO_{3(s)}$, Ca^{+2}, and CO_3^{-2} ions concentrations change over time were given. Which one is drawn correctly? Please explain the reason."

Five students in experimental group and one student in the control group could correctly select graphic III and correctly explain the reason for their selection.

For example, one student in the experimental group correctly stated that "the concentration of solid $CaCO_3$ does not change with time and maintains a constant value. Ca^{+2}, and CO_3^{-2} ions concentrations increase until equilibrium, and then they will remain constant at equilibrium. Moreover, the concentration of the solid does not have equal ions. Therefore, I selected the graphic III." Four students in the control group and one student in the experimental group answered the question with the misconception represented in graphic I. For example, a student in the control group explained the reason for selecting graphic I as "in my opinion, at the equilibrium, solid concentration must equal ions concentration. When I look at the alternatives, only graphic I show this. Therefore, the correct answer is graphic I. "A student in the control group answered the question incorrectly by selecting graphic II. The student explained the reason for this choice as "the concentration of the solid will decrease and ions concentrations will increase with time. Therefore, graphics II is correct drawing."

5.3.4 Factors Affecting Solubility Equilibrium

The students in the experimental and control groups were asked the factors affecting solubility equilibrium. Most of the students in the experimental group and a few students in the control group could answer these factors correctly. Most of the students in the control group and only one student in the experimental group could answer the question without misconceptions. Some of the students in the control group answered the question incorrectly. A few students in the experimental and control groups could not give any answer.

Related to the effect of temperature, all the students in the experimental group (six students) explained it correctly. For example, a student in the experimental group stated, "if the reaction is endothermic, as temperature increases, solubility increases and Ksp increases. If the reaction is exothermic, as temperature increases, solubility decreases and Ksp decreases." On the other hand, in the control group two students explained it correctly, while four students explained it with a misconception.

For example, a student explained it correctly as "The temperature and solubility have the right proportions in the endothermic reaction. There is an inverse proportion between temperature and solubility in the exothermic reaction." Four students explained the temperature effect on solubility with a misconception. For instance, three students in the control group answered the question with a misconception as "the value of Ksp always increases as temperature increases", and a student in the control group explained it with another misconception that "temperature has no effect on solubility."

There were correct explanations in both experimental (five students) and control (three students) groups about the nature of the solute or solvent. For example, three students in the experimental group and one student in the control group explained the nature of solute or solvent correctly as "apolar dissolves the apolar and polar dissolves the polar, that is, similar dissolves similar and Ksp only changes with temperature." A student in the experimental group and a student in the control group could not give any response to the question and two students in the control group explained the effect of solute or solvent incorrectly. For instance, two students in the control group explained the effect of the nature of solute or solvent as "there was no effect of the solute or solvent on the solubility." This explanation is incorrect because the type of substance can change the solubility.

Related to the effect of a common ion on solubility equilibrium, five students from the experimental group and one student from the control group answered correctly. For example, a student in the experimental group explained it as "Ksp does not change with the common ion and solubility decreases with adding the common ion," and a student in the control group explained it as "ion concentration changes when adding a common ion. Equilibrium shifts left side (entrants) and ion concentration decreases. Therefore, solubility decreases and Ksp cannot change. It changes only with temperature." Five students in the control group and one student in the experimental group answered the question with a misconception. For example, a student in the control group answered the question with the misconception as "solubility can not change with adding a common ion and Ksp decreases at a given temperature."

About the effect of an uncommon ion on solubility equilibrium, there were correct explanations in the experimental group (four students). For example, a student in the experimental group answered the question correctly as "when the uncommon ion was added, solubility increases if the ions don't react with ions in the solution. Ksp cannot change with adding an uncommon ion." There were also some partially correct answers in the experimental (two students) and the control (three students) groups. For example, a student from the experimental group and two students from the control group explained it as "there is no effect of uncommon ion on solubility and Ksp." These answers were accepted as partially correct because the statement that uncommon ions do not change the Ksp is correct, but the statement that solubility does not change with adding uncommon ion is incorrect. One student in the control group could not give any explanation related to the effect of an uncommon ion on solubility equilibrium.

Related to the effect of pressure, students in the experimental group (five students) and control group (two students) answered the question correctly. For example, a student in the experimental group explained it correctly as "solubility of solids do not change with pressure. There is no effect of pressure on solids." Some students in the control group (four students) and a student in the experimental group explained it with a misconception. For example, a student in the control group explained using the following a misconception: "the solubility of sparingly soluble salts is affected by change made in pressure."

Table 5.52 The Misconceptions Distribution of Students in Experimental and Control Groups Identified from Interviews

Misconception	EG #(%)	CG #(%)
The rate of dissolving increases with time until equilibrium is established.	0 (0%)	5 (83.3%)
At equilibrium, the concentrations of the ions produced are equal to the concentration of the salt.	1 (16.6%)	4 (66.6%)
The value of Ksp always increases as temperature increases.	0 (0%)	4 (66.6%)
At equilibrium, the concentrations of ions will remain constant although a common ion is added.	1 (16.6%)	5 (83.3%)
The solubility of sparingly soluble salts is affected by a change in pressure.	1 (16.6%)	4 (66.6%)
Ksp can be written for unsaturated solutions.	0 (0%)	5 (83.3%)
At the equilibrium, there is no solid.	0 (0%)	2 (33.3%)
Before the system reaches equilibrium, there is no precipitation reaction.	3 (50%)	4 (66.6%)
At equilibrium, there is no precipitation and dissolution or dissolution stops.	0 (0%)	1 (16.6%)

5.3.5 Daily Life Examples

The students in the experimental and the control groups were asked examples of solubility equilibrium in the daily life. All students (six students) in the experimental group gave the correct examples but three students in the control group wrongly gave examples. Students in the experimental group gave similar correct daily life examples such as "kidney stones," "stalactites and stalagmites in Insuyu caves," travertine in Pamukkale," "lime stone," "tooth decay," and "stomach x-ray is taken." In the control group, three students gave "dissolving tea and sugar", and "salt adding to the dinner" as incorrect examples to the daily life. Three students in the control group could not give an example of daily life on solubility equilibrium.

Interview results indicated that control group students had difficulty in writing a dissolution equation and Ksp, drawing, and reading graphic. Some students in the control group had a difficulty in the effect of temperature on solubility equilibrium whereas the students in the experimental group did not have any problem. Some students in the experimental and control group had difficulty in describing the nature of solute or solvent on solubility equilibrium. Most of the students in the control group and a student in the experimental group had misconceptions about the effect of a common ion on solubility equilibrium. In summary, misconceptions were detected in the interviews. These misconceptions were consistent with those detected from SECT. In other words, the interviews results verified the result of the SECT.

5.4 Students' Ideas about the 5E Learning Cycle Model

Semi-structured interviews were conducted to elicit the experimental group students` ideas about the implementation of the 5E learning cycle model at the end of the treatment. Two students were high achievers, two students were medium achievers, and two students were low achievers in the experimental group. Interview questions were analyzed by coding. Three themes were found: "comparison of the instruction based on the 5E learning cycle model and traditionally designed instruction," "changes in students," and "general ideas". The distributions of the number (percentages) of the students in the experimental group across codes are given in Table 5.53, and each category is explained in the following part.

Table 5.53 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 instruction based on the 5E learning cycle model and traditionally designed instruction	
- Daily life examples	3 (50%)
- Experiments and Activities	6 (100%)
- Participation of student	5 (83.3%)
- More enjoyable	2 (33.3%)
- Preference of approach	
· instruction based on 5E learning cycle model	6 (100%)
Changes in students	
- Increased attention to chemistry	4 (66.6%)
- Learning better	5 (83.3%)
- More effort	2 (33.3%)
- More talking	5 (83.3%)
- Willing to learn	3(50%)
General ideas	
- Suggestions	
· doing experiments individual	2(33.3%)
· doing experiments in the laboratory	3 (50%)
· active participation	2 (33.3%)
· more course credit	2 (33.3%)
· more experiments	2 (33.3%)
- Problems	
· noise	1 (16.6%)
· no problem	5 (83.3%)

5.4.1 Comparison of the Instruction Based on the 5e Learning Cycle Model and Traditionally Designed Instruction

Students in the experimental group asked to make a comparison about the instruction based on the 5E learning cycle model and traditionally designed instruction. Five codes formed according to their responses. These codes are "Daily life examples" (50%), "Experiments, and activities" (100%), "Students participation" (83.3%), "More enjoyable" (33.3%), and "Preference of approach" (100%).

Students said that daily life examples in instruction based on 5E learning cycle model were different from previous lessons. Three students stated that they were not given daily life examples in their previous classes, but recognized the inclusion of many daily life examples in this term. For example, a student expressed her views as "we learned the rate of reaction and chemical equilibrium before. In these lessons, we used the course book but in solubility equilibrium unit, we learned many daily life examples and chemistry is inside of the life. These examples helped us to learn more."

Another difference between instruction based on the 5E learning cycle model and traditionally designed instruction was activities and experiments according to students' responses (6 students). All experiments were conducted in the classes because the school did not have a laboratory during the treatment. For example, a student stated, "We conducted experiments about solubility equilibrium concepts in the classroom because this topic is suitable for experiments, but while participating in the gases unit in last year, and the rate of reaction and equilibrium in the last semester, we did not do any experiments. In this semester, chemistry courses were good because of conducting experiments and activities." Another student stated, "In this term, while making experiments and activities, I was relaxed and motivated easily to chemistry lessons".

Students' participation was another different thing viewed by the experimental group students (5 students) in the instruction based on 5E learning cycle model. Students said that in this semester the teacher wanted more participation and more discussion in the classes. For example, a student expressed his views as "there was more our participation in the classes. Our teacher asked many questions to discuss and wanted our comments. In the last semester, our teacher explained the topic and then she solved the problems in the board, but in this term, she did not it."

Two students in the experimental group said that in this term chemistry classes were more enjoyable. For example, a student stated, "Generally, I am bored in all the lessons, but in this solubility equilibrium topic, I always lived it up. The teaching process was good for me since the lessons included more enjoyable things."

Students were asked which type of instruction they preferred: 5E learning cycle model or the traditionally designed instruction. All students agreed that the instructions based on the 5E learning cycle model helped their learning. They selected the instruction based on the 5E learning cycle model for reasons such as learning better in these classes, increasing their attention to chemistry, making more effort, and doing experiments.

5.4.2 Changes in Students

Students asked their perceived changes during the instruction of the 5E learning cycle model. Students said that the treatment was helpful and effective to learn chemistry more permanently. They explained their perceived changes as "Increased attention to chemistry" (66.6%), "Learning better" (83.3%), "More effort" (33.3%), "More Talking" (83.3%), and "Willing to learn" (50%).

Some of the students stated that their attention and motivation increased through the implementation of the 5E learning cycle model. For example, a student stated, "Chemistry lessons did not get my attention in the last semester and last years. However, I want to listen to the chemistry courses and participate in the activities. I want to learn daily life examples and do experiments in the classroom. That is, I can say my attention and motivation to chemistry increased after about learning solubility equilibrium with activities."

Some students believed that their learning was better using the instruction based on the 5E learning cycle model. For example, a student expressed her views as "I think I internalized better chemistry. When you think there is no connection to everyday life that course, this course is more boring to you. However, with connections to everyday life, the chemistry was better, and we learnt better in this way. Moreover, our learning from this course became more persistent."

Some students claimed that they made more effort in implementation of the activities. For example, a student stated, "All the activities and experiments were good. The courses were more enjoyable. In the courses, we made more effort by conducting activities and participating in discussion."

Most of the students stated that their talking in the courses increased in the instruction based on the 5E learning cycle model. For example, a student expressed her views as "While implementing solubility equilibrium, our teacher always asked the questions and wanted our comments. So, we talked more in these courses."

Some students stated that their willingness to learn increased after learning process of solubility equilibrium. For example, a student stated, "during the courses, we learned many daily life examples and conducted activities and experiments. Since the process was funny and remarkable, we always wondered the following activities and wanted to learn new things."

5.4.3 General Ideas

The students were asked suggestions in order to improve their learning of chemistry concepts and problems encountered in the instruction based on the 5E learning cycle model. Students gave many suggestions such as that experiments could be done in the laboratory (3 students) and individually (2 students), that is that all students could have the equipment to do the experiments. Some students thought that "course credit" (2 students), and "experiments" (2 students) could be done more in order to make more learning permanent. Some students stated that active participation (2 students) could be increased more in order to support learning. Moreover, most of the students (5 students) stated that there was no problem while one student said that a noise created a problem during implementation.

In summary, students stated those daily life examples, activities and experiments, students' participation, and the 5E learning cycle model made gaining more enjoyable. These were the differences noted between the instruction based on the 5E learning cycle model and traditionally designed instruction. All students preferred chemistry classes taught using the 5E learning cycle model. All students enjoyed the 5E learning cycle instruction and stated that their thinking changed. They also stated that their attention and motivation to chemistry increased and they learned better. They made more effort and were more willing to learn during the implementation. The results of the interviews indicated that the instruction based on the 5E learning cycle model was more effective in supporting learning and increasing students` attitudes and motivation towards chemistry in positive way.

5.5 Classroom Observation Results

The treatment was conducted over seven weeks in an Anatolian high school in Ankara. In order to provide treatment verification, the researcher observed all class sessions for both the experimental and control groups during the treatment. When the researcher was observing, she sat in the back of the classroom and took notes about student–student interactions, students–teacher interactions, and treatment implementation. She only observed and in no way was she involved in the lessons.

The chemistry curriculum and the teacher were same in both the experimental and the control groups. The topic was solubility equilibrium concepts. Experimental group students were instructed using the 5E learning cycle model whereas the control group students were instructed with traditionally designed chemistry instruction. Both groups were instructed by the two chemistry teachers throughout the treatment. In other words, each teacher taught one experimental group and one control group. Prior the treatment, researcher explained the 5E learning cycle implementation and what they would do during the classes. Although the steps of 5E learning cycle model required students' participation and investigations, the experimental group students were not involved in the classroom discussions at the beginning of the treatment. However, students participated in the lessons and became more active after the teacher encouraged classroom participation. Generally, all students in the experimental group talked during instruction, especially in the engagement phase. Moreover, students were noisy in the exploration phase since this phase included an experiment. During the first week, while teacher was conducting the experiment, students were talking and laughing, causing a classroom management problem. However, students got used to the activities after the first week and were more attentive to the lessons. It can be said that these activities were motivating for the students.

In the control group, the traditional method was used. The teacher was active and students were passive in the lectures. At the beginning of the lesson, the teacher presented the subject, and solved the problem, especially algorithmic problems. After teacher solved the first problem, she asked questions to the students. Students who were willing solved the problem at the board. She generally used the whiteboard to explain the topics and solve the problems. While the teacher presented the subject, the students took notes in their notebooks. However, when the teacher asked conceptual questions, the students were unwilling to answer them. There were few students participating in the discussions. While discussing the subject, the students talked with each other and were noisy. The teacher warned them to be quite. Therefore, it was difficult to explain the subject and it was time consuming since the teacher gave extra explanations. The teacher gave handouts to the students to solve in the classroom. If all questions were not solved the classroom, she gave them as homework. Most of students completed the homework before the class ended.

In summary, instruction based on the 5E learning cycle model was more effective to teach solubility equilibrium concepts compared to traditionally designed instruction because it made students more active and gained the students' attention.

5.6 Summary of the Results

1. The analysis of pre-SCT results showed that there were no significant mean differences between the experimental and control groups with respect to the students' previous solution concept understanding.

2. The analysis of pre-ASTC results revealed that there was no statistically significant mean difference between the experimental and control groups with respect to students' previous attitudes towards chemistry as a school subject.

3. The analysis of pre-SPST results indicated that there was a significant mean difference between the experimental and control groups with respect to students' science process skills in favor of the control group. Therefore, to control for preexisting differences, SPST was assigned as a covariate in the statistical analyses of post-SECT and SERT scores.

4. The analysis of pre-MSLQ for motivation subscale showed that there was no significant mean difference between the experimental and control groups' students in terms of the motivational collective dependent variables of students' Intrinsic Goal Orientation (IGO), Extrinsic Goal Orientation (EGO), Task Value (TV), Control of Learning Beliefs (CLB), Self-Efficacy for Learning and Performance (SELP), and Test Anxiety (TA). In other words, before the treatment, student motivations in chemistry was not different in the experimental and control group.

5. The analysis of pre-MSLQ for the learning strategies subscale results revealed that there was no significant mean difference between experimental and control group students in terms of the collective dependent variables of Rehearsal (R), Elaboration (E), Organization (O), Critical Thinking (CT), Metacognitive Self-Regulation (MSR), Time and Study Environment (TSE), Effort Regulation (ER), Peer Learning (PL), and Help Seeking (HS). That

means, students` learning strategies were similar in the experimental and control groups before the treatment.

6. The analysis of post-SECT and post-ASTC results indicated that there was a significant mean difference between experimental and control groups with respect to understanding solubility equilibrium concepts and attitude towards chemistry as a school subject when the effect of SPST mean score was controlled in favor of the experimental group.

7. The analysis of post-SECT and post-ASTC results showed that there was a significant mean difference between males and females with respect to understanding solubility equilibrium concepts and attitude towards chemistry as a school subject when the effect of SPST mean score was controlled in favor of females.

8. The analysis of retention-SERT results revealed that there was a significant mean difference between scores of students taught by instruction based on the 5E learning cycle model and traditional instruction in students' retention test scores when science process skill was controlled as a covariate in favor of the experimental group.

9. The analysis of post-MSLQ for motivation subscale results indicated there was a significant mean difference between experimental and control group with respect to dependent variables of intrinsic goal orientation, task value, and self-efficacy for learning and performance in favor of the experimental group. There was a significant mean difference between the experimental and control group with respect to extrinsic goal orientation in favor of the control group. In addition, there was no significant mean difference between experimental and control group with respect to control of learning beliefs and task anxiety.

10. The analysis of the post-MSLQ for motivation subscale showed that there was no significant mean difference between males and females with respect to the dependent variables about motivation.

11. The analysis of the post-MSLQ for learning strategies subscale revealed that there was a significant mean difference between experimental and control group with respect to the dependent variables of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning in favor of the experimental group.

12. The analysis of the post-MSLQ for learning strategies subscale indicated that there was a significant mean difference between males and females with respect to the dependent variables of organization and help seeking in favor of the females.

13. The analysis of interviews in both the experimental and control groups showed that the instruction based on the 5E learning cycle model resulted in significant gains on scientific conceptions about solubility equilibrium concepts and elimination of misconceptions compared to traditionally designed instruction. In addition, interviews results helped to elucidate students` misconceptions observed in post-SECT.

14. The analysis of interviews in the experimental group revealed that daily life examples, activities and experiments, and students' participation were differences between the instructions based on the 5E learning cycle model and traditionally designed instruction. All students preferred to have chemistry classes in using the 5E learning cycle model. They also stated that their attention and motivation to chemistry increased and they learned more. They made more effort and were more willing to learn during the implementation.

15. The results of the interviews indicated that the instruction based on the 5E learning cycle model were more effective in supporting learning and increased students` attitudes and motivation toward chemistry in positive way.

16. Classroom observations revealed that instruction based on the 5E learning cycle model was more effective to teach solubility equilibrium concepts compared to traditionally designed instruction because it made students more active and students paid more attention to the lesson.

CHAPTER 6

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

6.1 Discussion of the Results

The main purposes of this study were to investigate the effect of instruction based on 5E learning cycle model as compared to traditional instruction and gender on 11^{th} grade students' understanding of solubility equilibrium conceptions, their attitudes towards chemistry, their perceived motivation (intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety) and their perceived use of learning strategies (rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environmental management, effort regulation, peer learning, help seeking).

In the present study, pre-tests assessing students' understanding of solution concepts, attitude towards chemistry, motivation and learning strategies in chemistry and science process skills were administered to the students in both groups in order to understand whether experimental and control groups were equal prior to the study. Solubility concept test was used as a pre-test instead of solubility equilibrium test because students did not know solubility equilibrium concepts and they could make a prediction about questions without thinking. Pre-test analyses indicated that mean score on pre-SCT was higher in the experimental group than the control group. The mean scores on pre-SCT were 11.07 and 12.00 in the control and experimental group, respectively. Considering minimum and maximum values that can be obtained from pre-SCT (min = 0, max = 20), the mean scores of pre-SCT were slightly above the average for both of the groups. However, students' previous knowledge in solution was not differing across the groups significantly. That means, students' readiness for learning solubility equilibrium was at medium level for both groups. Other pre-test analyses revealed non-significant differences across the groups with respect to attitude towards chemistry, and perceived motivation and use of learning strategies in chemistry. The only significant difference was detected between the two groups with respect to students' science process skill scores. Students in experimental group scored higher than those in control group in science process skill test. Therefore, students' science process skill scores were assigned as a covariate in the post-test and retention test analyses. For the treatment, experimental group students were instructed by 5E learning cycle model and control group students were taught by traditionally designed chemistry instruction.

In the current study, instruction based on 5E learning cycle model was used in the experimental group. The treatment mainly focused on students' misconceptions and their prior knowledge. In the first phase (engagement), the students were engaged in a learning task by asking a question, defining a problem, or showing a discrepant event. The activities presented in this phase hold students mentally and physically active by creating interest and generating curiosity. This phase initiated the process of disequilibrium by activating students' prior knowledge. In the second phase (exploration), concrete and hands-on activities were used to make students explore objects, events, or situations. During the exploration activities, students had a chance to establish relationships, observe patterns, identify variables, and question events. Students worked together and the teacher acted as facilitator. In the explanation phase, students were asked to make explanations based on the data obtained from the engagement and exploration activities. Then, the teacher introduced the scientific explanations of the phenomena involved in the learning task. In the elaboration phase, students involved in additional activities, which extend or clarify the concepts, processes, and skills. During this phase, students shared their understanding of the subject through their engagement in group discussions and cooperative learning situations. In this phase, students had also an opportunity to apply the newly acquired concepts in additional contexts, and problems. In the final phase (evaluation), teacher evaluated the students through formal and informal assessment techniques like questioning. Students received feedback on their conceptual understandings, process skills and behaviors that they acquired during the instruction.

On the other hand, traditionally chemistry instruction was used in the control group. The teacher generally used the whiteboard to explain the topics and solved algorithmic problems. In addition, the teacher did not consider students existing knowledge and misconceptions. Lecturing method was used generally during the instruction. The students were passive and the teacher was active in the lectures. That is to say, students listened to the teacher, and then took notes. There were limited interactions between the students and the teacher. These aforementioned points might be reasons for the effectiveness of instruction based on 5E learning cycle model on students' better understanding of the solubility equilibrium concepts. In summary, instruction based on the 5E learning cycle model was more effective in learning solubility equilibrium concepts than the traditionally designed instruction because it pushed students to be more active and gained the students' attention.

In the post-test analyses, the descriptive statistics revealed that post-SECT 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-SECT (min = 0, max = 23) were considered, the mean score of students in the experimental group was above the average ($\overline{X}$ = 15.19) but the mean score of students in the control group was at around the average ($\overline{X}$ = 10.66). The mean difference between the groups with respect to post-SECT was also tested statistically by controlling the effect of students' science process skill scores. Results showed that students instructed by using 5E learning cycle model scored significantly higher than those instructed by using traditional instruction on post-SECT. The proportion of the variance of student understanding in solubility equilibrium concepts explained by the treatment was 27%. The size of the observed group difference in understanding of solubility equilibrium conceptions was large according to Cohen's (1992) criteria. Two months later, the test measuring students' understanding of solubility equilibrium was re-administered to the students in both groups. It was found that students in the experimental group ($\overline{X}$ = 14.96) outperformed those in the control group ($\overline{X}$ = 9.18) significantly. The size of the mean difference in the retention test was larger than that of in the post-test. That is, the proportion of the variance of student understanding in solubility equilibrium explained by the treatment was 41% in retention test, while it was 27% in post-test. The findings obtained from this study are consistent with the findings of other national and international studies in terms of supporting the idea that learning cycle model leads to greater conceptual understanding (Ates, 2005; Ceylan & Geban, 2009; Demircioglu et al., 2004; Musheno & Lawson, 1999; Saygin, 2009; Turgut & Gurbuz, 2011; Yilmaz et al., 2011). When the characteristics of the learning cycle model are considered, these findings can be considered as expected outcomes, because students actively involved in the learning process and they constructed their own knowledge in the learning cycle class (Krajcik & Sutherland, 2010). At the beginning of the instruction of solubility equilibrium concepts, a demonstration, which naturally stimulated students to learn, was provided rather than direct information about the concepts intended to be taught. Through demonstrations, students were engaged in experiences with the concepts to be learnt. Immediately afterwards, students were involved in classroom discussions in order to discover the concepts from the data. Discussion of concepts under consideration in the classroom context facilitated students' understanding of those concepts. Students became convinced that new conception accepted as scientific was more meaningful to them. Finally, students were given opportunities, including conceptual change texts to develop the understanding of the newly discovered concept (Abraham & Renner, 1986; Renner et al., 1985). All of these activities facilitated construction of new concepts in a scientific way (Driver, 1988; Fellows, 1994).

Students' responses on each item of post-SECT were also examined in this study. For each item, the proportion of students' correct responses and misconceptions were examined. The proportions of students' correct responses in the experimental group were greater than that of in the control group on several items of the post-SECT. Students in the experimental group held fewer misconceptions about solubility equilibrium in most of the items, compared to those in control group. Treatment had an effect on elimination of students' misconceptions in solubility equilibrium. The difference between classroom activities provided in experimental and control group 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 5E learning cycle model. In the experimental group, students' prior conceptions were taken into account, and their misconceptions were activated through discussions. Students were dissatisfied with their existing conceptions through demonstrations, discussions, and conceptual change texts provided in learning cycle classes. Then, scientific conceptions were negotiated in small group and whole-class discussions. The important part of the learning cycle approach was the social interaction because the scientific concepts were discussed through student - student and student - teacher interaction. These discussions facilitated students' understanding of solubility equilibrium 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 teaching solubility equilibrium. The teacher taught the solubility equilibrium concepts directly without considering students' existing conceptions. According to Pintrich, Marx, & Boyle (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 learning cycle approach. A practical way of fostering conceptual change in science is to provide students with opportunities to experience scientific phenomena through demonstrations and to relate scientific conceptions with everyday life.

The current study also revealed that there were still some misconceptions held by a considerable number of students even after instruction of solubility equilibrium. However, students in experimental group held fewer misconceptions compared to those in control group. This finding implied that it is not easy to remediate misconceptions just by using traditional instructional methods (Pinarbasi et al., 2006). Prior conceptions were not abandoned by the learner completely (Garnett et al., 1995). 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 (Bilgin & Geban, 2006; Driver & Easly, 1978; Pinarbasi et al., 2006). Common misconceptions held by the students were, solubility of sparingly soluble salts is affected by the change made in pressure and volume (Onder, 2006; Cam, 2009), Ksp can change with the amount of solid or ions added at a given temperature (Onder, 2006), and solubility of salts at equilibrium can always be compared according to Ksp values (Cam, 2009). The other misconceptions detected in this study were, there is no precipitation and dissolution at equilibrium (Onder, 2006), the concentrations of ions will remain constant although a common ion is added at equilibrium (Onder, 2006), and compounds in solid form should be included while writing Ksp equations.

Attitude is very influential affective variable in science learning (Oliver & Simpson, 1988; Pintrich et al., 1993). It contributes to science achievement and conceptual change significantly (Germann, 1988; Mitchell & Simpson, 1982; Salta & Tzougraki, 2004). For this reason, the effect of the instruction based on 5E learning cycle model on students' attitudes towards chemistry was also investigated in this study. Prior to the study, students had the mean attitude score of 49.66 in the experimental and 48.16 in the control group. Since the maximum score and minimum score that can be obtained from the attitude scale are 75, and 15, respectively; students' mean scores of attitudes towards chemistry were positive but not high at the beginning of the study. After the treatment, students held more positive attitudes towards chemistry in the experimental group ($\overline{X}$ = 52.30), but not in the control group ($\overline{X}$ = 46.50). However, the difference in the mean scores of attitude towards chemistry was not statistically significant across the two groups. It can be concluded that 5E learning cycle model influenced students' attitudes towards chemistry in a positive way. This finding is supported by the studies conducted by Altun Yalcin et al. (2010), Ergin et al. (2008), Nuhoglu and Yalcin (2006), and Sasmaz Oren et al. (2009). Students' attitudes towards science can be improved by using effective instruction, including 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 towards science and conceptual understanding (Koballa & Glynn, 2004). However, contrary to the current study, Gonen et al. (2010), and Koseoglu, and Tumay (2010) could not find any effect of learning cycle model on students' attitudes towards subject matter. Moreover, this finding is also supported by classroom observations performed during the treatment. Students in the experimental group were more eager to participate to classroom discussions and activities compared to that of the control group. The reason why more positive attitudes in the experimental group might be due to the fact that the teachers gave importance to identification and elimination of students' misconceptions.

In addition, the effect of gender on students' attitudes towards chemistry was investigated. The results revealed that there was a significant mean difference between male and female students with respect to their attitudes towards chemistry. The results showed that females demonstrated more favorable attitudes towards chemistry than males. The finding of the present study is compatible with the assertions in the study by Ozyalcin Oskay et al. (2009) claiming that female students had better attitudes towards chemistry than males. On the other hand, Ozden (2008) demonstrated that males have more positive attitude towards chemistry compared to females, and Kan and Akbas (2006) found that there was no significant difference between males and female on attitudes towards science Moreover, this study also showed that there was no significant interaction between gender and treatment on students' attitudes towards chemistry.

Motivation is another affective variable influencing student learning (Pintrich & De Groot, 1990; Uredi & Uredi, 2005) and it can be developed using learning cycle model (Marek & Cavallo, 1997). Post-test results indicated a significant difference between the two groups with respect to intrinsic goal orientation, task value, and self-efficacy for learning and performance, in favor of the experimental group. However, the difference in the mean score of extrinsic goal orientation was significant across the groups, in the favor of control group. The reason of this finding can be implementation period for instruction based on 5E learning cycle model. The period of the treatment was only seven weeks. Therefore, that instructional time using this technique was not sufficient for the students to be aware of usefulness of the task, to improve expectation for positive products with their efforts instead of external factors, and to adapt in a new technique. Moreover, because the results of the current study showed that students pursuing intrinsic goal orientation engage in activities for challenge, curiosity, and mastery, rather than rewards and competition, which are signs of extrinsic goal orientation; it can be concluded that instruction based on 5E learning cycle model has no effect on extrinsic goal orientation. Furthermore, since the present study indicated that students in the experimental group believed the importance of daily life examples and experiments conducted during the treatment, it could be claimed that treatment has a positive effect on task value. In addition, the reason of why a significant difference was found between the experimental and the control groups with respect to self-efficacy for learning and performance might be due to the fact that instructional activities provided in 5E learning cycle class was a student - centered and new method. On the other hand, it was found that there was no significant difference between both the groups with respect to test anxiety. This reason of this result can be attributed to 5E learning cycle model because it was new for students and students participated in many extra activities compared to those in the control group. The finding indicating positive effects of 5E learning cycle model on students' intrinsic goal orientation and task value was also supported by the study of Ceylan (2008). Consistent with the current study and Ceylan's (2008) study, Saygin (2009) demonstrated an improvement on students' perceptions of intrinsic goal orientation in the learning cycle class in her study. Contrary to Ceylan's (2008) study, students' perceptions of extrinsic goal orientation was found higher in the traditional group than the learning cycle group in the current study. In addition, consistent with the findings of Saygin (2009), using learning cycle model improved students' perceptions of self-efficacy for learning and performance in the current study while in Ceylan's (2008) study there was not any improvement on the perceptions of self-efficacy for learning and performance. Furthermore, consistent with the study of Ceylan (2008), differences in the mean scores of control of learning beliefs and test anxiety were not significant across the two groups. However, Saygin (2009) revealed that students in the learning cycle class had higher levels of control of learning beliefs. Moreover, Yilmaz (2007) could not detect any effect learning cycle model on improvement of students' perceived motivation. Moreover, Sungur and Tekkaya (2006) investigated the influence of an instructional approach based on constructivism (problem-based learning) on students' perceived motivation and found consistent results with this study. The instruction based on constructivism significantly improved students' perceived intrinsic goal orientation and task value. In the current study, there was not any significant difference between males and females with respect to perceived motivation. The reason why no significant difference was found between those two in the present study might be due to similar student background characteristics, school climate, and experiences. However, Sungur (2004) revealed that males' perceived extrinsic goal orientation and test anxiety were higher than that of females; but females' perceived task value and self-efficacy for learning and performance were higher than that of males.

Self-regulation has also positive influence on student learning (Pintrich & De Groot, 1990; Uredi & Uredi, 2005). Post-test results indicated a significant difference between the two groups with respect to learning strategy variables (rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and peer learning), in favor of the experimental group. One reason why significant difference was found in this study might be due to the fact that instruction based on 5E learning cycle model gave importance to students' existing knowledge, and active participation. Another reason may be that it included student – centered activities such as demonstrations, experiments, daily life examples etc. Consistent with these findings, the influence of 5E learning cycle model was found effective on students' use of elaboration strategy in studies conducted by Ceylan (2008) and Yilmaz (2007), organization strategy in the study of Ceylan (2008), and metacognitive self-regulation strategy in the study of Saygin (2009). The current study also demonstrated that the differences in the mean scores of effort learning and help seeking were not significant across the two groups. This can be explained by duration of instruction based on 5E learning cycle model, whichwas only seven weeks. Therefore, that treatment time using this technique was not enough for the students to control their effort and attention, and learn peer help seeking. However, the influence of learning cycle model on students' use of help seeking strategy was positive in the study of Saygin (2009). Moreover, by using an instructional approach based on constructivism (problem-based learning) rather than learning cycle model, Sungur and Tekkaya (2006) supported the findings of current study by finding that the instructional approach based on constructivism improved students' use of elaboration, critical thinking, metacognitive self-regulation and peer learning strategies. However, inconsistent with the findings of the current study, Sungur and Tekkaya (2006) demonstrated that instructional approach based on constructivism was effective on development of effort regulation strategy. In addition, a significant difference was detected between females and males with respect to learning strategy variables including help seeking and organization. This can be because of the fact that students had similar experiences, and school climate. Inconsistent to this finding, Sungur (2004) detected a difference between females and males with respect to elaboration and organization strategies.

Interviews were conducted with 12 students in both groups. The purpose of interviews was to analyze students' reasoning about solubility equilibrium concepts. Six students from experimental group and six 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 the experimental group held more scientific conceptions and fewer misconceptions in solubility equilibrium unit compared to those in control groups. The interviews also helped to clarify students' misconceptions detected in post-SECT in an in-depth manner. It was found that the misconceptions observed in the interviews were consistent with those detected because of the concept test. Students had a difficulty in writing the dissolution equation with corresponding Ksp, drawing a graphic that shows dissolution and precipitation rates, interpreting given graphs about the concentration change of a salt (which is less soluble in water) and its ions, and interpreting the factors affecting the solubility equilibrium. In addition, students in the experimental group integrated their understanding of solubility equilibrium concepts with daily life situations. However, students in the control group could not connect their knowledge in solubility equilibrium with everyday life.

Using the semi-structured interview protocol, students were questioned about the implementation of the 5E learning cycle model. Semi-structured interviews were conducted with six students from the experimental group. The results indicated a variety of data about 'comparison of the instruction based on the 5E learning cycle model and traditional instruction', 'changes in students', and 'general ideas'. All the interviewed students enjoyed the activities in 5E learning cycle class and expressed that they learnt the chemistry concepts. This finding is supported by the study of Demircioglu et al. (2004). Students preferred to have chemistry classes designed in 5E learning cycle format in further chemistry classes. The students emphasized the value of daily life examples and experiments in their learning. The students felt them more active in 5E learning cycle classes compared to their previous semester chemistry classes.

In this study, although instruction based on 5E learning cycle model improved students' understanding of solubility equilibrium concepts, attitudes towards chemistry, motivation, and use of learning strategies; some challenges were observed during the implementation of this method. Students and teachers had to cope with several problems. Bozdogan and Altuncekic (2007) pointed out the problems when using the 5E teaching method as follows; it needs extra materials and long time, teachers' lack of knowledge about this method, and crowded classes.

To sum up, the present study showed that students had several misconceptions and learning difficulties in solubility equilibrium. Misconceptions held by the students impede their further learning negatively. Therefore, instructions must be designed considering identification and elimination students misconceptions by teachers. Traditionally designed chemistry instruction does not seem to be effective in developing conceptual understanding in solubility equilibrium. On the other hand, using instruction based on 5E learning cycle model resulted in a better acquisition of scientific concepts, remediation of students' misconceptions, and meaningful learning. Using this instruction also caused improved students' attitudes towards chemistry, perceived motivation, and perceived use of learning strategies. Therefore, it is suggested that using 5E learning cycle model should be preferred to using traditional instruction to help students to become more successful in learning chemistry.

6.2 Internal Validity

If the differences observed on the dependent variable are directly related to independent variables and not to any other unintended variables, the study has internal validity (Fraenkel & Wallen, 2009). Therefore, to control internal validity, threats are important to consider. Subject characteristics, mortality, location, instrumentation, testing, history, maturation, attitude of subjects, regression, and implementation were defined as potential internal validity threats (Fraenkel & Wallen, 2009).

Subject characteristic threat is the major threat to internal validity of a quasi-experimental study. This threat may occur in current study since students were not randomly assigned. To control this threat at the beginning of the study, students' academic achievement, age, attitude, gender, socio-economic status, and science process skills were examined and compared. Students' previous achievement and science process skills were used as covariate to minimize the prior differences. Moreover, all the students were in 11 grades and 16-17 years old.

Mortality threat was defined as students who drop out of the study because of illness, family relocation, or the requirements of other activities. Since both students in the experimental and control group answered all of the items, mortality threat was controlled in this study.

Location threat was controlled by using similar location, that is, all the students took the instruction and tests in each class during regular school hours in the classroom environment.

Instrument decay threat was controlled by using multiple-choice format (SCT, SECT, and SPST) and Likert scale (ASCT, and MSLQ) since all items includes different interpretation.

In order to control the threat of data collector characteristics in this study, the same data collector was used. In addition, students were given the same time on tests in all classes. To prevent data collector bias they were trained how to administer the instrument and not judging in favor of instruction based on 5E learning cycle model over traditional instruction.

Testing threat was not a problem in this study because time between pre-test and post-test was not short. That is, there was enough time (seven weeks) for desensitization.

History threat is defined as unanticipated or unplanned events that affect the response of students. In order to identify any extraordinary events that affect the students, the researcher continually made observations and interviewed the teachers and the students. No extraordinary or unplanned events occurred during the instruction and administration of the test. Therefore, history threat was assumed to be controlled.

Both groups experienced the seven-week treatment at the same time and both groups were given the instruments during regular school hour in the same week. This time was too short to provide significant physiological or psychological changes in students. Thus, maturation threat was controlled.

Subject attitude is another internal validity threat. The students in the control groups received traditional instruction although the students in experimental groups received instruction based on 5E learning cycle model. In order to control this threat, students in the experimental groups were told that they were experiencing regular instruction and students in the control groups were said that there was no superiority of instruction applied experimental classes.

In this study, there was no regression threat because students were not selected by their achievement level. In order to control for this threat, students' understanding of solution concepts, attitudes towards chemistry as a school subject, motivation, learning strategies, and science process skills were controlled by the pre-tests.

Another internal validity threat was implementation. Since there were two teachers in this study, this threat may occur. However, both teachers had one experimental and one control group to equate treatment groups. Moreover, teachers were given training sessions before the study to help standardize the intended implementation of the treatments. In addition, the researcher observed all classrooms during the treatments to determine whether treatments were applied as intended.

6.3 External Validity

Population Generalizability is called as the extent to which a sample of a study exemplifies the population of interest (Frankel & Wallen, 2009). Convenience sampling technique was used in this study due to lack of the random selection of the subjects in Turkey. The target population was Ankara, and the accessible population was Çankaya. There were 19 public high schools in Çankaya, and there were approximately 2000 students at 11th grade level. For this study, the sample included 109 students in a high school, and the number of the participants corresponded to 5.5% of the accessible population. Since this proportion of the sample was low and convenience sampling was used in the present study, it can be concluded that population generalizability of this study was limited. However, this study can be generalized to other high school students having the similar characteristics since students' ages ranged from 16 to 17, and they were coming from same middle-class families. In order to develop the generalizability of this study, more researches can be carried out with similar samples in similar settings.

6.4 Implications

In the light of the findings of the present study, the following suggestions are offered:

1. 5E learning cycle instruction including student-centered activities should use in the chemistry lesson rather than traditional instruction.

2. Chemistry teachers should take into account students' possible misconceptions in designing classroom activities for the elimination of them.
3. The sources of the students' misconceptions should be considered. As being one of the potential sources of students' misconceptions, teachers should be careful when explaining concepts in order not to give rise to any misconceptions in students.
4. In order to make a connection between students' existing knowledge and new knowledge, instructions should include daily life examples, and hands-on and minds-on activities.
5. Because of the spiral curriculum in the Turkish chemistry curriculum, understanding of solubility equilibrium at 11^{th} grade is related with the previously acquired chemistry conceptions including dissolution, stoichiometry, chemical equations, the particular nature of matter, ionic compounds, chemical equilibrium characteristics, solubility, the common ion effect, and Le Chatelier's principle (Raviolo, 2001). Since students' existing knowledge influences their further learning, the chemistry teachers should be aware of students' prior learning and they should cope with these misconceptions by embedding it within the instruction based on constructivism, like learning cycle approach.
6. Chemistry teachers should develop learning cycle lesson plans in all chemistry subjects. They should ensure that their students become active.
7. Activity books about chemistry topics should be written for chemistry teachers so that chemistry teacher can use those books as a guide when preparing learning cycle lesson plans.
8. Chemistry curriculum should include some activities for chemistry teachers to be used in the lesson plans based on learning cycle.

9. Chemistry teachers should be trained about implementation of the learning cycle, and designing activities.
10. Chemistry teachers should concentrate on the development of students' affective characteristics, including attitudes towards chemistry, perceived motivation to learn chemistry and perceived use of learning strategies.
11. Chemistry teachers should be more careful about classroom management issue because some unexpected situations may arise during the implementation of student-centered activities provided in the learning cycle class.

6.5 Recommendations

Based on the results of this study, the following things can be suggested:

1. Similar studies can be carried out with a larger sample size and in different high schools for the generalization of the findings to a larger population.
2. Future study could examine the effectiveness of instruction based on 5E learning cycle model as compared to traditional instruction and gender on high school students' understanding in different chemistry topics, and different grade levels.
3. Further study can include a whole semester chemistry units, which is a long-term study.
4. Further research can be conducted in order to investigate the effects of learning cycle approach on students' critical thinking skills and epistemological beliefs.

5. Further studies in which learning cycle class sessions were video-recorded could be conducted. Then, the videotapes can be used for the treatment verification.
6. In further studies, discourse analyses of the classroom interaction in learning cycle classes can be conducted.
7. Rather than the 5E learning cycle model, the effect of the 7E learning cycle model on students' outcomes can be further investigated.
8. Teachers' ideas about implementation of learning cycle model in a chemistry course can be further examined.

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APPENDIX A

STUDENT BACKGROUND QUESTIONNAIRE

1. Adınız, Soyadınız: ________________________
2. Sınıfınız: ___________
3. Cinsiyetiniz:
□ Kız □ Erkek
4. Yaşınız: _________
5. Geçen Döneme Ait Kimya Karne Notunuz: ___________
6. Annenizin Eğitim Durumu:
□ İlkokul □ Ortaokul □ Lise □ Üniversite □ Y. Lisans □ Doktora
7. Babanızın Eğitim Durumu :
□ İlkokul □ Ortaokul □ Lise □ Üniversite □ Y. Lisans □ Doktora
8. Anneniz Çalışıyor mu? :
□ Evet □ Hayır
9. Babanız Çalışıyor mu? :
□ Evet □ Hayır
10. Kullandığınız Okul Kitapları Hariç Evinizdeki Kitap Sayısı:
□ 0-25 □ 26-60 □ 61-100 □ 101-200 □ 200'den fazla
11. Evinizde size ait çalışma masası var mı?
□ Evet □ Hayır

APPENDIX B

ÇÖZELTİLER TESTİ

Bu test siz öğrenci arkadaşların Çözeltiler Konusundaki başarınızı ölçmeyi ve değerlendirmeyi amaçlamaktadır. 20 tane çoktan seçmeli sorudan oluşmaktadır. Aşağıdaki her bir soru için size en uygun seçeneği işaretleyiniz. Başarılar.....

1. Bir katının sudaki çözünürlüğü aşağıdaki etkenlerden hangisi ile değişir?

A. Çözeltiyi karıştırmak.

B. Katıyı toz haline getirmek.

C. Su miktarını arttırmak.

D. Sıcaklığını arttırmak.

E. Katı miktarını arttırmak.

2. Bir bardak saf su içerisine az miktarda yemek tuzu (NaCl) atılıyor ve karıştırılıyor. Yemek tuzuna suda çözününce ne olur?

A. Yemek tuzu erir.

B. Yemek tuzu su içerisindeki boşluklara yerleşir.

C. Yemek tuzu elementlerine ayrışır.

D. Su molekülleri ile etkileşen yemek tuzu, iyonlarına ayrışır.

E. Yemek tuzu yeni bir maddeye dönüşür.

3. Doymuş tuz çözeltisine aynı sıcaklıkta bir miktar tuz eklenirse,

I. Derişimi artar.

II. Çözünen madde miktarı değişmez.

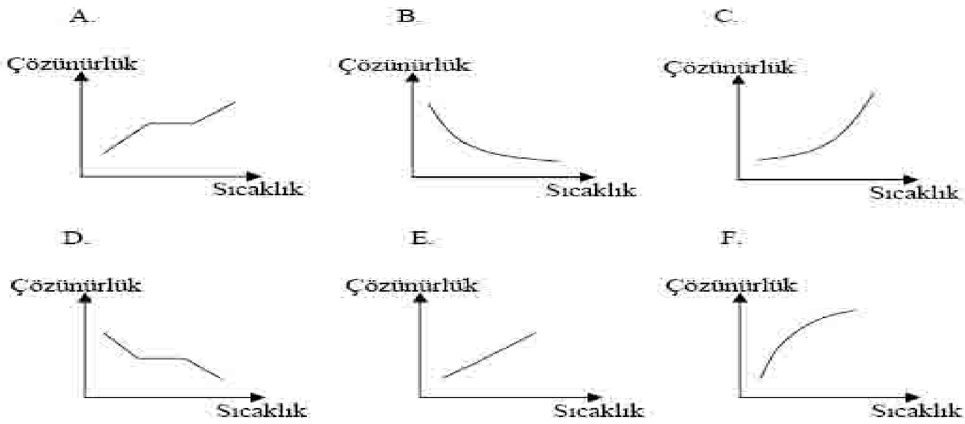
III. Buhar basıncı azalır.

yargılarından hangileri doğrudur?

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

E. II ve III F. I, II ve III

4. Aşağıdaki grafiklerden hangisi çözünürlüğü sıcaklıkla azalan bir madde için çizilebilir?



5. Bir litre çözeltinin içinde çözünmüş maddenin mol sayısına molar derişim denir. Buna göre, 1 molar tuzlu su çözeltisinden alınan iki örnekten, birinin hacmi 200 mililitre diğerininki ise 2 litredir. Bu iki çözelti için aşağıdaki ifadelerden hangisi söylenebilir?

A. Mol sayıları ve molar derişimleri farklıdır.

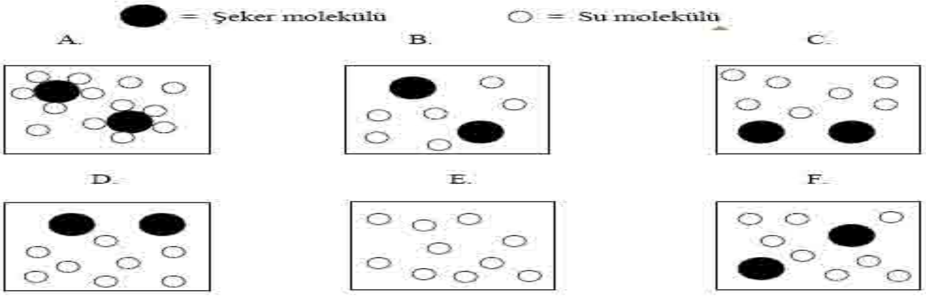
B. Mol sayıları farklı, molar derişimleri aynıdır.

C. Mol sayıları ve yoğunlukları aynıdır.

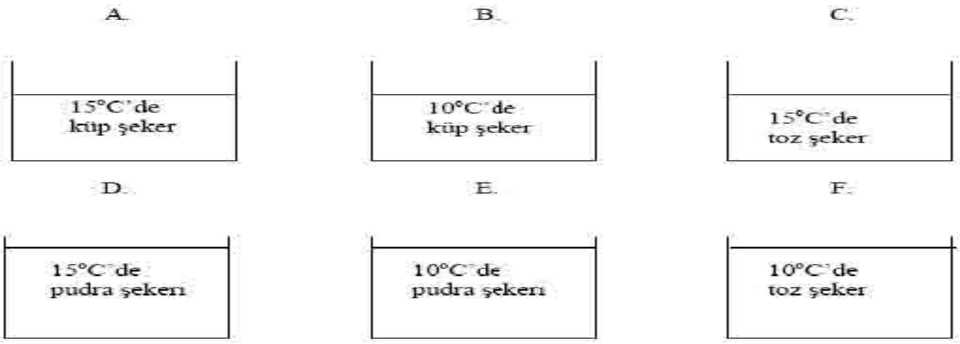
D. Yoğunlukları farklı, molar derişimleri aynıdır.

E. Mol sayıları ve molar derişimleri aynıdır.

6. Aşağıdakilerden hangisi, şekerli su çözeltisinin çok az bir kısmının anlık bir görüntüsünü temsil etmektedir?



7. Her birinde 100 mililitre su bulunan aşağıdaki kapların her birine, belirtilen sıcaklıklarda eşit miktarda şeker konuyor. Buna göre bu kapların hangisinde çözünme en hızlıdır?



8. Aşağıdaki madde çiftlerinin hangisinden çözelti elde edilemez?

A. Su, Amonyak
B. Su, Zeytinyağı

C. Sirke, Tuz

D. Sirke, Limon suyu

E. Su, Alkol

9. Aşağıdaki işlemlerden hangisi,

$$CaCl_{2(k\ )} \rightleftharpoons Ca^{+2}_{(suda)} + 2Cl^{-}_{(suda)} + ısı$$

denklemindeki $CaCl_{2(k)}$ sudaki çözünürlüğünü arttırır?

A. Bir miktar daha su ilave etmek.

B. Sıcaklığı düşürmek.

C. Çözeltiyi karıştırmak.

D. Bir miktar daha $CaCl_{2(k)}$ ilave etmek.

E. $CaCl_{2(k)}$ 'yi toz haline getirmek.

10. Aşağıdakilerden hangisi çözelti değildir?

A. Çeşme Suyu
B. Sodalı Su

C. Kolanya

D. Tuzlu Su

E. Etil Alkol

11. 4 gram NaOH'ın suda çözülüp toplam hacmi 500 mililitre olan çözeltisi yapılırsa çözeltinin molar derişimi kaç (mol/litre)'dir? (NaOH: 40 gram)

A. 2.10^{-4} B. 0.02 C. 0.20 D. 2 E. 20

12. 0,5 molar 200 mililitre $MgCl_2$ çözeltisinde kaç gram $MgCl_2$ çözünmüştür? (Mg: 24 gram, Cl: 35.5 gram)

A. 2.37 B. 9.50 C.1.05 D. 0.24 E. 38

13. Aşağıdaki örneklerin hangisinde KOH miktarı en fazladır?

(K: 39 gram, O: 16 gram, H: 1 gram)

A. 100 gram kütlece %10'luk KOH su çözeltisi.

B. 100 mililitre, 2 molar KOH su çözeltisi.

C. 0.2 mol KOH.

D. 12 gram KOH.

E. 2 litre 0.1 molar KOH su çözeltisi.

14. Aşağıdakilerden hangisi şeker su çözeltisi için doğrudur?

A. Şekerli su çözeltisinin ağırlığı, şekerin ve suyun ayrı ayrı ağırlıkları toplamından büyüktür.

B. Şekerli su çözeltisinin hacmi, şekerin ve suyun ayrı ayrı hacimleri toplamından büyüktür.

C. Şekerli su çözeltisinin ağırlığı, şekerin ve suyun ayrı ayrı ağırlıkları toplamından küçüktür.

D. Şekerli su çözeltisinin hacmi, şekerin ve suyun ayrı ayrı hacimleri toplamından küçüktür.

E. Yukarıdakilerden hiçbiri.

15. Kütlece %20'lik 100 gram X çözeltisi, kütlece %10'luk 300 gram X çözeltisi, 100 gram X ve 100 gram su karıştırılıyor. Karışımda kütlece % kaç X bulunur?

A. 20 B. 25 C. 27 D. 30 E. 33

16. %10'luk 150 gram tuz çözeltisine %25'lik yapmak için,

I. Bir miktar su buharlaştırmak.

II. Bir miktar tuz ilave etmek.

III. Bir miktar su ilave etmek.

işlemlerinden hangisi uygulanabilir?

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

17. Katı bir maddenin çözünürlüğüne,

I. Çözücünün türü

II. Karıştırmak

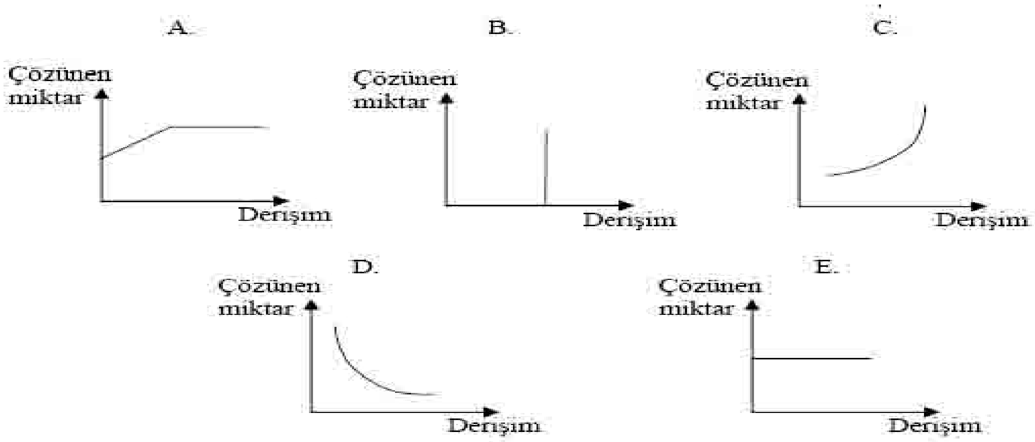
III. Sıcaklık

IV. Basınç

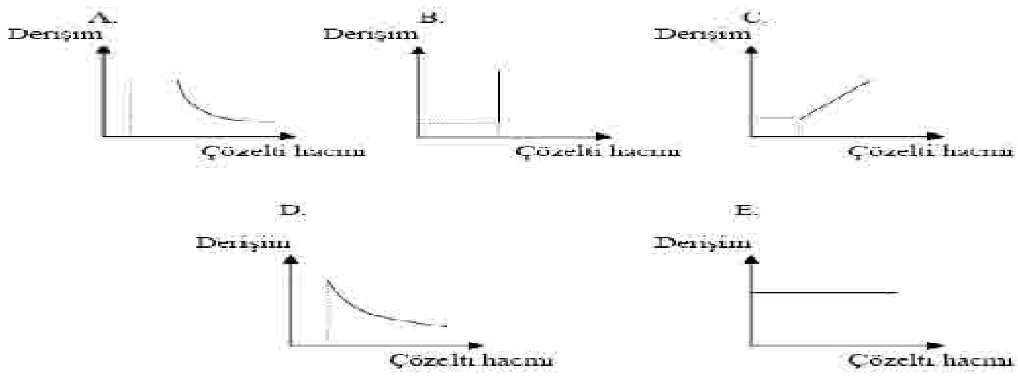
özelliklerinden hangisi etki eder?

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

18. İçerisinde yeterince katı bulunan sulu çözeltinin ısıtılmasına ilişkin çizilen çözünen miktar-derişim grafiklerinden hangisi doğrudur? (çözünme endotermiktir)



19. Katısı ile dengedeki doymuş bir çözeltiye bir miktar arı su yavaş yavaş eklenirse, çözelti hacmi ile derişim değişimini gösteren grafik aşağıdakilerden hangisi olabilir?



20. Aşağıdaki işlemler sonucunda,

I. Doymamış tuz çözeltisine sabit sıcaklıkta bir miktar tuz eklemek.

II. Doymuş tuz çözeltisine sabit sıcaklıkta bir miktar tuz eklemek.

III. Doymuş tuz çözeltisine sabit sıcaklıkta toz halinde bir miktar tuz eklemek.

tuz çözeltilerinin derişimleri nasıl değişir?

I. Çözelti	II. Çözelti	III.Çözelti
A. Artar	Değişmez	Artar
B. Artar	Artar	Değişmez
C. Değişmez	Artar	Artar
D. Değişmez	Değişmez	Artar
E. Artar	Değişmez	Değişmez

APPENDIX C

OBJECTIVES

1. Çözünmeyi tanımlar.
2. Çözünürlük kavramını açıklar.
3. Sıvı-katı çözeltilerinin oluşumunu açıklar.
4. Sıvı-sıvı çözeltilerinin oluşumunu açıklar.
5. Sıvı-gaz çözeltilerinin oluşumunu açıklar.
6. Çözünme olayında düzensizlik faktörünün etkisini açıklar.
7. Maksimum düzensizlik ve minimum enerjinin çözünme olayında etkisini açıklar.
8. Sulu çözeltilerin çözünenin yapısına göre sınıflandırılmasını kavrar.
9. Elektrolit olmayan çözeltileri bilir, açıklar.
10. Elektrolit çözeltileri bilir, açıklar.
11. Kuvvetli ve zayıf elektrolit çözeltiler arasındaki farkları söyler.
12. Suda az çözünen tuzların iyonlarından oluşumu gösterir.
13. Suda az çözünen tuzların iyonları arasında meydana gelen dengeyi yazar.
14. Az çözünen tuzların iyonları ile oluşturdukları dengenin denge bağıntısını yazar.
15. Çözünürlük sabitinin denge bağıntısından yazılması ile ilgili problemleri çözer.
16. Çözücünün türünün çözünürlük dengesine etkisinin açıklar.
17. Sıcaklığın etkisinin çözünürlük dengesine etkisinin açıklar.
18. Ortak iyon etkisinin çözünürlük dengesine etkisinin açıklar.
19. Yabancı maddelerin etkisinin çözünürlük dengesine etkisinin açıklar.
20. Çökelme şartlarının gerçekleşip gerçekleşmediğini anlayabilir.
21. Çökelme gerçekleşen tepkimeler içeren soruları çözebilir.

22. Çözünürlük çarpımı yardımı ile çözünürlük hesaplamasını yapar.
23. Seçimli çöktürmeyi açıklayıp yazar.
24. Az çözünen birden fazla tuzun aynı çözelti içerisinde çökmesi durumunda yapılacak işlem sırasını anlatıp yazar.
25. Seçimli çöktürme ile ilgili problemleri çözer.

APPENDIX D

ÇÖZÜNÜRLÜK DENGESİ TESTİ

AD SOYAD: **SINIF:**

Bu test siz öğrenci arkadaşların Çözünürlük Dengesi Konusundaki başarınızı ölçmeyi ve değerlendirmeyi amaçlamaktadır. 23 tane çoktan seçmeli sorudan oluşmaktadır. Aşağıdaki her bir soru için size en uygun seçeneği işaretleyiniz. Başarılar.....

1. Ag_2CO_3 suda çözündüğünde çözeltide Ag^+ ve CO_3^{-2} iyonları bulunmaktadır ve çözünürlüğü "S" mol/L'dir. Ag^+ ve CO_3^{-2} iyonlarının derişimleri ile çözünürlüğü (S) arasında nasıl bir ilişki vardır?

A. $S= [Ag^+]^2 + [CO_3^{-2}]$
B. $S= 2[Ag^+] + [CO_3^{-2}]$
C. $2S = [Ag^+]$, $S = [CO_3^{-2}]$
D. $S= 2[Ag^+] = [CO_3^{-2}]$
E. $S= [Ag^+] + [CO_3^{-2}]$

2. Katısı ile dengede olan bir çözelti için aşağıdakilerden hangisi doğrudur?

A. Yalnız çökelme olur, çözünme olmaz.
B. Dengeye ulaşınca çökelme başlamıştır.
C. Çözelti dengeye geldikten sonra çökme başlar.
D. Yalnız çözünme olur, çökelme olmaz.
E. Çözünme hızının çökelme hızına eşit olması durumudur.

3. Aşağıda oda sıcaklığındaki çözünürlük çarpımları verilen maddelerden 25^0C'deki suda çözünürlüğü en fazla olan hangisidir?

A. AgBr $K_ç = 3,6.10^{-13}$
B. Ag_2CO_3 $K_ç = 4.10^{-12}$
C. $SrCO_3$ $K_ç = 1,6.10^{-9}$
D. $Cu(OH)_2$ $K_ç = 3,2.10^{-20}$
E. $BaCO_3$ $K_ç = 8,1.10^{-9}$

4. Al_2S_3 denge durumunda az çözünen bir tuzdur. Bu bileşiğin çözünürlük çarpımı ($K_ç$) için aşağıdakilerden hangisi doğrudur?

$$Al_2S_{3(k)} \rightleftarrows 2Al^{+3}_{(suda)} + 3S^{-2}_{(suda)}$$

A. $K_ç = 2[Al^{+3}].3[S^{-2}]$

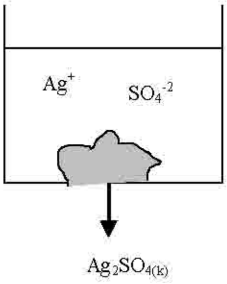
B. $K_ç = \frac{[Al^{+3}].[S^{-2}]}{[Al_2S_3]}$

C. $K_ç = [Al^{+3}]^3.[S^{-2}]^2$

D. $K_ç = [Al^{+3}]^2.[S^{-2}]^3$

E. $K_ç = \frac{[Al^{+3}]^2.[S^{-2}]^3}{[Al_2S_3]}$

5.



Yukarıdaki şekilde belirli bir sıcaklıkta katısı ile dengede olan Ag_2SO_4 çözeltisi vardır. Bu çözeltiye aynı sıcaklıkta bir miktar AgCl katısı ekleniyor. Buna göre, AgCl katısı eklemek Ag_2SO_4'ün çözünürlüğü nasıl etkiler?

A. Ag_2SO_4'ün çözünürlüğünü azaltır.
B. Ag_2SO_4'ün çözünürlüğünü arttırır.
C. Ag_2SO_4'ün çözünürlüğünü değiştirmez.
D. Ag_2SO_4'ün çözünürlüğünde beklenmedik değişmelere sebep olur.
E. Ag_2SO_4'ün çözünürlüğü hakkında bir şey söyleyemeyiz.

6. 100ml 0,1M Br^- iyonu içeren bir çözeltiye $AgNO_3$ çözeltisi ilave ediliyor. AgBr'ün çökmeye başlaması için gerekli minimum Ag^+ iyon derişimi kaç M olur?

(AgBr için $K_ç=5,4.10^{-13}$)

A. $[Ag^+] = 5,4.10^{-13}$
B. $[Ag^+] = 5,4.10^{-12}$
C. $[Ag^+] = 2,7.10^{-13}$
D. $[Ag^+] = 2,7.10^{-12}$
E. $[Ag^+] = 1,8.10^{-12}$

7. $Fe(OH)_{3(k)} \rightleftharpoons Fe^{+3}_{(suda)} + 3OH^{-}_{(suda)}$ tepkimesi dengede iken; aşağıdaki işlemlerden hangisi uygulanırsa Fe^{+3} derişimi artar?

A. Ortama $KOH_{(k)}$ eklemek.

B. Ortama $Fe(OH)_{3(k)}$ eklemek.

C. Ortama $Fe_2(CO_3)_{3(k)}$ eklemek.

D. Ortama $NaOH_{(k)}$ eklemek.

E. Su eklemek.

8. Sabit sıcaklıkta doymuş Ag_2SO_4 çözeltisine, bir miktar katı Ag_2SO_4 ekleniyor. Buna göre, Ag_2SO_4'ün çözünürlüğü ve $K_ç$'si hakkında ne söyleyebiliriz?

	Ag_2SO_4'ün çözünürlüğü	Kç
A.	Artar	Artar
B.	Artar	Azalır
C.	Artar	Değişmez
D.	Azalır	Artar
E.	Değişmez	Değişmez

9. $PbCl_{2(k)} + ısı \rightleftharpoons Pb^{+2}_{(suda)} + 2Cl^{-}_{(suda)}$

Doygun $PbCl_2$ çözeltisinin sıcaklığı artırılırsa $PbCl_2$ katısının,

I. Çözünürlüğü

II. Çözünürlük çarpımı

III. Kütlesi

niceliklerinin değişimi hangi seçenekteki gibi olur? (Buharlaştığı düşünülürse)

I	II	III
A. Artar	Artar	Azalır
B. Artar	Değişmez	Azalır
C. Azalır	Azalır	Artar
D. Değişmez	Değişmez	Artar
E. Değişmez	Artar	Değişmez

10. $BaSO_{4(k)} \rightleftarrows Ba^{+2}{}_{(suda)} + SO_4^{-2}{}_{(suda)}$

25^0C'de katısı ile dengede olan $BaSO_4$ tuzu yukarıdaki denklemdeki gibi çözünür. Sıcaklık sabit tutularak $BaSO_4$ çözeltisinin hacmi iki katına çıkartıldığında bu çözeltinin katısının bir kısmının çözünmediği gözlemleniyor. Son durumda Ba^{+2} ve SO_4^{-2} iyonlarının derişimi için aşağıdakilerden hangisi söylenebilir?

	$[Ba^{+2}]$	$[SO_4^{-2}]$
A.	Artar	Artar
B.	Artar	Azalır
C.	Azalır	Değişmez
D.	Değişmez	Değişmez
E.	Azalır	Azalır

11. 25^0C'de doymuş Ag_2S çözeltisine bir miktar PbS katısı ekleniyor. Denge tekrar sağlandığında Ag^+ ve S^{-2} çözeltisinin iyonlarının derişimleri ilk duruma göre nasıl değişir?

	$[Ag^+]$	$[S^{-2}]$
A.	Artar	Artar
B.	Azalır	Değişmez
C.	Azalır	Artar
D.	Artar	Azalır
E.	Değişmez	Değişmez

12. Belirli bir sıcaklıktaki doymamış $BaSO_4$ çözeltisine bir miktar X tuzu ekleniyor. X tuzu Ba^{+2} ve SO_4^{-2} iyonları ile bileşik oluşturmuyor.

$BaSO_{4(k)} \rightleftharpoons Ba^{+2}_{(suda)} + SO_4^{-2}{}_{(suda)}$

Buna göre, aşağıdaki seçeneklerden hangisi doğru olur?

A. Daha fazla $BaSO_4$ çözünür ve $K_ç$'si artar.

B. Bir miktar $BaSO_4$ çökelir ve $K_ç$'si azalır.

C. Daha fazla $BaSO_4$ çözünür ve $K_ç$'si azalır.

D. Bir miktar $BaSO_4$ çökelir ve $K_ç$'si değişmez.

E. Daha fazla $BaSO_4$ çözünür ve $K_ç$'si değişmez.

13. Aşağıda üç katının $K_ç$ değerleri verildiğine göre, aynı koşullardaki çözünürlükleri arasındaki ilişki aşağıdakilerden hangisidir?

	Katı	Kç
I.	XY	1.10^{-8}
II.	X_2Y	4.10^{-9}
III.	XY_3	$3,2.10^{-8}$

A. I> II> III

B. III> II> I

C. II> I> III

D. I> III> II

E. III> I> II

14. 25^0C'de katısıyla dengede olan $Ca_3(PO_4)_2$ sulu çözeltisi vardır. Buna göre, aşağıdakilerden hangisi doğrudur?

($Ca_3(PO_4)_2$ için $K_ç = 1,3.10^{-32}$)

A. $Ca^{+2}_{(suda)}$ ve $PO_4^{-3}{}_{(suda)}$ iyonlarının derişimi çözeltinin derişimine eşittir.

B. Çözeltide çökme olmaz.

C. Çözeltide çözünmemiş $Ca_3(PO_4)_{2(k)}$ vardır.

D. $Ca_3(PO_4)_2$ %100 iyonlaşır.

E. Çözeltide $Ca^{+2}_{(suda)}$ ya da $PO_4^{-3}{}_{(suda)}$ iyonları yoktur.

15. 25^0C'ta 0,012 gram $MgSO_4$ çözülerek 2 litre doygun çözelti hazırlanıyor. Buna göre, $MgSO_4$ ün 25^0C ta $K_ç$ değeri kaçtır? (Mg= 24, S= 32, O= 16)

A) $K_ç= 3,6.10^{-5}$

B) $K_ç= 5.10^{-5}$

C) $K_ç= 1.10^{-8}$

D) $K_ç= 14,4.10^{-5}$

E) $K_ç= 2,5.10^{-9}$

16. 4.10^{-5} gram $MgCO_3$ çözeltisi üzerine 25^0C'de katısı ile dengede bulunan 500 ml su eklenerek doygun olmayan $MgCO_3$ çözeltisi hazırlanıyor. Buna göre,

I. $[Mg^{+2}]$

II. CO_3^{-2} iyonlarının mol sayısı

III. Kç

IV. $MgCO_3$ katısının mol sayısı

ifadelerinden hangisi(leri) hesaplanabilir? (Mg:24, C: 12, O:16)

A. Yalnız III

B. II ve IV

C. I ve II

D. I, II ve III

E. I, III ve IV

17. Çözünürlük ile $K_ç$'nin büyüklüğü arasındaki ilişki aşağıdaki seçeneklerin hangisinde doğru olarak belirtilmiştir?

A. İkisi arasında ilişki yoktur.

B. $K_ç$ küçüldükçe çözünürlük artar.

C. Çözünürlük her zaman $K_ç$'nin kareköküdür.

D. $K_ç$ büyüdükçe çözünürlük artar.

E. $K_ç$ büyüdükçe çözünürlük azalır.

18. 25^0C'de $BaSO_4$'ün sulu çözeltisi katısıyla dengededir. Bu çözelti için aşağıdakilerden hangisi söylenebilir?

A. $BaSO_4$'ün çözünme hızı çökelme hızına eşittir.

B. Çözelti dengeye ulaştığında $Ba^{+2}_{(suda)}$ ve $SO_4{}^{-2}{}_{(suda)}$ iyonları oluşumu gözlenmez.

C. $[BaSO_{4(k)}]$ zamanla azalır.

D. Sistem dengedeyken $[BaSO_{4(k)}] = [Ba^{+2}_{(suda)}] = [SO_4{}^{-2}{}_{(suda)}]$ olur.

E. Çözelti dengeye ulaşmadan önce $BaSO_{4(k)}$ katısı oluşumu gözlenmez.

19. 25^0C'de katısıyla dengede olan $Ag_2S_{(k)}$'ün sulu çözeltisinin basıncı 2 katına çıkartılıyor. Buna göre, Ag_2S'ün çözünürlüğü, Ag^+ ve S^{-2} iyonlarının derişimi nasıl değişir?

	Ag_2S'ün çözünürlüğü	$[Ag^+]$	$[S^{-2}]$
A.	Artar	Artar	Artar
B.	Artar	Azalır	Azalır
C.	Azalır	Artar	Artar
D.	Değişmez	Azalır	Azalır
E.	Değişmez	Değişmez	Değişmez

20. $Fe(OH)_{3(k)} \rightleftarrows Fe^{+3}_{(suda)} + 3OH^{-}_{(suda)}$

Doygun $Fe(OH)_3$ çözeltisine sabit sıcaklıkta bir miktar $KOH_{(k)}$ eklenerek çözülürse,

I. $Fe(OH)_3$ ün çözünürlüğü

II. Fe^{+3} iyonlarının molar derişimi

III. Çözünürlük çarpımı ($K_ç$)

niceliklerinin değişimi hangi seçenekteki gibi olur?

	I	II	III
A.	Azalır	Azalır	Azalır
B.	Azalır	Azalır	Değişmez
C.	Artar	Değişmez	Artar
D.	Değişmez	Azalır	Değişmez
E.	Azalır	Artar	Azalır

21. $XY_{(k)} \rightleftarrows X^{+}_{(suda)} + Y^{-}_{(suda)} + ısı$

Çözünme denklemi yukarıdaki gibi olan $XY_{(k)}$ sulu çözeltisi $30^{0}C$'de katısıyla dengededir. Bu çözeltinin sıcaklığı $25^{0}C$'a düşürülüyor. Buna göre aşağıdakilerden hangisi doğrudur?

A. $K_ç$ artar.

B. $[X^{+}]$ ve $[Y^{-}]$ azalır.

C. $K_ç$ değişmez.

D. $K_ç$ azalır.

E. Bir miktar XY katısı çöker.

22. Çözünürlük çarpımının ($K_ç$) büyüklüğü ile çözünme hızı arasındaki ilişki aşağıdaki seçeneklerin hangisinde belirtilmiştir?

A. Çözünme hızı daima $K_ç$'nin iki katıdır.

B. Bir ilişki yoktur.

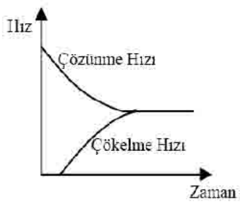
C. Yüksek $K_ç$, yüksek çözünme hızını ifade eder.

D. Düşük $K_ç$, yüksek çözünme hızını ifade eder.

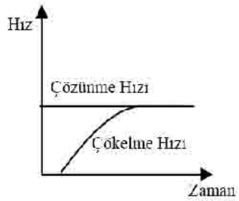
E. Çözünme hızı daima $K_ç$'nin kareköküdür.

23. 25^0C'de AgCl sulu çözeltisi katısı ile dengededir. Bu çözeltinin hız zaman grafiği aşağıdakilerden hangisinde doğru olarak çizilmiştir?

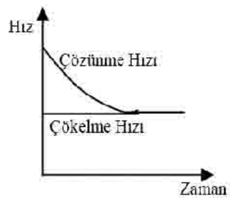
A.



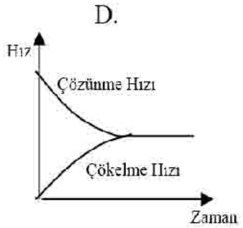
B.



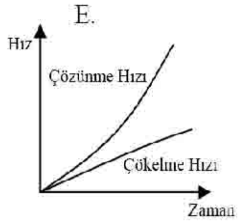
C.



D.



E.



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

SCIENCE PROCESS SKILL TEST

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

Bu testin orijinali James R. Okey, Kevin C. Wise ve Joseph C. Burns tarafından geliştirilmiştir. Türkçe'ye çevrisi ve uyarlaması ise Prof. Dr. İlker Özkan, Prof. Dr. Petek Aşkar ve Doç. Dr. Ömer Geban tarafından yapılmıştır.

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

a. Her oyuncunun almış olduğu günlük vitamin miktarını.

b. Günlük ağırlık kaldırma çalışmalarının miktarını.

c. Günlük antrenman süresini.

d. Yukarıdakilerin hepsini.

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

a. Arabaların benzinleri bitinceye kadar geçen süre ile.

b. Her arabanın gittiği mesafe ile.

c. Kullanılan benzin miktarı ile.

d. Kullanılan katkı maddesinin miktarı ile.

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

a. Arabanın ağırlığı.

b. Motorun hacmi

c. Arabanın rengi

d. a ve b

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

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

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

c. Büyük evlerin ısınma giderleri fazladır.

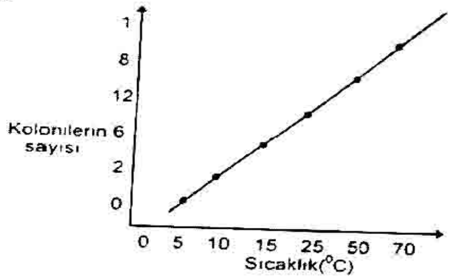
d. Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

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

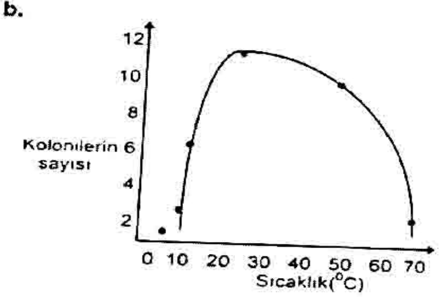
Deney odasının sıcaklığı (°C)	Bakteri kolonilerinin sayısı
5	0
10	2
15	6
25	12
50	8
70	1

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

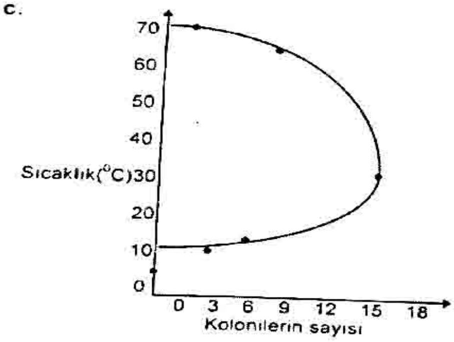
a.



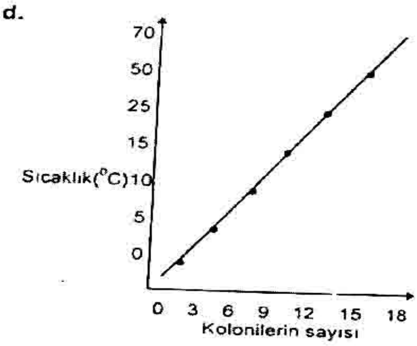
b.



c.



d.



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

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

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

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

d. Arabalar eskidikçe kaza yapma olasılıkları artar.

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

a. Her deneyde arabanın gittiği toplam mesafe ölçülür.

b. Rampanın (eğik düzlem) eğim açısı ölçülür.

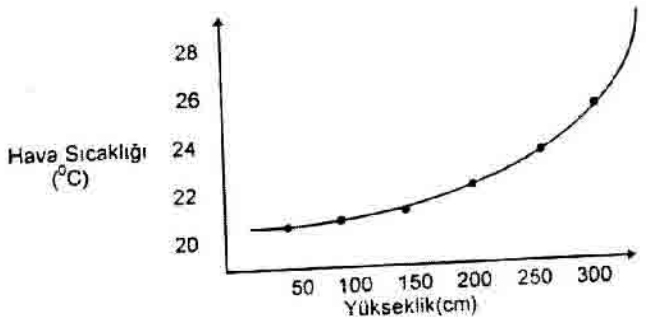
c. Her iki deneyde kullanılan tekerlek tiplerinin yüzey genişlikleri ölçülür.

d. Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

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

a. Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.
b. Ne kadar çok mısır elde edilirse, kar o kadar fazla olur.
c. Yağmur ne kadar çok yağarsa, gübrenin etkisi o kadar çok olur.
d. Mısır üretimi arttıkça, üretim maliyeti de artar.

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

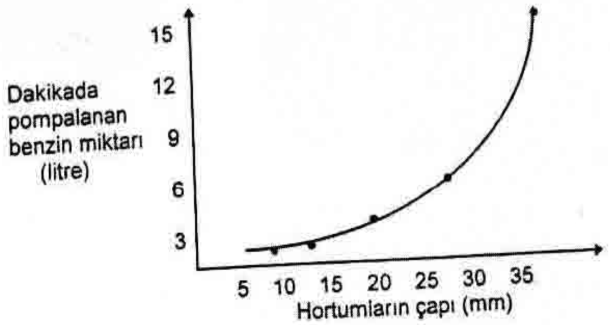


a. Yükseklik arttıkça sıcaklık azalır.
b. Yükseklik arttıkça sıcaklık artar.
c. Sıcaklık arttıkça yükseklik azalır.
d. Yükseklik ile sıcaklık artışı arasında bir ilişki yoktur.

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

a. Topları aynı yükseklikten fakat değişik hızlarla yere vurur.
b. İçlerinde farklı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.
c. İçlerinde aynı miktarlarda hava olan topları, zeminle farklı açılardan yere vurur.
d. İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

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



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

a. Hortumun çapı genişledikçe dakikada pompalanan benzin miktarı da artar.
b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.
c. Hortumun çapı küçüldükçe dakikada pompalanan benzin miktarı da artar.
d. Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

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

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

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

12. Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?

a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.

b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.

c. Güneş farklı maddeleri farklı derecelerde ısıtır.

d. Günün farklı saatlerinde güneşin ısısı da farklı olur.

13. Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

14. Araştırmada bağımlı değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

15. Araştırmada bağımsız değişken hangisidir?

a. Kovadaki suyun cinsi

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

16. Can, yedi ayrı bahçedeki çimenleri biçmektedir. Çim biçme makinasıyla her hafta bir bahçedeki çimenleri biçer. Çimenlerin boyu bahçelere göre farklı olup bazılarında uzun bazılarında kısadır. Çimenlerin boyları ile ilgili hipotezler kurmaya başlar. Aşağıdakilerden hangisi sınanmaya uygun bir hipotezdir?

a. Hava sıcakken çim biçmek zordur.

b. Bahçeye atılan gübrenin miktarı önemlidir.

c. Daha çok sulanan bahçedeki çimenler daha uzun olur.

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

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

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

17. Bu araştırmada sınanan hipotez hangisidir?

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

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

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

d. Kullanılan suyun miktarı arttıkça sıcaklığı da artar.

18. Bu araştırmada kontrol edilebilen değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

19. Araştırmanın bağımlı değişkeni hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

20. Araştırmadaki bağımsız değişken hangisidir?

a. Her bardakta çözünen şeker miktarı.

b. Her bardağa konulan su miktarı.

c. Bardakların sayısı.

d. Suyun sıcaklığı.

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

a. Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.

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

c. Farklı alanlardaki bitkilere verilen su miktarını ölçer.

d. Her alana ektiği tohum sayısına bakar.

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

a. Kullanılan toz ya da spreyin miktarı ölçülür.
b. Toz ya da spreyle ilaçlandıktan sonra bitkilerin durumları tespit edilir.
c. Her fidede oluşan kabağın ağırlığı ölçülür.
d. Bitkilerin üzerinde kalan bitler sayılır.

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

a. 10 dakika sonra suyun sıcaklığında meydana gelen değişmeyi kaydeder.
b. 10 dakika sonra suyun hacminde meydana gelen değişmeyi ölçer.
c. 10 dakika sonra alevin sıcaklığını ölçer.
d. Bir litre suyun kaynaması için geçen zamanı ölçer.

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

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

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

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

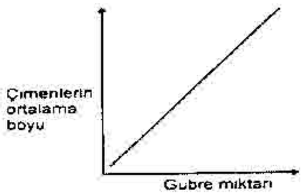
d. Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

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

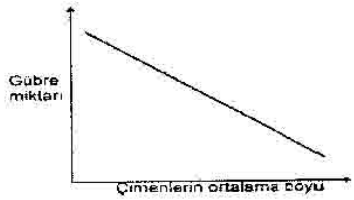
Gübre miktarı (kg)	Çimenlerin ortalama boyu (cm)
10	7
30	10
50	12
80	14
100	12

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

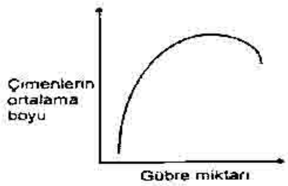
a.



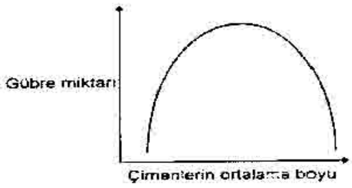
b.



c.



d.



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

a. Farelerin hızını ölçer.

b. Farelerin, günlük uyumadan durabildikleri süreyi ölçer.

c. Her gün fareleri tartar.

d. Her gün farelerin yiyeceği vitaminleri tartar.

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

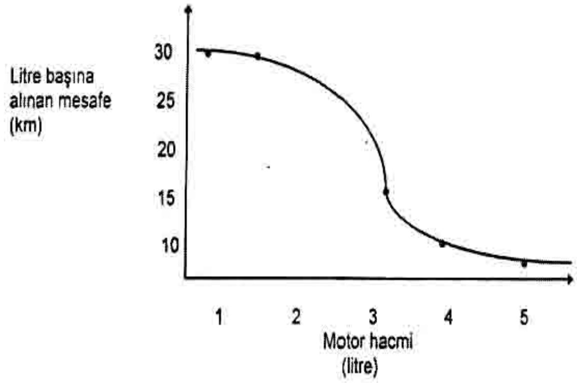
a. Daha fazla şekeri çözmek için daha fazla su gereklidir.

b. Su soğudukça, şekeri çözebilmek için daha fazla karıştırmak gerekir.

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

d. Su ısındıkça şeker daha uzun sürede çözünür.

28. Bir araştırma grubu, değişik hacimli motorları olan arabaların randımanlarını ölçer. Elde edilen sonuçların grafiği aşağıdaki gibidir:



Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

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

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

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

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

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

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

29. Bu araştırmada sınanan hipotez hangisidir?

a. Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.

b. Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.

c. Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.

d. Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

30. Bu araştırmada kontrol edilen değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı.

31. Araştırmadaki bağımlı değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı.

32. Araştırmadaki bağımsız değişken hangisidir?

a. Her saksıdan elde edilen domates miktarı

b. Saksılara karıştırılan yaprak miktarı.

c. Saksılardaki toprak miktarı.

d. Çürümüş yaprak karıştırılan saksı sayısı

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

a. Kullanılan mıknatısın büyüklüğü ile.

b. Demir tozlarını çeken mıknatısın ağırlığı ile.

c. Kullanılan mıknatısın şekli ile.

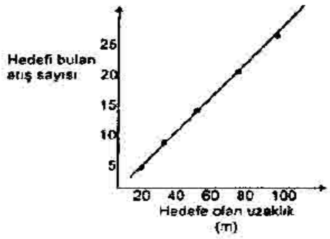
d. Çekilen demir tozlarının ağırlığı ile.

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

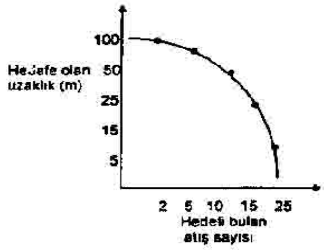
Mesafe(m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

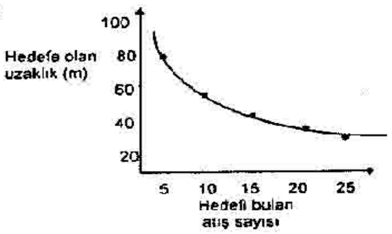
a.



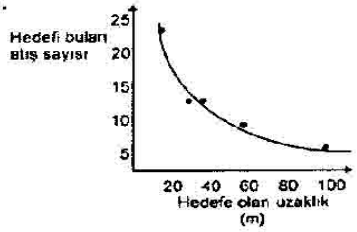
b.



c.



d.



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

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

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

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

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

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

a. TV nin açık kaldığı süre.

b. Elektrik sayacının yeri.

c. Çamaşır makinesinin kullanma sıklığı.

d. a ve c.

APPENDIX G

ÖĞRENMEDE GÜDÜSEL STRATEJİLER ANKETİ

Bu anket iki kısımdan oluşmaktadır. İlk kısımda Kimya dersine karşı tutumunuzu, motivasyonunuzu, ikinci kısımda ise Kimya dersinde kullandığınız öğrenme stratejileri ve çalışma becerilerini belirlemeye yönelik ifadeler yer almaktadır. Cevap verirken aşağıda verilen ölçeği göz önüne alınız. **Eğer ifadenin sizi tam olarak yansıttığını düşünüyorsanız, 7' yi yuvarlak içine alınız. Eğer ifadenin sizi hiç yansıtmadığını düşünüyorsanız, 1' yi yuvarlak içine alınız. Bu iki durum dışında ise 1 ve 7 arasında sizi en iyi tanımladığını düşündüğünüz numarayı yuvarlak içine alınız.**
Unutmayın Doğru ya da Yanlış cevap yoktur yapmanız gereken sizi en iyi tanımlayacak numarayı yuvarlak içine almanızdır.

1 --- 2 --- 3 --- 4 --- 5 --- 6 -- 7

beni hiç yansıtmıyor yansıtıyor

A. Motivasyon

1 --- 2 --- 3 --- 4 --- 5 --- 6 – 7

beni hiç yansıtmıyor yansıtıyor

1. Kimya dersinde yeni bilgiler öğrenebilmek için, büyük bir çaba gerektiren sınıf çalışmalarını tercih ederim.	1 2 3 4 5 6 7
2. Eğer uygun şekilde çalışırsam, kimya dersindeki konuları öğrenebilirim.	1 2 3 4 5 6 7
3. Kimya sınavları sırasında, diğer arkadaşlarıma göre soruları ne kadar iyi yanıtlayıp yanıtlayamadığımı düşünürüm.	1 2 3 4 5 6 7
4. Kimya dersinde öğrendiklerimi başka derslerde de kullanabileceğimi düşünüyorum.	1 2 3 4 5 6 7
5. Kimya dersinden çok iyi bir not alacağımı düşünüyorum.	1 2 3 4 5 6 7
6. Kimya dersi ile ilgili okumalarda yer alan en zor konuyu bile anlayabileceğimden eminim.	1 2 3 4 5 6 7
7. Benim için şu an kimya dersi ile ilgili en tatmin edici şey iyi bir not getirmektir.	1 2 3 4 5 6 7
8. Kimya sınavları sırasında bir soru üzerinde uğraşırken, aklım sınavın diğer kısımlarında yer alan cevaplayamadığım sorularda olur.	1 2 3 4 5 6 7
9. Kimya dersindeki konuları **öğrenemezsem** bu benim hatamdır.	1 2 3 4 5 6 7
10.Kimya dersindeki konuları öğrenmek benim için önemlidir.	1 2 3 4 5 6 7

11. Genel not ortalamamı yükseltmek su an benim için en önemli şeydir, bu nedenle kimya dersindeki temel amacım iyi bir not getirmektir.	1 2 3 4 5 6 7
12. Kimya dersinde öğretilen temel kavramları öğrenebileceğimden eminim.	1 2 3 4 5 6 7
13. Eğer başarabilirsem, kimya dersinde sınıftaki pek çok öğrenciden daha iyi bir not getirmek isterim.	1 2 3 4 5 6 7
14. Kimya sınavları sırasında bu dersten başarısız olmanın sonuçlarını aklımdan geçiririm.	1 2 3 4 5 6 7
15. Kimya dersinde, öğretmenin anlattığı en karmaşık konuyu anlayabileceğimden eminim.	1 2 3 4 5 6 7
16. Kimya derslerinde öğrenmesi zor olsa bile, bende merak uyandıran sınıf çalışmalarını tercih ederim.	1 2 3 4 5 6 7
17. Kimya dersinin kapsamında yer alan konular çok ilgimi çekiyor.	1 2 3 4 5 6 7
18. Yeterince sıkı çalışırsam kimya dersinde başarılı olurum.	1 2 3 4 5 6 7
19. Kimya sınavlarında kendimi mutsuz ve huzursuz hissederim.	1 2 3 4 5 6 7
20. Kimya dersinde verilen sınav ve ödevleri en iyi şekilde yapabileceğimden eminim.	1 2 3 4 5 6 7
21. Kimya dersinde çok başarılı olacağımı umuyorum.	1 2 3 4 5 6 7
22. Kimya dersinde beni en çok tatmin eden şey, konuları mümkün olduğunca iyi öğrenmeye çalışmaktır.	1 2 3 4 5 6 7
23. Kimya dersinde öğrendiklerimin benim için faydalı olduğunu düşünüyorum.	1 2 3 4 5 6 7
24. Kimya dersinde, iyi bir not getireceğimden emin **olmasam** bile öğrenmeme olanak sağlayacak ödevleri seçerim.	1 2 3 4 5 6 7
25. Kimya dersinde bir konuyu **anlayamazsam** bu yeterince sıkı çalışmadığım içindir.	1 2 3 4 5 6 7
26. Kimya dersindeki konulardan hoşlanıyorum.	1 2 3 4 5 6 7
27. Kimya dersindeki konuları anlamak benim için önemlidir.	1 2 3 4 5 6 7
28. Kimya sınavlarında kalbimin hızla attığını hissederim.	1 2 3 4 5 6 7
29. Kimya dersinde öğretilen becerileri iyice öğrenebileceğimden eminim.	1 2 3 4 5 6 7
30. Kimya dersinde başarılı olmak istiyorum çünkü yeteneğimi aileme, arkadaşlarıma göstermek benim için önemlidir.	1 2 3 4 5 6 7
31. Dersin zorluğu, öğretmen ve benim becerilerim göz önüne alındığında, kimya dersinde başarılı olacağımı düşünüyorum.	1 2 3 4 5 6 7

B. Öğrenme Stratejileri

1 --- 2 --- 3 --- 4 --- 5 --- 6 -- 7

beni hiç yansıtmıyor yansıtıyor

32. Kimya dersi ile ilgili bir şeyler okurken, düşüncelerimi organize etmek için konuların ana başlıklarını çıkarırım.	① ② ③ ④ ⑤ ⑥ ⑦
33. Kimya dersi sırasında başka şeyler düşündüğüm için önemli kısımları sıklıkla kaçırırım.	① ② ③ ④ ⑤ ⑥ ⑦
34. Kimya dersine çalışırken çoğu kez arkadaşlarıma konuları açıklamaya çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
35. Genelde, ödevlerime rahat konsantre olabileceğim bir yerde çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
36. Kimya dersi ile ilgili bir şeyler okurken, okuduklarıma odaklanabilmek için sorular oluştururum.	① ② ③ ④ ⑤ ⑥ ⑦
37. Kimya dersine çalışırken kendimi çoğu zaman o kadar isteksiz ya da o kadar sıkılmış hissederim ki, planladıklarımı **tamamlamadan** çalışmaktan vazgeçerim.	① ② ③ ④ ⑤ ⑥ ⑦
38. Kimya dersiyle ilgili duyduklarımı ya da okuduklarımı ne kadar gerçekçi olduklarına karar vermek için sıklıkla sorgularım.	① ② ③ ④ ⑤ ⑥ ⑦
39. Kimya dersine çalışırken, önemli bilgileri içimden defalarca tekrar ederim.	① ② ③ ④ ⑤ ⑥ ⑦
40. Kimya dersinde bir konuyu anlamakta zorluk çeksem bile hiç kimseden yardım almaksızın kendi kendime çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
41. Kimya dersi ile ilgili bir şeyler okurken bir konuda kafam karışırsa, basa döner ve anlamak için çaba gösteririm.	① ② ③ ④ ⑤ ⑥ ⑦
42. Kimya dersine çalışırken, daha önce okuduklarımı ve aldığım notları gözden geçirir ve en önemli noktaları belirlemeye çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
43. Kimya dersine çalışmak için ayırdığım zamanı iyi değerlendirebiliyorum.	① ② ③ ④ ⑤ ⑥ ⑦
44.Eğer Kimya dersi ile ilgili okumam gereken konuları anlamakta zorlanıyorsam, okuma stratejimi değiştiririm.	① ② ③ ④ ⑤ ⑥ ⑦
45. Kimya dersinde verilen ödevleri tamamlamak için sınıftaki diğer öğrencilerle çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
46. Kimya dersine çalışırken, dersle ilgili okumaları ve ders sırasında aldığım notları defalarca okurum	① ② ③ ④ ⑤ ⑥ ⑦
47. Ders sırasında veya ders için okuduğum bir kaynakta bir teori, yorum ya da sonuç ifade edilmiş ise, bunları destekleyen bir bulgunun var olup olmadığını sorgulamaya çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
48. Kimya dersinde yaptıklarımızdan **hoşlanmasam bile** başarılı olabilmek için sıkı çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
49. Dersle ilgili konuları organize etmek için basit grafik, sema ya da tablolar hazırlarım.	① ② ③ ④ ⑤ ⑥ ⑦

50. Kimya dersine çalışırken konuları sınıftaki arkadaşlarımla tartışmak için sıklıkla zaman ayırırım.	
51. Kimya dersinde işlenen konuları bir başlangıç noktası olarak görür ve ilgili konular üzerinde kendi fikirlerimi oluşturmaya çalışırım.	
52. Çalışma planına bağlı kalmak benim için zordur.	
53. Kimya dersine çalışırken, dersten, okuduklarımdan, sınıf içi tartışmalardan ve diğer kaynaklardan edindiğim bilgileri bir araya getiririm.	
54. Yeni bir konuyu detaylı bir şekilde çalışmaya başlamadan önce çoğu kez konunun nasıl organize edildiğini anlamak için ilk olarak konuyu hızlıca gözden geçiririm.	
55. Kimya dersinde işlenen konuları anladığımdan emin olabilmek için kendi kendime sorular sorarım.	
56. Çalışma tarzımı, dersin gereklilikleri ve öğretmenin öğretme stiline uygun olacak tarzda değiştirmeye çalışırım.	
57. Genelde derse gelmeden önce konuyla ilgili bir şeyler okurum fakat okuduklarımı çoğunlukla **anlamam.**	
58. İyi anlamadığım bir konuyu öğretmenimden açıklamasını isterim.	
59. Kimya dersindeki önemli kavramları hatırlamak için anahtar kelimeleri ezberlerim.	
60. Eğer bir konu zorsa ya çalışmaktan vazgeçerim ya da yalnızca kolay kısımlarını çalışırım.	
61. Kimya dersine çalışırken, konuları sadece okuyup geçmek yerine ne öğrenmem gerektiği konusunda düşünmeye çalışırım.	
62. Mümkün olduğunca Kimya dersinde öğrendiklerimle diğer derslerde öğrendiklerim arasında bağlantı kurmaya çalışırım.	
63. Kimya dersine çalışırken notlarımı gözden geçirir ve önemli kavramların bir listesini çıkarırım.	
64. Kimya dersi için bir şeyler okurken, o anda okuduklarımla daha önceki bilgilerim arasında bağlantı kurmaya çalışırım.	
65. Ders çalışmak için devamlı kullandığım bir yer (oda vs.) vardır	
66. Kimya dersinde öğrendiklerimle ilgili ortaya çıkan fikirlerimi sürekli olarak gözden geçirmeye çalışırım.	
67. Kimya dersine çalışırken, dersle ilgili okuduklarımı ve derste aldığım notları inceleyerek önemli noktaların özetini çıkarırım.	
68. Kimya dersinde bir konuyu anlayamazsam sınıftaki başka bir öğrenciden yardım isterim.	
69. Kimya dersiyle ilgili konuları, ders sırasında öğrendiklerim ve okuduklarım arasında bağlantılar kurarak anlamaya çalışırım.	
70. Kimya derslerinde verilen ödevleri ve derse ilgili okumaları zamanında yaparım.	

71. Kimya dersindeki konularla ilgili bir iddia ya da varılan bir sonucu her okuduğumda veya duyduğumda olası alternatifler üzerinde düşünürüm.	① ② ③ ④ ⑤ ⑥ ⑦
72. Kimya dersinde önemli kavramların listesini çıkarır ve bu listeyi ezberlerim.	① ② ③ ④ ⑤ ⑥ ⑦
73. Kimya derslerini düzenli olarak takip ederim.	① ② ③ ④ ⑤ ⑥ ⑦
74. Konu çok sıkıcı olsa da, ilgimi **çekmese** de konuyu bitirene kadar çalışmaya devam ederim.	① ② ③ ④ ⑤ ⑥ ⑦
75. Gerektiğinde yardım isteyebileceğim arkadaşlarımı belirlemeye çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
76. Kimya dersine çalışırken iyi anlamadığım kavramları belirlemeye çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦
77. Başka faaliyetlerle uğraştığım için çoğu zaman kimya dersine yeterince zaman ayıramıyorum.	① ② ③ ④ ⑤ ⑥ ⑦
78. Kimya dersine çalışırken, çalışmalarımı yönlendirebilmek için kendime hedefler belirlerim.	① ② ③ ④ ⑤ ⑥ ⑦
79. Ders sırasında not alırken kafam karışırsa, notlarımı dersten sonra düzenlerim.	① ② ③ ④ ⑤ ⑥ ⑦
80. Kimya sınavından önce notlarımı ya da okuduklarımı gözden geçirmek için fazla zaman **bulamam**.	① ② ③ ④ ⑤ ⑥ ⑦
81. Kimya dersinde, okuduklarımdan edindiğim fikirleri sınıf içi tartışma gibi çeşitli faaliyetlerde kullanmaya çalışırım.	① ② ③ ④ ⑤ ⑥ ⑦

APPENDIX H

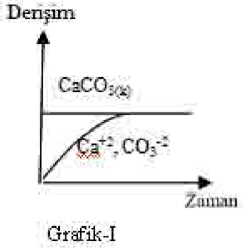
SEMI-STRUCTURED INTERVIEW SCHEDULE

1. $Ca_3(PO_4)_2$ katısının çözünme denklemini ve çözünürlük çarpımı ($K_ç$) ifadesini yazabilir misiniz?

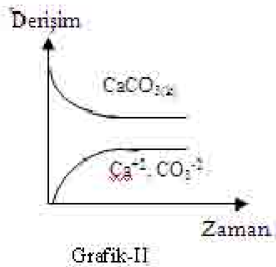
- Çözünürlük dengesi yazarken $Ca_3(PO_4)_2$ katısını yazılır mı?
  - ✓ Evet ise neden yazılacağını açıklar mısınız?
  - ✓ Hayır ise neden yazılmayacağını açıklar mısınız?
- Tüm çözeltiler için çözünürlük çarpımı ($K_ç$) yazabilir miyiz?
- Örneğin doymuş $Ca_3(PO_4)_2$ katısı ile dengede olsun. Bu denge anında ortamda $Ca_3(PO_4)_2$ katısı, Ca^{+2} ve PO_4^{-3} iyonlarından hangileri bulunur? Açıklayabilir misiniz?
- Çözelti katısı ile dengeye gelmeden önce çökelme olur mu?
  - ✓ Evet ise sebebini açıklar mısınız?
  - ✓ Hayır ise sebebini açıklar mısınız? Çözünme bitmeden çökelme olmaz mı?

2. Az çözünen bir tuz için çözünme ve çökelme hızının zamanla değişimini gösteren bir grafik çizebilir misiniz? Nedenini açıklar mısınız?

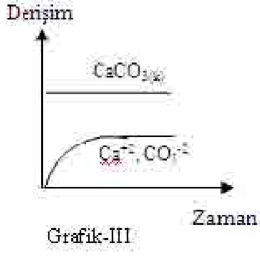
3.



Grafik-I



Grafik-II



Grafik-III

Yukarıdaki $CaCO_3$ çözeltisine ait $CaCO_3$ katısının derişimi Ca^{+2} ve CO_3^{-2} iyon derişimlerinin zamanla değişimini gösteren grafiklerden hangisi doğru çizilmiştir? Nedenini açıklayabilir misiniz?

4. Çözünürlük dengesine etki eden faktörler nelerdir?

- Sıcaklığın etkisi nasıldır?
  - ✓ Katıların çözünürlüğü sıcaklıktan nasıl etkilenir?
  - ✓ Endotermik ve ekzotermik çözünmelerde çözünürlük sıcaklıkla nasıl değişir?
- Sıcaklığın artması çözünürlük çarpımını($K_ç$) arttırır mı?
- Çözücü ve çözünenin etkileri nasıldır?
  - Polar maddeler polar çözücülerde apolar maddeler apolar çözücülerde çözünür ne demektir? Açıklayabilir misiniz?
- Ortak iyon nasıl etki eder?
  - Katısı ile dengede olan bir çözeltiye ortak iyon içeren başka bir çözelti eklediğimizde $K_ç$ değeri değişir mi? Nedenini açıklar mısınız?
- Yabancı iyon nasıl etki eder?
  - ✓ Katısı ile dengede olan bir çözeltiye yabancı iyon içeren başka bir çözelti eklediğimizde $K_ç$ değeri değişir mi? Nedenini açıklar mısınız?
- Basincin etkisi nasildir?

5. Az çözünen tuzlar için, $K_ç$ değeri fazla olan daha hızlı çözünür diyebilir miyiz? Açıklayabilir misiniz?

6. Günlük hayatımızda çözünürlük dengesi ile karşılaştığımız olaylar var mı?

- Evet ise örnek verebilir misiniz?

Geleneksel Metod ile 5E Öğrenme Döngüsü Farkı

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

- Hangi sınıf aktiviteleri sizin çözünürlük dengesi konusunu anlamanıza daha çok yardımcı oldu? Açıklar mısınız?
- Bu dönem yaptıklarınız hoşunuza gitti mi?

2. Kimya dersinin bu dönemdeki gibi mi yoksa geçen dönemdeki gibi mi olmasını istersiniz? Neden?

Öğretmen Farkı

3. Geçen dönem ile kıyasladığınızda bu dönem Kimya öğretmeninizde değişiklikler oldu mu? Evet ise bu değişikliklerden bahseder misiniz?
    - Peki, hangisinin (geçen dönemki öğretmen mi yoksa bu dönemki öğretmen mi) öğrenmenizde daha etkili olduğunu düşünüyorsunuz?
4. Geçen dönem ile kıyasladığında bu dönem sizde değişiklikler oldu mu? Evet ise bu değişikliklerden bahseder misiniz?

Genel Sorular

5. Geçen dönem ile kıyasladığınızda bu dönem Kimya derslerinde problemler yaşadınız mı?
   Evet ise bu problemlerden bahseder misiniz?
6. Kimya derslerinde genel olarak yaşadığınız problemler var mı? Evet, ise bu problemlerden bahseder misiniz?
7. Bu problemlere çözüm önerileriniz var mı? Varsa neler olabilir? Kimya konularını daha iyi öğrenmeniz için neler yapılabilir

APPENDIX I

CLASSROOM OBSERVATION CHECKLIST

	Evet	Hayır	Kısmen
1. Ders öğrencilerin dikkatini çekecek, merak uyandıran sorularla başladı mı?			
2. Öğrenciler soru sormaları için motive edildi mi?			
3. Öğrenciler konuyu öğrenmek için ihtiyaç hissetmeye başladılar mı?			
4. Öğretmen öğrencilere konuyla ilgili günlük hayattan örnekler verdi mi?			
5. Öğrencilerden gelen sorular cevaplanmak için dersin sonuna bırakıldı mı?			
6. Konuyla ilgili sayısal problemler çözüldü mü?			
7. Öğrenciler öğrendikleri konuyu yeni bir durum içerisinde uygulama fırsatı buldular mı?			
8. Öğrenciler gözlem ve değerlendirme yaparak aktiviteleri gerçekleştirdi mi?			
9. Öğrenci aktif olarak derse katıldılar mı?			
10. Öğretmen derste ve etkinlikler esnasında yönlendirici miydi?			
11. Öğretmen kavramları açıklarken öğrencilerin önbilgilerini göz önünde bulundurdu mu?			
12. Öğrenciler etkinlikler esnasında grup halinde çalıştılar mı?			
13. Öğrenciler deneyler sonucunda elde ettikleri bulguları tartışarak yorum yaptılar mı?			
14. Öğrenciler dersin işlenişinden hoşlandılar mı?			
15. Öğrencilerin konuyu anlayıp anlamadıklarını değerlendirmek için sözlü veya yazılı sınav yapıldı mı?			
16. Konu verilen ders planına uygun anlatıldı mı?			

APPENDIX J

ACTIVITY 1

KONU: ÇÖZÜNÜRLÜK DENGESİ VE ÇÖZÜNÜRLÜK ÇARPIMI
SÜRE: 5 SAAT

HEDEFLER	Bu bölümün sonunda öğrenciler; 1. Suda az çözünen tuzların iyonlarından oluşumu gösterir. 2. Suda az çözünen tuzların iyonları arasında meydana gelen dengeyi yazar. 3. Az çözünen tuzların iyonları ile oluşturdukları dengenin denge bağıntısını yazar. 4. Çözünürlük sabitinin denge bağıntısından yazılması ile ilgili problemleri çözer.
1. DİKKAT ÇEKME	Öğrencilerin derse motivasyonlarını sağlamak için günlük hayatta karşılaştıkları, çözünürlük dengesi olayı ile ilgili birkaç soru sorulur.
2. KEŞFETME	Öğrencilerin düşünmelerini sağlayacak bir gösteri deneyi yapılır ve tartışma ortamı oluşturulur. Buradaki amaç TGA yöntemini kullanarak denge tepkimelerinin deneyle gösterilebilmesidir.
3. AÇIKLAMA	Bu basamakta suda az çözünen tuzların iyonları arasındaki denge ve denge bağıntısının yazılması açıklanır. Çözünürlük tipleri (formülü XY, XY_2 veya X_2Y, XY_3 veya X_3Y, X_2Y_3 veya X_3Y_2) ve çözünürlük hesaplamaları hakkında bilgi verilir.
4. DERİNLEŞTİRME	İlgi çekici bir soru sorularak bu soru çözünürlük dengesi kullanılarak açıklanır.
5. DEĞERLENDİRME	Öğrencilere değerlendirmek amacıyla kavramsal değişim metinleri dağıtılır.

1. BASAMAK: DİKKAT ÇEKME

Öğrencinin konuya motivasyonunu sağlamak için aşağıdaki sorular yöneltilir.

Hiç Alanya'da bulundunuz mu? Damlataş mağarasını ziyaret ettiniz mi?
Burdur'u gördünüz mü? İnsuyu mağarasını ziyaret ettiniz mi?
Sizce bu mağaralar nasıl oluşmuştur?

Bu sorularla sınıf ortamında tartışma ortamı sağlanır. Öğrencilerden cevapları alındıktan sonra keşfetme aşamasına geçilir.

2. BASAMAK: KEŞFETME

(TGA)
Öğretmen tarafından bir gösteri deneyi yapılır.
Deney:
Amaç: Denge tepkimelerini gözlemlemek
Le Chatelier kuralına göre madde ilavesinin denge tepkimesine etkisinin incelenmesi

Araç ve Gereç
- Beherglass, 100ml (1)
- Deney tüpü (5)
- Dereceli silindir, 10ml (1)
- Tüplük (1)
- Damlalık (1)

Kimyasallar ve Diğer Malzemeler
- Demir(III) klorür çözeltisi, 0,1 M
- Potasyum tiosiyanür çözeltisi, 0,1 M
- Potasyum klorür çözeltisi, 0,1 M
- Sodyum hidroksit çözeltisi, 0,1 M
- Saf su
- Asetat kalemi

Düzeneğin Kurulumu

Tüplüğe 5 deney tüpü yerleştirilir ve 1'den 5'e kadar asetat kalemiyle numaralandırılır.

0,1 M $FeCl_3$ çözeltisinden 2ml, 100 ml'lik beherglasa dökülür.

Aynı beherglasa 0,1 M KSCN çözeltisinden 2 ml konur. Çözeltileri karıştırmak için beherglas çalkalanır.

$FeCl_3$, KSCN ve karışım ($FeSCN^{+2}$) çözeltilerinin renkleri "Gözlemler ve Veri Tabloları" bölümüne yazılır.

Beherglasa yaklaşık 80 ml saf su konarak açık kırmızı portakal renkli bir çözelti elde edilir.

Her deney tüpüne dereceli silindir kullanılarak 10 ml oluşan çözeltiden konur.

Deney tüpü-1, renk karşılaştırması yapmak için tüplüğün en sonuna konur.

Deneyin Yapılışı

1. Renk değişene kadar deney tüpü-2'deki çözeltiye 0,1 M KSCN çözeltisi damla damla eklenir.
2. Renk değişimi oluşana kadar 0,1 M $FeCl_3$ çözeltisinden deney tüpü-3'teki çözeltiye damla damla eklenir.
3. Renk değişimi oluşana kadar 0,1 M KCl çözeltisinden deney tpü-4'deki çözeltiye damla damla eklenir.
4. Renk değişimi oluşana kadar 0,1 M NaOH çözeltisinden deney tüpü-5'deki çözeltiye damla damla eklenir.
5. Çözeltilerin renkleri deney tüpü-1'deki çözeltini rengiyle karşılaştırılır ve gözlemler "Gözlemler ve Veri Tabloları" bölümündeki tabloya yazılır.

GÖZLEMLER VE VERİ TABLOLARI

1. Çözeltilerin rengini yazınız.

İyonlar	Fe^{+3}	SCN^-	$FeSCN^{+2}$
İyonun rengi			

2. Aşağıdaki tabloyu deney tüpü-1'deki referans çözeltisiyle oluşan çözeltilerin renklerini karşılaştırarak doldurunuz.

İlave edilen çözeltiler	Deney tüpü 2- KSCN	Deney tüpü 3- $FeCl_3$	Deney tüpü 4- KCl	Deney tüpü 5- NaOH
Renkteki değişim (daha açık veya daha koyu)				

DEĞERLENDİRMELER VE SONUÇLAR

1. Le Chatelier prensibini kullanarak çözeltilerin ilavesi dengeyi nasıl etkiler? Açıklayınız. Hangi yöne doğru denge değişmiştir?

KSCN ilavesi ile:

$FeCl_3$ ilavesi ile:

KCl ilavesi ile:

NaOH ilavesi ile:

2. Fe^{+3}, SCN^- ve $FeSCN^{+2}$ iyonları derişimlerinin eklenen maddelerden nasıl etkilendiğini belirtiniz (arttı, azaldı).

	Fe^{+3}	SCN^-	$FeSCN^{+2}$
KSCN ilavesinden sonra:			
$FeCl_3$ ilavesinden sonra:			
KCl ilavesinden sonra:			
NaOH ilavesinden sonra:			

Deney yapılırken her aşamada öğrencilerin tahminlerini defterlerine yazmaları istenir. Öğretmen öğrencilerin tahminlerini aldıktan sonra deneyin basamaklarını yapar. Öğrencilerin tepkimeleri gözlemlemelerini sağlar ve gözlemlerini kaydetmelerini ister. Öğrencilere deney sonucunda gözlemlerini ve sonuçlarını yazmaları için "Gözlemler ve Veri Tabloları" ve "Değerlendirmeler ve Sonuçlar" adlı yukarıda verilen bir kağıt dağıtılır. Öğrencilerin bu sorulara cevap vermeleri için zaman tanınır ve sınıfta tartışma ortamı oluşturulur. Verilen cevaplara göre öğretmen yeni sorular yöneltebilir.

3. BASAMAK: AÇIKLAMA

Öğretmen, bir önceki konunun denge olduğunu hatırlatır. Aşağıdaki şu bilgileri tekrarlar.

Bir çözücü içerisinde çözünme miktarı sınırlı olan maddeler, çözücüleri ile doygun çözeltilerinde bir denge oluşturabilirler.

Maksimum düzensizlik ve minumum enerji eğilimleri zıt yönleri desteklediği olaylar denge olayları olarak tanımlamıştık. Bu durum çözünme olayları için de geçerlidir.

Bugünkü konumuz, suda az çözünen katı maddelerin oluşturdukları çözünürlük dengeleri.

Öğretmen, bir önceki derste AgCl'ün çözünürlüğü ile yapılan deneyi hatırlayıp hatırlamadıklarını sorar ve şu açıklamaları yapar.

AgCl tuzu suda çok az çözünen bir katıdır, bunu görmüştük. Bir kaptaki saf su içerisine belirli bir sıcaklıkta aşırı miktarda AgCl katısı atıldığında, çözelti doygun hale gelene kadar az miktarda AgCl katısı suda çözünür. Çözelti doygun hale geldiğinde kalan katı miktarı sabit kalır.

AgCl'nin suda çözünmesi ve çökmesi çift yönlü gerçekleşen olaylardır. Katı AgCl suya atıldığında ilk anda çözünme olayı, çökme olayından hızlıdır. Zamanla çözeltide Ag^{+} ve Cl^{-} iyon derişimi aratacağından çökme olayı hızlanır. Çözünme ve çökelme hızları eşit olduğu andan itibaren birim zamanda çözünen AgCl katısı ile *çöken AgCl katısının miktarları eşit olur. Bu dinamik bir dengedir. Bu denge hali çözünürlük dengesi olarak adlandırılır. Her dinamik denge olayının bir denge sabiti vardır. Dolayısıyla az çözünen tuzların sulu çözeltilerindeki iyonları ve katısı arasında dinamik denge için de bir denge sabiti vardır. Buna çözünürlük denge sabiti denir ve $K_ç$ sembolü ile gösterilir.*

Öğretmen AgCl tuzunun suda iyonlaşma denklemini ve $K_ç$ ifadesini tahtaya yazar.

$$AgCl_{(k)} \rightleftharpoons Ag^{+}_{(suda)} + Cl^{-}_{(suda)}$$

$K_ç = [Ag^{+}][Cl^{-}]$

Katısı ile dengede olan bir çözeltinin denge sabiti $K_ç$; iyonlarının derişimi çarpımına eşittir. İyonların katsayıları ise derişimlere üst olarak yazılır.

$$X_aY_{b(k)} \rightleftharpoons aX^{+b}_{(suda)} + bY^{-a}_{(suda)}$$

$K_ç = [X^{+b}]^a [Y^{-a}]^b$

Bu temel kuralı verdikten sonra öğretmen suda az çözünen tuzlardan oluşan çözeltilerin çözünme denklemlerini ve $K_ç$ bağıntılarını yazmalarını isteyen bir tane etkinlik kağıdı dağıtır.

Etkinlik

Aşağıdaki az çözünen tuzların suda çözünme denklemlerini ve $K_ç$ bağıntılarını yazınız.

$BaSO_{4(k)} \rightleftarrows$

$K_ç =$

$PbCl_{2(k)} \rightleftarrows$

$K_ç =$

$Ca_3PO_{4(k)} \rightleftarrows$

$K_ç =$

$Ag_2CrO_{4(k)} \rightleftarrows$

$K_ç =$

$Pb(NO_3)_{2(k)} \rightleftarrows$

$K_ç =$

$CdCO_{3(k)} \rightleftarrows$

$K_ç =$

$AgC_2H_3O_{2(k)} \rightleftarrows$

$K_ç =$

$Hg_2Cr_2O_{7(k)} \rightleftarrows$

$K_ç =$

Bu etkinlikten sonra birinci basamakta sorulan Damlataş ve İnsuyu mağaralarının oluşumu ile ilgili sorular aşağıdaki açıklama kağıdı dağıtılır. Öğrencilerin okuması istenir ve olay üzerinde konuşulur.

Etkinlik

Alanya- Damlataş mağarası nasıl oluşmuştur?
Burdur-İnsuyu mağarası nasıl oluşmuştur?

Bu büyük ve güzel mağaraların tavanlarını ve zeminlerini sarkıt ve dikitler süslemektedir. Bunları anlamak için çözünürlük dengesi konusunu bilmeniz gerekir. Bu mağaralar genel olarak yer altı sularının yarıklardan sızması sonucu kireçtaşı ($CaCO_3$) katmanlarını oyarak oluşmuşlardır.

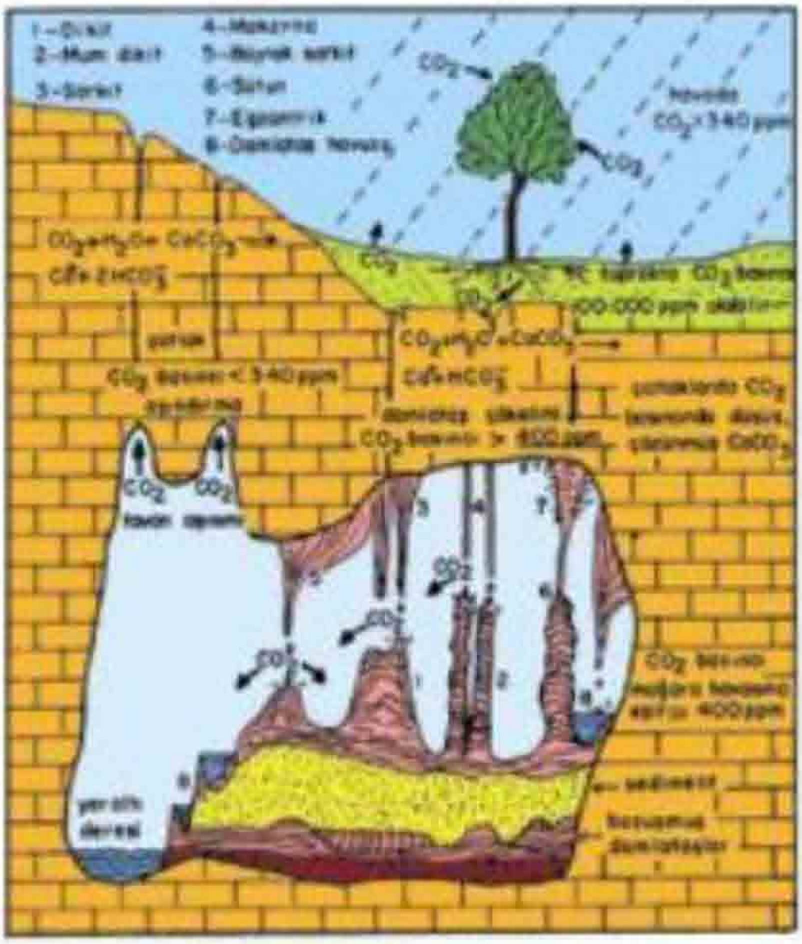
Yeryüzü çeşitli katmanlardan oluşur. Bu katmanlardan birisi de kireç taşı katmanıdır. Normalde suda çözünürlüğü çok düşük olan $CaCO_3$ yağmur suyunun yeryüzünden yer altı katmanlarına doğru sızarak akması esnasında yağmur suyu tarafından çözünür. Burada etken yağmur suyunun düşünüldüğünün aksine saf su olmamasıdır. Yağmur suyu yeryüzüne inerken ve verimli topraklarından aşağıya doğru süzülürken bu kısımlarda yer alan CO_2'i çözer. CO_2 yağmur suyunun asitleşmesine neden olur. Bu asitleşmenin denklemi aşağıda belirtildiği gibidir.

$$CO_{2\,(g)} + H_2O_{(s)} \rightleftharpoons H_3O^+_{(suda)} + HCO_3^-{}_{(suda)}$$

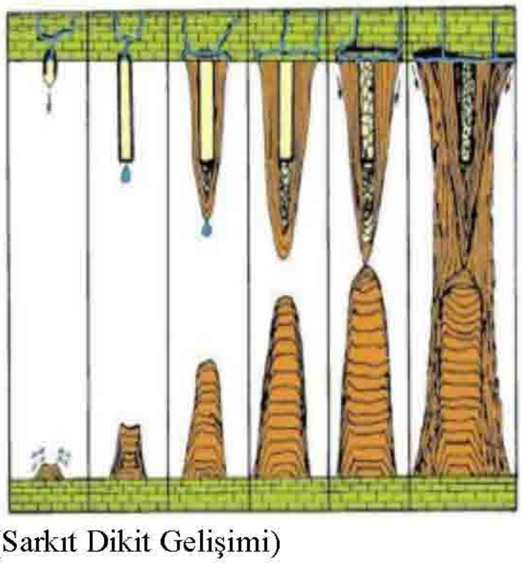
Saf suda çözünmeyen $CaCO_3$ bu şekilde asitlik özelliğine sahip olan yağmur suyunda çözünür. $CaCO_3$ yağmur suyunda çözünme reaksiyonu aşağıdaki gibidir.

$$CaCO_{3(k)} + CO_{2\,(g)} + H_2O_{(s)} \rightleftharpoons Ca^{+2}_{(suda)} + 2HCO_3^-{}_{(suda)}$$

Yağmur suyu yeraltında yer alan $CaCO_3$ tabakasını uzun yıllar sonucunda aşındırarak bu tabakanın boşalmasına ve kireç taşı mağarası oluşumuna neden olur. Bu süreç mağara oluşumundan sonra da devam eder. Mağaranın üst kısmında özellikle verimli toprakların bulunduğu kısımda (burada çeşitli canlılar yaşayabildiği için CO_2 oranı verimsiz topraklara göre çok yüksektir) yağmur suyu $CaCO_3$'ı çözmeye devam eder. Ancak bu çözünme mağaranın içersinde çökelme ile birlikte devam etmektedir. Mağaranın üst kısmından damlayan yağmur suyu uzun bir süreçte sarkıtları, yere damladığı noktada ise bu çökelmeler sonucu dikitleri oluşturur. Bu çözünme ve çökelme bir denge içerisindedir. Çevremizde karşılaştığımız doğa harikası mağaralar ve içinde yer alan sarkıt ve dikitlerin oluşumu çözünürlük dengesi sonucu oluşmuştur.



Mağaralarda damlataşların çökelim sistemi



(Sarkıt Dikit Gelişimi)

Bu etkinlikten sonra öğretmen ikinci basamakta yaptığı deney sonuçları üzerine konuşur. Renk değişimi olmasının çözünme olayını gösterdiğini, bir süre sonra renk değişiminin durmasının çökelme olduğunu açıklar.

Öğretmen, çözünürlük tipleri ve çözünürlük hesaplamalarına geçer. Bu konuyu şu şekilde anlatır.

- **Formül XY tipinde ise;**

AgCl, CuBr, $CaCO_3$, gibi tuzlar XY tipi formüle sahiptirler.

$$XY_{(k)} \rightleftharpoons \underset{S\ mol/L}{X^{+}_{(suda)}} + \underset{S\ mol/L}{Y^{-}_{(suda)}}$$

S= doymuş çözeltini molar derişimi ve belirli sıcaklıktaki çözünürlüğüdür.

$K_ç = [X^+][Y^-]$

$K_ç = (s)(s)$

$\boxed{K_ç = s^2}$

- **Formül XY_2 veya X_2Y tipinde ise;**

$PbCl_2$, Ag_2S, $MgBr_2$ gibi tuzlar suda çözündüklerinde oluşan iyonlardan birinin derişimi diğerinin 2 katı olur.

$$XY_{2(k)} \rightleftharpoons \underset{S\ mol/L}{X^{+2}_{(suda)}} + \underset{2.S\ mol/L}{2Y^{-}_{(suda)}}$$

$K_ç = [X^{+2}][Y^-]^2$

$K_ç = (s)(2s)^2$

$K_ç = \boxed{4s^3}$

- **Formül XY_3 veya X_3Y tipinde ise;**

$Fe(OH)_3$, $Ag_3(PO_4)$ gibi tuzlar suda çözündüklerinde oluşan iyonlardan birinin derişimi diğerinin 3 katı olur.

$$X_3Y_{(k)} \rightleftharpoons \underset{3.\ S\ mol/L}{3\,X^{+}_{(suda)}} + \underset{S\ mol/L}{Y^{-3}_{(suda)}}$$

$K_ç = [X^{+}][Y^{-3}]^2$

$K_ç = (3s)^3\,(s)$

$\boxed{K_ç = 27s^4}$

- **Formül X_2Y_3 veya X_3Y_2 tipinde ise;**

Al_2S_3 ve $Ca_3(PO_4)_2$ gibi tuzlar suda çözündüklerinde oluşan iyonlardan birinin derişimi diğerinin 1,5 katı olur.

$$X_2Y_{3(k)} \rightleftharpoons \underset{2.\ S\ mol/L}{2X^{+3}_{(suda)}} + \underset{3.\ S\ mol/L}{3Y^{-2}_{(suda)}}$$

$K_ç = [X^{+3}]^2[Y^{-2}]^3$

$K_ç = (2s)^2\,(3s)^3$

$\boxed{K_ç = 108.s^5}$

Bu kuralları verdikten sonra öğretmen hepsiyle ilgili sayısal işlem gerektiren problemleri tahtada çözdürür.

<u>Sorular</u>

1) XY tuzunun belli bir sıcaklıktaki $K_ç$ değeri, $K_ç = 1.10^{-10}$'dur. Bu tuzun, saf sudaki çözünürlüğü kaç mol/L'dir?

(Cevap: 10^{-5} mol/L)

2) $Pb(ClO_3)_2$ tuzu için belli bir sıcaklıkta $K_ç = 3,2.10^{-14}$'tür. $Pb(ClO_3)_2$ için aynı sıcaklıkta çözünürlük kaç mol/L'dir?

(Cevap: 2.10^{-5} mol/L)

3) Ag_3PO_4 ile hazırlanan 25 L doygun sulu çözeltide çözünmüş 5.10^{-3} mol $Ag_3(PO_4)$ vardır. Buna göre $Ag_3(PO_4)$'ün $K_ç$ değeri kaçtır?

(Cevap: $K_ç = 4,32.10^{-14}$)

4) X_2Y_3 katısı ile hazırlanan 10 litre doymuş çözeltideki Y^{-2} iyonlarının mol sayısı 3.10^{-3} olduğuna göre, bu sıcaklıktaki $K_ç$ değeri kaçtır?

(Cevap: $K_ç = 1,08.10^{-18}$)

5) $1,56.10^{-2}$ gram Ag_2SO_4 suda çözülerek 500 ml doygun çözelti hazırlanıyor. Buna göre, Ag_2SO_4 çözeltisinin çözünürlük çarpımı ($K_ç$) kaçtır? (Ag: 108, S: 32, 0: 16)

(Cevap: $K_ç = 4..10^{-12}$)

6)

	Katı	Kç
I.	AB	1.10^{-8}
II.	A_2B	4.10^{-9}
III.	AB_3	27.10^{-8}

Aynı koşullarda $K_ç$ değerleri verilen üç katıyı çözünürlüklerine göre sıralayınız.

(Cevap: III > II > I)

4. BASAMAK: DERİNLEŞTİRME

Öğretmen sert suların sıhhi tesisatlarda pul pul kalıntılar bıraktığını söyler. Buna kimyasal bir açıklama getirebilir misiniz? Diye sorarak öğrencilerden yorum yapmalarını ister.

Öğretmen öğrencilerle olayı tartıştıktan sonra aşağıdaki açıklamayı yapar.

İçme suyu göllerden veya diğer kaynaklardan elde edilir. Bu kaynaklar önemli miktarda normalde suda az çözünen $CaCO_3$ ve $MgCO_3$ içerirler. İçme suyu kaynaklarını yağmur suları beslemektedir ve yağmur suyu pek çok insan tarafından elde edilebilecek en saf su olduğu düşünülmektedir. Ancak yağmur suyu atmosferden yere inerken bazı gazları çözer. Bu gazlardan biriside asidik özelliğe sahip olan CO_2 gazıdır ve yağmur suyunu asitliğini artırır. Yağmur suyu $CaCO_3$ ve $MgCO_3$ zengini topraklara akarken asitlik özelliği sonucu bu tuzları eritir.

$$(CO_{2\,(g)} + H_2O_{(s)} \rightleftarrows H_3O^+_{(suda)} + HCO_3^-{}_{(suda)})$$

$$(CaCO_{3(k)} + CO_{2\,(g)} + H_2O_{(s)} \rightleftarrows Ca^{+2}_{(suda)} + 2HCO_3^-{}_{(suda)})$$

$CaCO_3$ ve $MgCO_3$ tuzları sağlığa zararlı olmamasına rağmen içme suyunda bu tuzların bulunması rahatsız edici olabilir. Örneğin, bu tuzların çözünürlük dengesi sabiti çok düşük olduğu için su, $CaCO_3$ ve $MgCO_3$ ile çabucak doygunluğa ulaşır. Hatta bir damla su buharlaşırken $CaCO_3$ ve $MgCO_3$ yönünden doygunluğa ulaşabilir. Doymuş çözelti çözünmüş iyonlarından bazılarını çökeltir. Bu çökelti musluklarda, lavabolarda, yemek kaplarında pul pul birikintiler olarak görülebilir. Arabaların ve bulaşıkların sert su ile yıkanması sonucunda bazı $CaCO_3$ ve $MgCO_3$ noktaları, lekeleri su buharlaşırken çökelmesi sonucu oluştuğu gözlemlenir.

Öğretmen sınıfta sert suyun fayda ve zararları nedir? diye sorar. Öğrencilerin yorumlarını aldıktan sonra aşağıdaki kağıdı öğrencilere dağıtır.

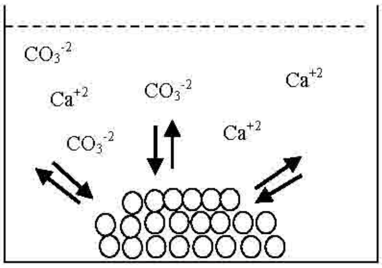
SU SERTLİĞİ

DEZAVANTAJLARI	*AVANTAJLARI*
Sabun köpürtmek zordur.	Bazı insanlar tadından dolayı sert suları tercih ederler.
Sabun ile reaksiyon vererek sabun kiri oluşturur.	Suda içerdiği kalsiyumdan dolayı çocukların diş ve kemikleri için iyidir.
Su ısıtıcılarında ve demliklerde kireçlenmeye sebep olur. Bu da su ısıtırken enerji kaybına neden olur.	Kalp hastalıkları riskinin azaltılmasında yardımcı olur.
Su borularında kalıntı oluşturarak tıkanmasına neden olabilir.	Kek yapımında keki kabartmak için kullanılır.
	Bakır ve kurşun boruların kireç taşı ile iç yüzeylerinin kaplanması ile zehirleyici etkileri önlenir.

5. BASAMAK: DEĞERLENDİRME

Öğretmen öğrencilere konuyla ilgili kavramsal değişim metinlerini dağıtır.

Kavramsal Değişim Metni-1



$$CaCO_{3(k)} \rightleftharpoons Ca^{+2}_{(suda)} + CO_3^{-2}{}_{(suda)}$$

Doymuş $CaCO_3$ katısı ile dengededir. $CaCO_3$ katısı, Ca^{+2} ve CO_3^{-2}iyonlarının oluşumu ile ilgili ne söyleyebiliriz?

Cevap:

Bazı öğrenciler denge anında çözünmenin ve çökelmenin olmadığına inanıyorlar. Şeklimize baktığımızda, $CaCO_3$ katısının çözünüp Ca^{+2} ve CO_3^{-2}iyonlarını oluşturmadığını ve bu iyonların yine $CaCO_3$ katısını oluşturmadığını düşünüyorlar.

Bu düşünceye sahip olmalarının en yaygın sebeplerinden biri kitapların denge durumunu anlatan resimlerde denge anında her şeyin bittiğini ve durduğunu gösteren çizimleridir. Öğrencileri yanılgıya götüren diğer bir görüş günlük hayattaki deneyimleridir. Pazarda sebze ve meyve alırken gördüğü terazinin iki kolundaki eşitliği denge olarak bildiği için çözeltiler içinde bunun böyle olduğunu düşünüyorlar. Gerçekten bu böyle midir, denge anında her şey duruyor mu????

Çözünme hızının çökelme hızına eşit olduğu durumda çözelti katı ile dengededir.

Doymuş çözeltiler katısı ile dengede iken çözünme ve çökelme devam eder. Şeklimize baktığımızda bir yandan $CaCO_3$ katısının çözünüp Ca^{+2} ve CO_3^{-2}iyonlarını oluşturmakta ve bu iyonlar tekrar $CaCO_3$ katısını oluşturmaktadır. Bu çözünme ve çökelme hızarlının eşit olduğu duruma <u>*çözünürlük dengesi*</u> denir.

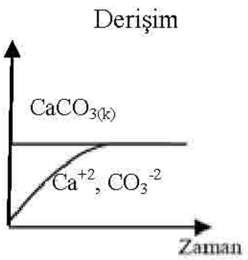
Kavramsal Değişim Metni-2

Doymuş $CaCO_3$ katısı ile dengededir. Sabit bir sıcaklıkta $CaCO_3$ katısının derişimi, Ca^{+2} ve CO_3^{-2}iyon derişimlerinin zamanla değişimini gösteren bir

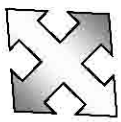
??

Cevap:

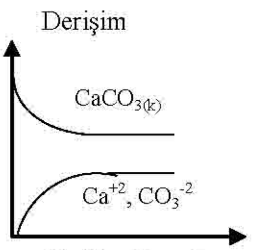
Neden böyle bir grafik çizdiniz açıklayınız?



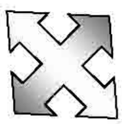
Grafik-I



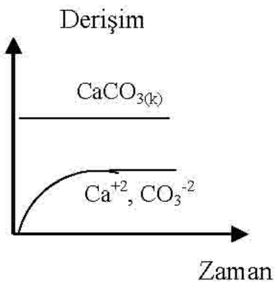
Eğer grafik-1'deki gibi grafiğinizi çizdiyseniz, maalesef çiziminiz doğru değil. Sizde bazı öğrenciler gibi katısı ile dengede olan bir çözeltide katı tuzun derişiminin iyonlarına eşit olduğunu düşünenlerdensiniz. Böyle düşünülmesinin bir sebebi denge denince iki tarafta bir şeyler eşitmiş gibi düşünülmesi olabilir. Diğer bir sebebi de katılar denge denkleminde yazılmadığı için, sanki çözeltinin derişimi iyonların her birinin derişimiyle aynı olmak zorundaymış gibi düşünülmesi olabilir.



Grafik- II Zaman



Çizimleri Grafik-II' deki gibi olanlarda maalesef doğru çizmemişler. Bu çizimi yapanlar dipte çözünmeden duran katının derişmini göz ardı ederek sadece çözücüde çözünen katının derişimini düşünerek katı tuzun derişiminin azalacağını düşünüyorlar. Böyle düşünülmesinin sebebi katının bir kısmı iyonlaştığına göre katının derişiminin azalacağı gibi yanlış bir şey düşünmelerinden olabilir. Katıların derişimi dış etkilerle değişmez. Çünkü katının miktarı azaldıkça hacmi de azalacak dolayısıyla derişimde bir değişme olmaz.



Grafik-III

√

Eğer siz grafik-III' deki gibi çizdiyseniz, evet doğru çizmişsiniz. Ca^{+2} ve CO_3^{-2} iyonlarının derişimi, katının bir miktarı iyonlaştığı için zamanla artmakta fakat katının derişimi değişmemektedir. Çözünme ve çökelme hızları eşitlendiği için iyonlardaki bu artış zamanla azalıp sabit bir değere ulaşır. Bundan dolayı iyonların derişimi bir süre artar sonra da sabit bir değerde kalır.

Kavramsal Değişim Metni-3

?? Sabit bir sıcaklıkta katısı ile dengede olan $Cu(OH)_2$ tuzun çözünürlük çarpımı ($K_ç$) ifadesini yazınız?

Cevap:

$K_ç \quad \frac{[Cu^{+2}]\,[OH^-]}{[Cu(OH)_2]} \qquad K_ç \quad \frac{[Cu^{+2}]\,[OH^-]^2}{[Cu(OH)_2]} \qquad K_ç = [Cu^{+2}]\,2[OH^-]$

Eğer bu şekillerden biri gibi yazdıysanız, maalesef doğru değil. ☹ Bazı öğrenciler gibi sizde çözünürlük çarpımı denklemi yazarken derişimi değişmeyen katıların da yazıldığını düşünüyorsunuz. Bu yanlış bir düşüncedir. Böyle yazmanızda denge konusu işlenirken denge bağıntısı ürünlerin derişimi çarpımı girenlerin derişimleri çarpımına bölerek bulunması etkili olabilir. Kimya ders kitaplarında örnek olarak da genellikle girenler kısmında gaz verildiği ve denge bağıntısında da gazlar alındığı için öğrenci sorgulamadan çözünürlük dengesi bağıntısında da girenlerin derişimi yazılacak diye düşünür.

Gelin şimdi doğrusunu yazalım……☺

İlk olarak $Cu(OH)_2$'ün çözünürlük denklemini yazalım.

$$Cu(OH)_{2(k)} \rightleftharpoons Cu^{+2}{}_{(suda)} + 2OH^{-}{}_{(suda)}$$

$$K = \frac{[Cu^{+2}]\,[OH^{-}]^2}{[Cu(OH)_2]}$$

Denge bağıntısı böyle yazılır. Fakat biz katıların derişimlerinin sabit olduğunu biliyoruz. $K_ç$ ifadesi katının derişimi ile K denge sabitinin çarpımı ile elde edilir. Yani hem K denge sabiti, hem de katının derişimi sabit olduğu için iki sabit sayının derişimi sabit sayı olur. Sonuç olarak;

$$K^*[Cu(OH)_2] = K_ç = [Cu^{+2}]\,[OH^{-}]^2$$

Katılar $K_ç$ ifadesinde yazılmaz.

bu şekilde yazabiliriz. Kitaplarda her katı için bir $K_ç$ değeri verilmiştir. Bu $K_ç$ değerleri belirli sıcaklıkta (genellikle 25^0C'de) bu şekilde hesaplanır. Dolayısıyla $K^*[Cu(OH)_2]$ çarpımı $K_ç$ değerine eşit olduğu için katılar $K_ç$ ifadesinden yer almazlar.

<u>Katıların derişimi neden sabit????</u>

AB katısı 50 gr'dır. Suya atıldığında 25 gr. AB katısı çözünmeden kalır.buna göre AB katısının derişimi ilk ve son durumlarda nedir?????

(M_{AB}= 25 gr., d_{AB}= 5)

I. Durumda;

AB katısının hacmi (V), d=m/V’den → 5=50/V, V= 10

AB’nin mol sayısı n=m/MAB’den → n=50/25, n=2 mol

AB’nin derişimi M=n/V’den → M=2/10, $\boxed{M=1/5}$

İlk ve son durumda katının derişimi aynıdır ve bu yüzden sabittir.

Durumda; (katının 25 gr. Çözünmemiştir.)

AB katısının hacmi (V), d=m/V’den → 5= 25/V, V= 5

AB’nin mol sayısı n=m/MAB’den → n=25/25, n=1 mol

AB’nin derişimi M=n/V’den → $\boxed{M=1/5}$

Kavramsal Değişim Metni-4

$CaCO_3$ katısı az çözünen bir tuzdur. Katısı ile dengeye gelmeden önce çökelme olur mu????????

Cevap:

Eğer bu soruya cevabınız çökelme olmaz yönünde ise, maalesef cevabınız doğru değil. Birçok öğrencide olduğu gibi siz de çözelti katısı ile dengeye gelmeden önce çökelmenin olmadığı gibi yanlış bir düşünceye sahipsiniz. Çökelmenin başlaması için çözünmenin bitmesi gerektiğini mi düşünüyorsunuz? Acaba çözünme bitmeden çökelme olmaz mı? Şöyle düşünelim. $CaCO_3$ katısı çözünmeye başladıktan bir müddet sonra çözeltideki Ca^{+2} ve CO_3^{-2} iyonları sayısı artacak ve bu iyonlar $CaCO_3$ katısı oluşturmak için tekrar birleşerek çökelme ihtimalini artıracaktır. Başka bir deyişle dengeye gelmeden önce çözeltide katı oluşur. Çözünürlük dengesi tanımına bakarsak, çözünme hızının çökelme hızına eşit olması durumuydu. Önceden bir miktar çökelme olmalı ki bu eşitlik yani çözünme hızının çökme hızına eşitliği sağlansın.

Çözelti katısıyla dengeye gelmeden önce bir miktar çökelme olur.

CURRICULUM VITAE

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