DEVELOPMENT AND IMPLEMENTATION OF A TRAINING PROGRAM DESIGNED TO ENHANCE PROSPECTIVE CHEMISTRY TEACHERS' CONTENT KNOWLEDGE, PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO MISCONCEPTIONS AND TEACHING EFFICACY BELIEFS

by

Sibel Yiğit

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ABSTRACT

DEVELOPMENT AND IMPLEMENTATION OF A TRAINING PROGRAM DESIGNED TO ENHANCE PROSPECTIVE CHEMISTRY TEACHERS' CONTENT KNOWLEDGE, PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO MISCONCEPTIONS AND TEACHING EFFICACY BELIEFS

This study was conducted to develop a training program in order to enhance prospective chemistry teachers’ content knowledge in subjects of particulate nature of matter, chemical equilibrium and acid strength, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs and evaluate the effects of this program on participants. The participants were 22 prospective chemistry teachers from a public university. The training program was designed according to student misconceptions in mentioned subjects and implemented several instructional strategies. The participants attended the training program which took five sessions. The findings of this study revealed that prospective chemistry teachers had several misconceptions before attending the training program. After attending the training program, the content knowledge of prospective chemistry teachers were increased in particulate nature of matter, chemical equilibrium and acid strength subjects. The results also indicated that prospective teachers had a high level of pedagogical content knowledge in terms of understanding the nature of misconceptions before attending the training program. Attending the training program increased prospective chemistry teachers’ pedagogical content knowledge related to misconceptions in both of understanding the nature of misconceptions and strategies to identify and change student misconceptions aspects. Moreover, the results also showed that the teaching efficacy beliefs of prospective chemistry teachers in terms of efficacy in using particular teaching methods were increased after the training program. Finally, the results showed that teaching efficacy beliefs of prospective chemistry teachers in terms of efficacy in teaching certain chemistry subjects were enhanced in the subject of “chemical equilibrium”, but not affected for the subject of “particulate nature of matter” and “acid strength”.

ÖZET

ADAY KİMYA ÖĞRETMENLERİNİN ALAN BİLGİLERİNİ, KAVRAM YANILGILARINA YÖNELİK PEDAGOJİK ALAN BİLGİLERİNİ VE ÖĞRETİM ÖZ-YETERLİLİK İNANÇLARINI ARTTIRMAYI HEDEFLEYEN BİR EĞİTİM PROGRAMININ GELİŞTİRİLMESİ VE UYGULANMASI

Bu çalışma aday kimya öğretmenlerinin maddenin tanecikli yapısı, kimyasal denge ve asitlik kuvveti konularındaki alan bilgilerini, kavram yanılgılarına yönelik pedagojik alan bilgilerini ve öz-yeterlilik inançlarını arttıracak bir eğitim programı geliştirmek ve bu programın katılımcılar üzerindeki etkilerini ölçmek amacıyla yapılmıştır. Katılımcılar bir devlet üniversitesinde öğrenim gören 22 aday kimya öğretmenidir. Eğitim programı öğrenci kavram yanılgılarını dikkate alarak hazırlanmış, çeşitli öğretim stratejilerini içermiştir. Katılımcılar beş hafta süren eğitim programına katılmışlardır. Bu çalışmanın bulguları aday kimya öğretmenlerinin programa katılmadan önce çeşitli kavram yanılgılarına sahip olduğunu göstermiştir. Bu programa katılmanın sonucunda aday kimya öğretmenlerinin maddenin tanecikli yapısı, kimyasal denge ve asitlik kuvveti konularındaki alan bilgileri artmıştır. Bununla birlikte, çalışmanın sonuçları aday kimya öğretmenlerinin programa katılmadan önce kavram yanılgılarının doğası hakkındaki anlayışları bakımından ileri seviyede pedagojik alan bilgisine sahip olduğunu göstermiştir. Bu programa katılmanın sonucunda aday kimya öğretmenlerinin pedagojik alan bilgileri hem kavram yanılgılarının doğası hakkındaki anlayışları bakımından hem de öğrenci kavram yanılgılarının tespit edilmesi ve düzeltilmesine yönelik öğretim stratejileri bakımından gelişmiştir. Ayrıca, sonuçlar aday kimya öğretmenlerinin bazı öğretim yöntemlerini kullanmaya yönelik öğretim öz-yeterlilik inançlarının programa katıldıktan sonra arttığını göstermiştir. Son olarak, bulgular aday kimya öğretmenlerinin bazı kimya konularını öğretmeye yönelik öğretim öz-yeterlilik inançlarının kimyasal denge konusunda geliştiğini, maddenin tanecikli yapısı ve asitlik kuvveti konularında ise değişmediğini göstermiştir.

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LIST OF ACRONYMS/ABBREVIATIONS

CCT	Chemistry Concept Test
CCT-B	Chemistry Concept Test Form B
KBCMTEQ	Knowledge and Beliefs about Chemistry Misconceptions and Teaching Efficacy Questionnaire
PCK	Pedagogical Content Knowledge
PEF	Program Evaluation Form
PU	Partial Understanding
PUSM	Partial Understanding with Specific Misconception
SM	Specific Misconception
SU	Scientific Understanding

1. INTRODUCTION

Contemporary approaches of teaching and learning require highly-qualified teachers having advanced and organized content and pedagogical knowledge. For the prospective teachers who do not have any experience of teaching in real classrooms, it seems difficult to have the advanced knowledge of pedagogy in terms of each subject. Thus, prospective teachers face difficulty in the instruction of many subjects in the first years of their teaching career.

Chemistry is the science of chemical concepts. Shulman (1987) emphasizes that teachers must have a full understanding of the subject matter that they are expected to teach, to be able to teach it well. Thus, prospective chemistry teachers are expected to have correct and sufficient conceptual knowledge. If the students or even teachers do not have necessary and adequate conceptual knowledge, they may unconsciously develop concepts that are not scientific. If prospective teachers have non-scientific conceptions, that will be called as misconceptions in this study from now on, about the subject matter, they will probably transmit their own misconceptions to students during the instruction when they start to teach. Furthermore, it is meaningless to expect teachers who are unaware of their own misconceptions to determine and eliminate their students' misconceptions. Moreover, according to Halim and Meerah (2002), teachers may ignore misconceptions in their instruction although they are aware of the fact that their students have certain misconceptions. Thus, prospective teachers also must recognize the importance of the misconception as a factor affecting their students' learning.

Bandura (1997) indicates that, individuals' beliefs in their abilities affect their performance in any work. Teachers with higher teaching efficacy might be expected to teach more effectively than the teachers with lower teaching efficacy. Yet, teachers' self-confidence seems to increase with greater teaching expertise (Appleton, 1999). For this reason, prospective teachers are expected to have low teaching efficacy-beliefs because of lack of their teaching expertise. The teachers' self-confidence in teaching seems to be an important factor how they teach in terms of the topics chosen and instructional strategies

(Appleton, 1999). According to Harlen and Holroyd (1997), teachers with low confidence cope requirements of teaching science by teaching minimum required subjects and relying on expository teaching. Prospective teachers may need to have high teaching efficacy beliefs to implement teaching methods of constructivist learning approach in their classroom.

To guide students for construction of knowledge and teach chemistry effectively, prospective teachers must have advanced content knowledge, awareness in terms of misconceptions of students, knowledge of instructional strategies to overcome these misconceptions and also need high self-confidence in their teaching. The present study attempts to develop and apply a training program for prospective chemistry teachers to improve their content knowledge in certain chemistry topics, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. The training program is developed by taking into consideration the data collected during a research project from high school students that reflect their misconceptions (Yakmaci-Guzel, 2012). In the program, various instructional strategies were integrated and included to help prospective teachers deal with these students' misconceptions.

1.1. Significance of the Study

Results of research studies involving chemistry teachers' misconceptions indicated that teachers as well as students had misconceptions in several chemistry subjects (Kruse and Roehrig, 2005, Tan and Taber, 2009). This study is significant because, in this study, a training program was developed in order to change prospective chemistry teachers' own misconceptions, increase their understanding related to misconceptions and increase their knowledge of instructional strategies about how to change their future students' misconceptions.

In Turkey, chemistry teacher education programs offer a number of chemistry courses that prospective chemistry teachers learn content knowledge in the first years of their university education. In the final years of these programs, prospective teachers take pedagogical courses to learn various aspects of education such as teaching methods, curriculum, learner psychology, classroom management, and so on. Yet, chemistry teacher education programs do not offer a specific course about how to teach a chemistry subject by taking misconceptions into account. Thus, the training program developed in this study is significant to improve prospective chemistry teachers' knowledge about teaching specific chemistry subjects while taking misconceptions into account. Moreover, the training program would be a model for the development of other training programs for prospective teachers. Hopefully, similar training programs for different chemistry topics or for completely other disciplines of science inspiring from this program can be developed. The results of this study can give ideas to teacher educators regarding integration of similar activities to some courses in teacher education programs in Turkey.

According to Gomez-Zwiep (2008), despite the vast number of research studies about misconceptions, findings of these studies were not reflected enough to real classrooms. There exists a gap between the research literature and the practice in schools. Thus, it is seen that teachers need awareness and encouragement about the necessity of integration of the findings regarding students' misconceptions in instructional practices. This study is significant because it attempts to close the gap between the theory and practice by developing a training program for prospective teachers in order to create awareness about common student misconceptions and instructional activities to address these misconceptions.

1.2. Statement of the Research Problem

Shulman (1987) emphasized the comprehension of content to be able to teach it. Teachers are expected to understand what they teach in several ways. Yet, research studies which were conducted to investigate content knowledge of teachers showed that in-service and prospective teachers had a variety of misconceptions in chemistry subjects (Boz, 2009; Cheung, 2009; Haidar, 1997; Kikas, 2004). The training program, developed for this study, aimed to increase prospective chemistry teachers' comprehension of specific content knowledge in order to teach it.

In order to develop pedagogical content knowledge (PCK), teachers need experiences in teaching (De Jong and Van Driel, 2004). Moreover, teaching experiences were also found a factor affecting teaching efficacy beliefs of teachers (Appleton, 1999).

Since prospective teachers do not have teaching experiences, they are expected to have limited PCK and teaching efficacy beliefs. Thus, the training program, in this study, aimed to increase prospective chemistry teachers' PCK related to misconceptions and their teaching efficacy beliefs.

1.3. Purpose of the Study

The current research study has two main purposes. The first purpose of this study is to develop a training program for prospective chemistry teachers to improve their subject matter knowledge in subjects of particulate nature of matter, chemical equilibrium, and acid strength, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. The second purpose of this study is to evaluate the impacts of the training program on prospective chemistry teachers who participated in the program.

1.4. Research Questions

This research study investigates the answers of the following four research questions:

(i) Is there any difference in prospective chemistry teachers' chemistry content knowledge before and after attending the training program?

(ii) Is there any difference in prospective chemistry teachers' pedagogical content knowledge;
- in terms of understanding the nature of misconceptions before and after attending the training program?
- in terms of strategies to identify and change student misconceptions before and after attending the training program?

(iii) Is there any difference in prospective chemistry teachers' teaching efficacy beliefs before and after attending the training program?

(iv) What are the prospective chemistry teachers' opinions about the training program?

2. LITERATURE REVIEW

The literature review chapter has five main parts. In the first part of the literature review, the term "concept" was described. In the second part the term "misconceptions" was defined, the sources of misconceptions were explained, and common misconceptions held by students about a variety of chemistry subjects were overviewed. Thirdly, conceptual change and different perspectives to conceptual change models were described, the findings of some research studies which implemented different teaching methods for conceptual change were summarized. Then, knowledge of teachers was defined. In this section, content knowledge of teachers was described and the findings of research studies which aimed to investigate and/or improve the content knowledge of science and chemistry teachers were stated. Afterwards, pedagogical content knowledge of teachers was described and the findings of some research studies about science and chemistry teachers' pedagogical content knowledge according to various aspects were mentioned. Finally, self-efficacy beliefs were defined and related studies about teaching efficacy beliefs of teachers were reviewed.

2.1. Concepts

Understanding of concepts is an important aspect of chemistry education. According to Ausubel (1968), the most important factor that influences students' learning is their existing conceptions. Merrill, Tennyson, and Posey (1992) defined the term concept as "a set of specific objects, symbols or events which are grouped together on the basis of shared characteristics and which can be referenced by a particular name or symbol" (p.6). Carey (2000) defined concepts as "units of mental representation roughly equivalent to a single word such as *object, animal, alive, heat, weight,* and *matter*" (p.14).

Concepts may act as building blocks of more complex structures. Core concepts can be described as the base of knowledge which we build other knowledge upon (Zirbel, 2004). Individual concepts can be connected and form more complex representational structures, such as propositions (e.g. "all animals die") and theories (e.g. "the theory of natural selection") (Carey, 2000). Also two concepts can be combined and form a different representational structure (e.g. "density is the matter per volume") (Zirbel, 2004).

DiSessa (1993) indicated that humans gradually acquire a sense of mechanism about how things work and analyze specific elements of this mechanism. Knowledge structures of individuals are described as knowledge in pieces that include ideas, categories, concepts, models and theories. DiSessa (1993) described a hypothetical knowledge structure and called it as phenomenological primitive (p-prim). P-prims are described as small knowledge structures involving configurations of a few parts of a large physical system. In some cases, p-prims are behavioural which allows them to have important roles in explaining physical phenomena. Also, p-prims may be self-explanatory, it explains something's happening as because that's the way things are.

DiSessa (1993) also pointed out that students' learning difficulties may be resulted from one particular p-prim or a number of p-prims. In the next section students' learning difficulties were explained by their misconceptions as a tool.

2.2. Misconceptions

A child develops beliefs to understand the things happening in its surroundings from the very earliest days of his/her life. Thus, students start formal science teaching with their prior conceptions which may be inconsistent with accepted scientific ideas (Driver, 1983). Misconceptions are defined as any conception that differs from scientifically accepted meaning of the term (Nakhleh, 1992).

According to Chinn and Malhotra (2002), students' pre-instructional conceptions influence their observation. When a heavy rock and a light rock were dropped, they would hit the ground at the same time. Yet, some students who predicted the heavy rock to hit the ground first, observed that the heavy rock hit the ground first and some students who predicted the light rock to hit the ground first, observed that the light rock hit the ground first. Driver (1983) also indicated that students' expectations affect their observation in an experiment. Students may observe their expectation rather than the results of the experiments.

Different researchers used different terminologies for misconceptions such as preconceptions (Ausubel, 1968), alternative conceptions (Gilbert and Swift, 1985) alternative frameworks (Driver, 1983), naïve beliefs (Caramazza, McCloskey and Green, 1981), and children's science (Osborne and Freyberg, 1985). A variety of terms to describe misconceptions can be seen in the literature as a result of a variety of non-scientific ideas and their sources. For example, misconceptions indicate misinterpretation of knowledge whereas informal concepts are used for the ideas which the students got from informal settings like television and friends. A single idea which is not found to be scientific is called as alternative conception and a structure of these ideas is called as alternative framework (Taber, 2002).

Vosniadou (1994) described misconceptions as synthetic concepts because learners generate these conceptions via integrating scientifically-accepted information into their previous experiences. Vosniadou and Brewer (1992) investigated the development of children's conceptual knowledge about the earth's shape. Children generally have an initial concept of the earth as a flat, stable and stationary object. Yet, when they start science instruction, the earth is described as an astronomical object which is spherical and rotating around its axis. Scientific model of earth completely violates children's initial models so students tend to generate synthetic models to resolve the conflict. One of the student generated models was hollow sphere model that students believed that the earth was spherical but had hollow inside where the people live in. Another model was dual earth model that children believed there were two earths; flat earth and spherical earth, people lived on flat earth and the spherical earth was a planet.

Driver (1983) indicated that misconceptions had a resistant nature. Even if students were given opportunities to change their misconceptions, it might not be helpful. Students might maintain their misconceptions especially when the problem was presented in new contexts (Driver, 1983). Gooding and Metz (2011) claimed that, the longer a misconception remained unchallenged, the more likely it was entrenched. The knowledge connections were expected to be strengthened, thus, it would make misconceptions more resistant to change.

2.2.1. Sources of Misconceptions

Several sources of misconceptions have been determined by different studies (Taber, 2002). According to Duit and Treagust (1995), students' misconceptions result from their sensual experiences, language experiences, cultural background, peer groups, mass media and formal instruction. Different research studies considered language as one of the important sources of misconceptions. For example, students believe that the products of a neutralization reaction will always be neutral because the name of the reaction includes the term "neutral" (Schmidt, 1997). Also, students may think that oxygen is involved in all redox reactions because of the syllable "ox" in the term (Schmidt, 1997). Similarly, using anthropomorphic language during the instruction of chemical phenomena may lead several misconceptions. For example, students believe atoms to be alive when they are instructed as atoms "want" or "need" to gain or lose electrons (Taber, 2002). Also, the ontological difference between terms that are used in both scientific and everyday language may cause misconceptions. For example, students perceive the concept of force as a power possessed by a living organism or a machine in daily life but in physics it is a measure of strength of interaction between objects. Thus, students' wrong ontological categorization of these concepts may cause misconceptions (Duit and Treagust, 1995).

Research studies indicated that science instruction may either support students' existing misconceptions or cause new misconceptions (Duit and Treagust, 1995). First of all, teachers can have misconceptions if they do not have adequate background and training in science. Also, errors in textbooks may be another source of misconceptions (Duit and Treagust, 1995). Models and diagrams in textbooks, which are not properly constructed, may cause misconceptions in students (Kikas, 2004). Furthermore, analogies may cause misconceptions if they are not explained well. Using analogies to visualize molecular world by observing macroscopic phenomena can cause misconceptions in students (Kikas, 2004). For example, students may imagine microscopic phenomena as copies of the macroscopic ones and they consider that the only difference among two is the difference in their scales (Albanese and Vicentini, 1997).

One of the other sources of misconceptions may be learners' misinterpretation of knowledge, students may generalize or wrongly categorize new concepts. For example, when students learn the term isomers as the compounds having the same number of atoms, they may generalize isomeric compounds as members of the same class of organic compounds (Schmidt, 1997). Also, students may wrongly categorize a hydrogen bond as a covalent bond to hydrogen (Taber, 2002).

2.2.2. Misconceptions in Chemistry

Several research studies documented a variety misconceptions in many chemistry topics, like chemical reactions (Lee, 1999), bonding (Coll and Treagust, 2003), mole concept (Haidar, 1997), vapour pressure (Canpolat, Pinarbasi and Sozbilir, 2006), gases (Cetin, Kaya and Geban, 2009), solution chemistry (Ozden, 2009a), ionization energy (Tan, Taber, Goh and Chia, 2005), and electrochemistry (Ogude and Bradley, 1994). The misconceptions related to particulate nature of matter, chemical equilibrium and acids and bases which were the chosen chemistry topics of this study were explained in detail in the following sub-sections.

2.2.2.1. Misconceptions in Particulate Nature of Matter. Particulate nature of matter is one of the most basic subjects in chemistry. Talanquer (2009) analyzed research on student misconceptions about the particulate nature of matter and tried to categorize novice and advanced students' ideas and reasoning. The analysis revealed that novice students' ideas were influenced by the physical appearance of a substance for example these students might attribute different properties to rigid and powdery solids. On the other hand, advanced student ideas were influenced by structural similarity of substances. Students' ideas about the structure of matter were categorized as continuity for novice ideas and granularity and corpuscularity for more advanced ideas. Novice learners generally thought that matter was continuous. Adadan, Irving and Trundle (2009) also showed that students perceive matter as continuous rather than the collection of particles. On the other hand, granularity ideas included when thinking of a substance was made up of little pieces of the same material and corpuscularity ideas included that the substance was conceived of as made up of distinctive particles. Moreover, Johnson (1998) conducted a three-year longitudinal study, from seventh to ninth grade, in order to understand students' understanding of particle theory. According to students' responses, four models of matter were constructed from a novice understanding of matter to advanced understanding. The first one is called as model X, students perceive matter as continuous. The second one is model A, students believe that particles exist in the continuous substance. The third one is model B, students think that particles are the substance, but with macroscopic character. Finally, the fourth model is model C, students think that, particles are the substance, but properties of state are collective. The sequence of models from X to C represents stages of progression for the particle theory. The results indicated that the number of students categorized in model X, A and B generally decreased and correspondingly the number of students categorized in model C increased with years of schooling.

Talanquer (2009) indicated that novice learners assumed that some material existed in particles whereas advanced learners assumed that the particles in a substance were separated by empty space. Novick and Nussbaum (1978) showed that eight grade students believed that the space between the particles of a matter was filled with something such as air, dust, oxygen gas, nitrogen gas, etc.

Talanquer (2009) indicated that novice students' ideas about the structure of matter supported that particles that comprised a substance had the same properties of a macroscopic sample of that material. Advanced learners recognized that new properties could emerge from interactions between multiple particles. In their study, Ben-Zvi, Eylon and Silberstein (1986) investigated 10^{th} grade students' view about atoms. The students were asked to compare: (i) the properties of a metallic wire and one single atom of this wire and (ii) the properties of the gas which was formed when the metallic wire was evaporated and one single atom of this gas. The results of the study showed that, 46.2% of the students in that study could not differentiate the properties of the macroscopic matters and the properties of one single, isolated atom. Moreover, 66.3% of these students stated that the atom of solid and the atom of gas had different properties. Albanese and Vicentini (1997) indicated that students attribute the properties of bulk matter to atoms and molecules. In their study, 80% of the students attributed a colour to an atom.

Adadan *et al.* (2009) showed that students had a variety of misconceptions about particulate nature of matter. In their study, students had the idea that the space between particles of liquids was intermediate compared to those of solids and gases. Moreover, students believed that particles of solids did not move. In addition, they thought that, the size of the particles changed as the matter changed phase.

Stains and Talanquer (2007) investigated undergraduate chemistry students' perceptions of elements, compounds, and mixtures. In the study, participants were expected to categorize given microscopic representations as elements, compounds or mixtures. The results of the study showed that many students preferred to use a single criterion to differentiate the representations of different matters. They used "having identical atoms or not" as a criterion for elements and "having bond or not" as a criterion for compounds. Using only one criterion sometimes led them to inappropriate classifications. A high number of participating chemistry students perceived molecular elements and mixtures of substances that had common atoms as compounds. Furthermore, mixtures whose components have one to one ratio were classified as compounds by several participants.

2.2.2.2. Misconceptions in Chemical Equilibrium. Understanding chemical equilibrium is important because it is fundamental for understanding other chemistry topics such as solubility, acid and base behaviour and oxidation/reduction reactions (Bergquist and Heikkinen, 1990). Yet, research studies indicated that students had a number of misconceptions about this subject.

Bergquist and Heikkinen (1990) analyzed students' misunderstandings about the chemical equilibrium and summarized these misconceptions. This analysis showed that students had difficulty to understand the concentrations of reactants and products at chemical equilibrium. Students tended to apply stoichiometric mole ratios among product and reactant concentrations at equilibrium. Also, students generally believed that concentrations fluctuate as the equilibrium was established. Hackling and Garnett (1985) also showed that high school students thought that there was an arithmetical relationship between the concentrations of reactants and products. Bilgin and Geban (2006) showed that tenth grade students had a non-scientific understanding about chemical equilibrium that the concentrations of reactants were equal to the concentrations of products.

Bergquist and Heikkinen (1990) indicated that students assumed that the forward reaction had to be completed before the reverse reaction started. Moreover, in their study, Sepet, Yilmaz and Morgil (2004) indicated high school students believed that the forward and reverse reactions were completed when one of the matters were consumed. Some of these students also thought that the rate of forward reaction was higher than that of reverse reaction at equilibrium.

Bilgin and Geban (2006) showed that students misused Le Chatelier's principle. Students believed that when equilibrium was re-established following a change in the concentration of one of the reagents, the concentrations of reactants and products would be equal to their initial equilibrium values. Also, according to Tyson, Treagust and Bucat (1999), even students can obtain the correct answer by using Le Chatelier's principle, these students may not have a sound and scientific understanding.

Despite the fact that applying Le Chatelier's Principle in inappropriate situations may cause incorrect conclusions about the changes of concentration, volume, pressure and temperature, the principle is still over-emphasized in high schools (Cheung, 2009). Wheeler and Kass (1978) developed a Misconception Identification Test about chemical equilibrium and administered it to ninety-nine 12th grade chemistry students. The results showed that the majority of students in their study were not aware of the fact that Le Chatelier's principle cannot be applied in all situations, such as situations which included a change both in the amount of the reagents and the volume of the equilibrium system. Thus, students in that study made incorrect predictions. Griffiths (1994) also indicated that students could have a misconception that Le Chatelier's principle applied to all equilibrium systems including equilibria involving mixed phases.

2.2.2.3. Misconceptions in Acids and Bases. Research studies showed that students also had difficulty in understanding acids and bases. Sheppard (2006) interviewed with high school students in order to examine their understanding of titration. The results showed that students had difficulty with the concepts of acid-base chemistry such as pH, neutralization and strength. Some of the students, in that study, perceived pH only a measure of acidity but not basicity. Also, according to some students, neutralization is just mixing of acid and base rather than a chemical reaction. Majority of the students expected a neutral product as a result of the neutralization. Similarly, majority of the students thought that equal amount of acid and base is an adequate condition for a neutral product.

Sheppard (2006) indicated that students related the strength of an acid or base to the pH value of their solutions. Griffiths (1994) indicated that students could have a misconception that strong acids had a higher pH than weak acids.

Nakhleh (1992) indicated that students had difficulty to draw sub-microscopic representations of an acid or a base. Some students could draw non-particulate representations such as waves or bubbles while drawing sub-microscopic representation of an acid solution.

As it was seen from the research literature on misconceptions in chemistry, students might have a variety of misconceptions in the subjects of particulate nature of matter, chemical equilibrium and acids and bases. A high number of research studies were conducted to change student misconceptions via conceptual change strategies that were reported in the next section.

2.3. Conceptual Change

Kuhn's (1962) ideas about change of a theory in science created foundations of the conceptual change approach. According to Kuhn (1962), paradigms are shared beliefs, assumptions, and practices in the processes of science. When normal science encounters anomalies that cannot be explained with the existing paradigm, science enters a period of crisis. Only, a revolutionary change in paradigm can solve the accumulation of anomalies and it results scientific discoveries.

According to Piaget (1970), intellectual adaptation is described as a process of achieving equilibrium between assimilation and accommodation. Assimilation is defined as the integration of a particular reality into existing framework whereas accommodation is defined as modification of the framework. Intellectual adaptation was found similar to biological adaptation, an organism was well-adapted to an environment when it could preserve its structure by assimilating its nourishment to be able to draw from the external environment and also accommodate its structure to the various particularities of that environment. A change in knowledge structures of individuals via enriching knowledge structure or changing existing knowledge structure were described as conceptual change (Vosniadou, 2007a).

According to Posner, Strike, Hewson, and Gertzog (1982), learning is rational activity, students comprehend and accept concepts which they see intelligible and rational. Posner *et al.* (1982) proposed a widely accepted conceptual change model and suggested four conditions for conceptual change to occur. The four conditions which were necessary for accommodation were described as:

(i) Dissatisfaction: Individuals generally do not tend to replace their old concepts with the new ones, if the old ones encounter difficulties. In order to change their existing concepts, individuals must experience unsolved puzzles and anomalies, so they must realize that their concepts do not solve the problem at hand. There must be dissatisfaction with the existing concepts. Anomalies are major sources of dissatisfaction. For example, an observation which is contradictory to predicted outcomes can be used to lead students to be dissatisfied with their conceptions.

(ii) Intelligibility: Individuals must understand how experience can be structured by a new concept. Students must understand the meaning of the new concept and the new concept must make sense for students. Analogies and metaphors can be used to make new concepts intelligible.

(iii) Plausibility: New concept must be initially plausible, it must fit into an individual's existing knowledge structures without a problem. Also, the new concept must have the capacity to solve experienced anomalies and seem more meaningful.

(iv) Fruitfulness: If the new concept is intelligible and plausible and solve apparent anomalies, students may attempt to associate new conceptions with the experience. If the new concept not only resolves predecessors' anomalies but have potential to be extended and applied in further problem situations, the accommodation of new conception will seem persuasive.

According to Weaver (2009), after dissatisfaction occurred, a learner is open to considering new concepts to replace or modify existing ones. Yet, new concepts will only be accepted if they are found to be intelligible, plausible and fruitful. Posner *et al.* (1982) also emphasized conceptual ecology, individuals' current concepts, in the acceptance of a new concept in place of a misconception. According to Hewson (1992), there are two major components of conceptual change model: conditions of the conceptual change model and a person's conceptual ecology.

Original conceptual change theory was criticized because it presented a radical conceptual change and only emphasized cognitive factors. Vosniadou (2007a) criticized the original conceptual change model because it described conceptual change as a rational process of theory replacement and introduced a change like a gestalt shift that occurs in a very short time. According to Vosniadou (2007b), for a successful conceptual change, teachers must find ways to enhance individual students' motivation by creating a social classroom environment. According to Weaver (2009), conceptual change process was presented as a new conception, which was found to be acceptable, would lead to immediate accommodation of existing knowledge framework. Pintrich, Marx and Boyle (1993) suggested considering motivational beliefs of learners and classroom contextual factors in the process of conceptual change in addition to cognitive factors. Teaching for conceptual change should also increase students' motivation to change their beliefs.

The review of the literature on conceptual change showed that different educators described conceptual change with different terms (Tyson, Venville, Harrison and Treagust, 1997). Changing conceptual structure with just addition of knowledge was described as assimilation (Posner *et al.*, 1982), conceptual capture (Hewson, 1992) or conceptual enrichment (Vosniadou, 1999). On the other hand, conceptual change was generally described as changing existing conceptual structure rather than simple addition. Changing existing conceptual structure was described as accommodation (Posner *et al.*, 1982) or conceptual exchange (Hewson, 1992).

Weaver (2009) emphasized that students could pass a chemistry exam despite the fact that they had certain misconception in that subject. For example, they might believe that a reaction stopped completely when it reached equilibrium despite the fact that they were able to provide correct numerical answers for typical equilibrium problems. Thus, only carefully applied learning experiences can move students to full integration of target concepts. According to Gooding and Metz (2011), teachers should provide their students opportunities for conceptual change. For students to identify their own misconceptions, it is suggested that teachers should expect clarification of students' responses, evidence for their claims, evaluation for data rather than just collecting it. Teachers should also use wait time while asking a question and not seek for a right answer. Minds-on instructional interventions, such as discrepant events, inquiry-based activities, and others, would help students reconstruct and internalize their knowledge.

Instructional interventions that target conceptual change may not be always successful. Alternative to assimilation and accommodation, learners may simply reject a new conception. Rejection can occur when the new experience is so disparate from learner's existing conceptions and it is different from ignoring the new conception. Also, learners may exclude a concept, categorize it separately, not integrated into other knowledge framework, and so learners can use it in specific cases. In addition to rejection and exclusion, learners may try reinterpretation of the new concepts, learners develop an understanding of a new concept by forcing it to fit within existing conceptions (Weaver, 2009).

Zirbel (2004) indicated that conceptual change may not occur even conceptual change model was viewed as a teaching tool and all stages necessary for meeting conditions were followed. Students may find new concepts plausible and able to apply it at the time of instruction, but, it does not necessarily mean that the student will undergo a definite shift in his/her view of thinking. The student may hold his or her misconceptions while accepting and using the new concepts, the prior and new concept may coexist as different entities. Thus, students must become so familiar with the new concepts in order to feel the new concepts as their own concepts, and make the transition from borrowing new concepts to owning them. In addition, Gooding and Metz (2011) stated that, after teaching new concepts, some students might continue to have their non-scientific beliefs and some of them might seem to change their beliefs but could turn back to their original misconceptions. Tyson *et al.* (1997) also indicated conceptual change did not mean complete extinguishing of all prior conceptions of students at the end of an instruction aimed conceptual change, prior concepts may appear in particular contexts.

2.3.1. Research on Conceptual Change Learning

As indicated in the following sections, researchers implemented numerous types of teaching methods for conceptual change. The findings of some research studies which emphasized different instructional methods were summarized in the following paragraphs.

2.3.1.1. Conceptual Change via Multi-representational Instruction. Adadan, Trundle and Irving (2010) investigated the effect of an instruction that involved multi-representation of particulate nature of matter on conceptual progression of nineteen 11^{th} grade students. Students were expected to predict, observe and explain certain chemical phenomena in the laboratory, drew molecular models of observed chemical events and also write a journal to reflect their ideas about the activity. After the multi-representational instruction, 11 of the 19 eleventh-grade students' conceptions reflected scientific understanding of the particulate nature of matter whereas none of the students' understandings were categorized as fully scientific before the instruction.

Sanger (2000) investigated how college students identified particulate drawings in terms of the state, the physical composition and the chemical composition of matter. A question that expected to classify given particulate drawings of five substances was asked to 65 students, these students constituted the control group. According to the analysis, 29 of 65 students classified the representation of a compound as a homogeneous mixture and the representations of homogeneous mixtures as heterogeneous mixtures. Moreover, seven of 65 students classified a compound as a homogeneous mixture. According to these results, the author designed a lesson for another group of students, the students who participated this lesson consisted the experimental group. In the lesson, macroscopic samples like Cu, water, I_2 in water and their computer generated microscopic samples were used. According to the comparison of experimental and control groups, 88% of the control group and 97% of the experimental group answered the first part of the question which was related to the states of matter, correctly. For the second part of the question which was related to the physical composition of matter, 46% of the control group and 80% of the experimental group answered correctly. For the third part of the question which was related to the chemical composition of matter, 84% of the experimental group students and 69% of the control group students made correct categorization.

2.3.1.2. Conceptual Change via Hands-On Activities. Cetin, Kaya and Geban (2009) compared the effects of conceptual change oriented instruction and traditional instruction on remediation of students' misconceptions about gas concept. Conceptual change oriented instruction emphasized the use of hands-on activities and analogy whereas traditional instruction included lecturing and discussion. Gases Concept Test, developed by one of the authors, was administered to both groups of students before and after the instruction. According to the statistical analysis, it was seen that, experimental group had significantly higher mean score than the control group although both groups had similar scores on pre-test.

Costu, Ayas and Niaz (2010) extended Predict-Observe-Explain teaching strategy via integrating discussion and constructed Predict-Discuss-Explain-Observe-Discuss-Explain strategy and investigated the effect of this strategy on first year university students' conceptual understanding of evaporation. Evaporation Conceptual Test was developed for that study and administered as pre-, post- and delayed test. According to the results, students had better conceptual understanding and less misconceptions about evaporation at the end of the study. Also, there was no significant difference between the post-test and delayed post-test scores, it showed that learning resulted from Predict-Discuss-Explain-Observe-Discuss-Explain strategy was permanent.

2.3.1.3. Conceptual Change via Group Discussion and Analogy. Bilgin (2006) investigated the effectiveness of small group discussion on prospective teachers' conceptual understanding of chemical equilibrium. The results showed that small group discussions facilitated learning, the students in experimental group demonstrated better understanding and had less misconceptions in chemical equilibrium concepts than the control group.

Tsai (1999) used analogy activity to overcome junior high school students' misconceptions about microscopic views of phase change. Students in experimental group role-played as Br atoms and imitated the motion of Br_2 molecules and the space between particles at three different temperatures. On the other hand, the control group had traditional instruction of microscopic views of phase change. At the end of the study, a post-test was administered to all students and it was seen that the scores of experimental and control groups were not statistically different. Yet, the results of delayed test, that was administered four weeks after the post-test, showed that experimental group had better scores in microscopic views of phase change that the control group and the difference was statistically different. The findings of the study showed that analogy activity resulted long-term learning.

As it can be seen in the studies reported here, a variety of strategies to achieve conceptual change were tried. Choosing appropriate teaching strategies to overcome students' misconceptions in different chemistry topics has been found to be related to chemistry teachers' knowledge of content and pedagogy that was described in the next section.

2.4. Teacher Knowledge

Teaching begins with a teachers' understanding of what is to be learnt and how it is to be taught and ends with comprehension of the subject after a series of activities in which students are provided instruction and opportunities for learning (Shulman, 1987). According to Shulman (1987), the categories of teacher knowledge in order to promote students' comprehension would include:

- content knowledge
- general pedagogical knowledge
- curriculum knowledge
- pedagogical content knowledge
- knowledge of learners
- knowledge of educational contexts
- knowledge of educational ends, purposes and values

Shulman (1987) indicated four major sources of teacher knowledge: (i) scholarship in content disciplines; which refers to knowledge, understanding and skills in the discipline, (ii) the materials and the settings of the educational process; which indicate curriculum, textbooks and other factors related to school organizations, (iii) research on learning, teaching and schooling; which includes findings and methods of research about teaching, learning, human development and also foundations of education (iv) practice; because of the fact that teaching is a learned profession.

Among these categories of teacher knowledge listed above, content knowledge and pedagogical content knowledge were chosen as variables in this study, and so were explained in detail in the following sub-sections.

2.4.1. Content Knowledge

Shulman (1986) described content knowledge as "the amount and organization of knowledge per se in the mind of the teacher" (p. 9). Subject matter knowledge was seen more than knowledge of facts or concepts of a domain, it also required understanding the structures of the subject matter (Shulman, 1986).

Cochran and Jones (2003) stated that subject matter knowledge had four components: (i) content knowledge, (ii) substantive knowledge, (iii) syntactic knowledge, (iv) beliefs about the subject matter. Content knowledge of a teacher includes knowledge of the facts and the concepts of the subject matter. Substantive knowledge refers the explanatory structures or paradigms of the field. Syntactic knowledge includes the methods and processes by which new knowledge in the field was generated. Beliefs about the subject matter refer teachers' feelings about various aspects of the subject matter.

Content knowledge of teachers was also found as a factor affecting their instructional practices. Teachers' content knowledge affects their choices in selecting particular curricula and specific curriculum materials (Grossman, 1990). Moreover, according to Carlsen (1993), there is a relationship between subject-matter knowledge of teachers and the cognitive level of the questions they asked in their teaching. The teachers attempt to use high cognitive level of questions when they feel knowledgeable in the subject matter. When they are teaching unfamiliar subjects, they tend to ask lower level questions.

As indicated in the following sections, numerous research studies were conducted to investigate and/or improve content knowledge of chemistry and science teachers in subjects of “particulate nature of matter”, “chemical equilibrium” and “acid strength”. The methods and findings of some of these research studies were summarized in the following sub-sections.

2.4.1.1. Content Knowledge of Teachers in Particulate Nature of Matter. Kikas (2004) investigated the conceptions of science (physics and chemistry) teachers about three natural phenomena; velocity, seasons and freezing. In the study, teachers were expected to evaluate given explanations, which were scientific or containing misconceptions. The results of the study showed that 63% of the science teachers evaluated the scientifically valid explanation for freezing as scientifically correct and 23% of science teachers evaluated explanation with a misconception, which stated a change in the size of atoms during the phase changes, as valid.

Valanides (2000) investigated 20 prospective primary teachers' conceptions of both macroscopic and microscopic properties and changes in dissolution process and the effects of filtering and heating solutions. According to the results of the study, some prospective teachers thought that a solid would break into smaller and invisible pieces when dissolved in water. From 20 participants, eight prospective teachers predicted that a chemical change would occur and the mass would be conserved if water and alcohol were mixed. When water and alcohol were mixed, 17 prospective teachers thought this would be a chemical change because they observed a decrease in volume. Also, five prospective teachers changed their decision about the conservation of mass when they observed a decrease in volume. Moreover, seven prospective teachers believed that liquids and their molecules would expand if water-alcohol mixture was heated. Only five prospective teachers thought that the molecules of the water vapour should be the same as the molecules of water. Six of the prospective teachers explained that water changed to air when it boiled. Also, seven prospective teachers thought that oxygen and hydrogen are produced as a result of evaporation and 10 prospective teachers indicated that the size of molecules depended on their temperature.

In the study conducted by Jarvis, McKeon and Taylor (2005), 22 prospective primary teachers participated in a workshop composed of three sessions to eliminate their problems in understanding science. The courses focused on the concepts of particulate theory of matter, energy, genetics and evolution. In the workshop, participants' discussions of science problems were used as the strategy. In sessions, participants were given a problem, wrote and discussed their ideas and they participated in a variety of activities such as short talks, videos and practical activities. At the end of the workshop, important conceptual improvements and increased self-confidence were observed among the prospective teachers.

Gabel, Samuel and Hunn (1987) devised a Nature of Matter Inventory and administered it to prospective elementary teachers in order to identify their views of the particulate nature of matter. The inventory aimed to assess prospective teachers' ability to distinguish the particulate views of elements, compounds, solids, liquids, gases, homogeneous and heterogeneous mixtures, chemical and physical changes. The results of the study showed that prospective teachers had some common errors in their drawings such as changing the size of atoms as the matter changed phase, drawing the particles of gases in an orderly fashion, and adding lines to show the surface level of a liquid.

Ozden (2009b) investigated primary prospective teachers' misconceptions about atoms and molecules by analyzing their drawing. A total of 92 primary science, mathematics and elementary prospective teachers participated in the study. Prospective teachers were expected to draw representations of atoms and molecules in physical changes during the activities. The drawings of prospective teachers were classified as non-representational drawings, partial drawings and comprehensive representational drawings. The majority of the drawings of prospective elementary teachers were found to be in non-representational drawings category and the majority of the drawings of prospective science teachers were found to be in partial drawings category.

2.4.1.2. Content Knowledge of Teachers in Chemical Equilibrium. Chemistry teachers seem to be unaware of the inadequacy of Le Chatelier's Principle. Cheung (2009) asked three chemical equilibrium problems to secondary school teachers to identify whether they would use Le Chatelier's Principle when the use of the principle was not appropriate. The first and the third questions on the test provided equilibrium situations that Le Chatelier's Principle could not solve these problems. On the other hand, the second question could be solved by using Le Chatelier's Principle. The results of the study showed that 28 of the 33 participating teachers and 17 of the 33 teachers tried to answer, respectively, the first and the third question by using Le Chatelier's Principle despite the fact that the use of the principle was not appropriate. For the second question, 22 of the 33 teachers made an incorrect prediction and 12 of them stated Le Chatelier's Principle as the reason of their choice but they misused the principle.

Dogan, Aydogan, Isikgil and Demirci (2007) investigated prospective chemistry teachers and high school students' misconceptions and level of understanding in using Le Chatelier's principle with conceptual questions. The participants of the study were 36 prospective chemistry teachers at the fifth year of chemistry teacher education program and a total of 69 tenth-grade students from two different high schools. According to the analysis of the results, it was seen that, both prospective chemistry teachers and high school students had similar difficulties in the application and understanding of Le Chatelier's principle.

2.4.1.3. Content Knowledge of Teachers in Acids and Bases. Bradley and Mosimege (1998) investigated prospective teachers' conceptions of acids and bases. Analysis of student teachers' responses showed that 42% of the participating student teachers believed that aqueous solutions of all salts are neutral. Moreover, 32% of the sample could not correctly compare the basicity of conjugate bases of some common acids. Furthermore, 32% of the participants wrote a reaction equation when they were expected to draw a solution of hydrochloric acid at the particulate level. Some of the student teachers stated that an acid turns red lithmus paper blue. Also, several students confused the terms amphoteric and diprotic.

Ekiz, Bektas, Tuysuz, Uzuntiryaki, Kutucu, and Tarkin (2011) investigated prospective chemistry teachers' explanations about ionization and dissolution processes. According to the researchers, the dissociation of an acid in water must be described as ionization because a chemical change would occur and it was completely different from dissolution of ionic salts in water. Among the seven participants, only three stated that solid AgCl slightly dissolved in water and two of them could draw this process at the molecular level. Four participants thought that AgCl ionized in water rather than it dissolved. Only one participant stated that HCl ionized in the water and correctly explained the change. Three participants stated that HCl was dissolved in water. None of the participants could represent the ionization of HCl in water correctly.

Boz (2009) administered a questionnaire with five open-ended questions to 38 prospective chemistry teachers. The questions in the questionnaire aimed to evaluate prospective chemistry teachers' concepts of acids and bases in terms of macroscopic properties, neutralization and the relationship between the acid strength and concentration. The results of the study showed that most of the prospective chemistry teachers were aware of the macroscopic properties of acids and bases. Among 38 prospective teachers, 10 prospective teachers believed that all salts were neutral. In addition, majority of prospective teachers could not differentiate concentration and strength of an acid, only six prospective teachers could state that the hydrochloric acid had the same strength for three solutions with different concentration values.

2.4.2. Pedagogical Content Knowledge (PCK)

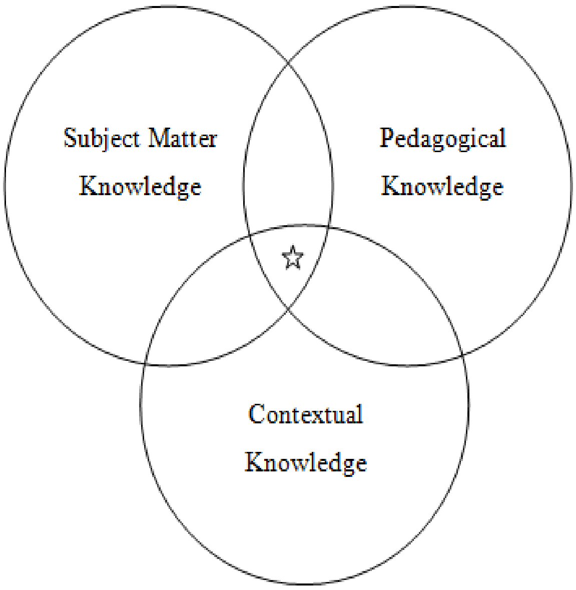
Shulman (1986) described pedagogical content knowledge as "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (p. 9). National Research Council (1996) defined pedagogical content knowledge as "special understandings and abilities that integrate teachers' knowledge of science content, curriculum, learning, teaching and students" (p. 62). Kind (2009) described PCK as knowledge which a teacher used in the process of teaching.

Knowing about a topic is completely different from knowing about particular teaching and learning demands of that topic. A teacher has to have both the knowledge of the subject matter and the knowledge of its teachability and learnability. Furthermore, the demands of learning about one chemistry topic are different from the demands of learning about another one. Thus, prospective chemistry teachers should not only know how to teach, but also know how to teach chemical equilibrium or how to teach stoichiometry (Bucat, 2004).

PCK is the knowledge that distinguishes a teacher from a scientist. A scientist does not have to think about effective teaching strategies of the subject. Different from scientists, teachers should have pedagogical content knowledge to choose the most appropriate examples, representations, illustrations, and analogies to teach a subject effectively. For this reason, teachers should possess both of subject matter knowledge and pedagogical skills specific to the subject for effective teaching (Aslan-Tutak, 2009). According to Bucat (2004), each chemistry teacher possesses a unique knowledge of chemistry and expected to re-package his/her knowledge in such a way that provide students' understandings. This re-packaging procedure will be related to the nature of the subject matter. Thus, teachers have to know the subject matter knowledge, not only for itself, but also know the subject matter for teaching and learning it.

Appleton (2006) described the term "science pedagogical content knowledge" for elementary school teachers and secondary science teachers as "the knowledge a teacher uses to construct and implement a science learning experience or series of science learning experiences" (p.35). Science pedagogical content knowledge is in relationship with other forms of teacher knowledge and includes ways of science content understandable for students.

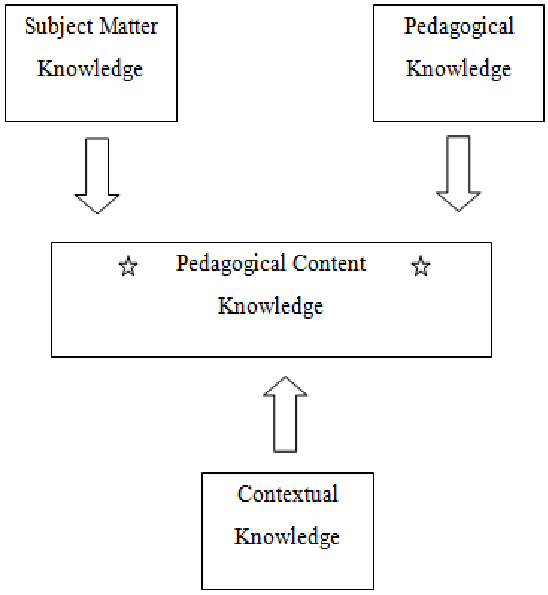
Gess-Newsome (1999) proposed two models of teacher knowledge: Integrative Model and Transformative Model each composed of three constructs: subject matter, pedagogy and context. In Integrative Model, teacher knowledge is expressed by the intersection of knowledge in three domains: subject matter, pedagogy and context. According to this model, teaching is the act of integrating knowledge in these domains and PCK does not exist in this model. In instruction, a teacher uses independent knowledge bases of subject matter, pedagogy and context and integrates them to create effective learning environments. Integrative Model is seen analogical to mixtures in chemistry, subject matter knowledge, pedagogical knowledge and context knowledge are found together as separate entities (Gess-Newsome, 1999).



☆ : knowledge needed for classroom teaching

Figure 2.1. Integrative Model of teacher knowledge.

On the other hand, in Transformative Model, PCK is seen as a synthesis formed through transformation of knowledge in subject matter, pedagogy and context into a unique form. According to this model, teacher use PCK to help their students understand specific concepts in instruction. Transformative Model is seen analogical to compounds in chemistry, subject matter knowledge, pedagogical knowledge and context knowledge compose a new form of knowledge, PCK (Gess-Newsome, 1999). In addition, according to Ball, Thames and Phelps (2008), not only knowledge of content or not only knowledge of pedagogy but an amalgam of knowledge is central to the knowledge needed for teaching. Also, Kind (2009) stated that content and pedagogy were blended in PCK, a teacher combined his understanding about a topic with instructional strategies and additional knowledge to promote student learning.



☆ : knowledge needed for classroom teaching

Figure 2.2. Transformative Model of teacher knowledge.

Magnusson, Krajcik, and Borko (1999) described five components of PCK. The first one is orientation toward science teaching, which refers to knowledge of goals for teaching science at a particular grade level. The second one is the knowledge and beliefs about science curriculum, which refers to knowledge of objectives for students in the subject taught and knowledge of programs and materials relevant to particular topic. The third one is knowledge and beliefs about students' understanding of specific science topics, which refers to knowledge of requirements for learning and student difficulties for a subject. The fourth one is knowledge and beliefs about assessment in science, which refer to knowledge of dimensions to be assessed and the methods to assess learning. Finally the fifth one is the knowledge and beliefs about instructional strategies for teaching science, which refer to knowledge of subject-specific and topic-specific strategies while teaching a subject.

According to Grossman (1990), PCK is developed by four sources. Firstly, prospective teachers have memories of experiences, with their own teachers, about how to teach particular topics and these experiences of prospective teachers may affect their approach while teaching. Also, prospective teachers may recognize their memories of themselves as students so better understand their students' expectations. Secondly, knowledge of a discipline forms the base for development of PCK, subject matter knowledge contributes to teaching particular subject matter. Thirdly, professional coursework also contributes the development of PCK. Subject-specific method courses aim to provide the knowledge about a subject necessary for teaching it. Fourthly, PCK is acquired through classroom teaching experiences. Teachers also have chance to test the knowledge they acquired from other sources.

Abell (2007) reviewed the studies conducted by Magnusson *et al.* (1999) and Grossman (1990) about teacher knowledge and formed a model of science teacher knowledge by combining the findings of these researchers.

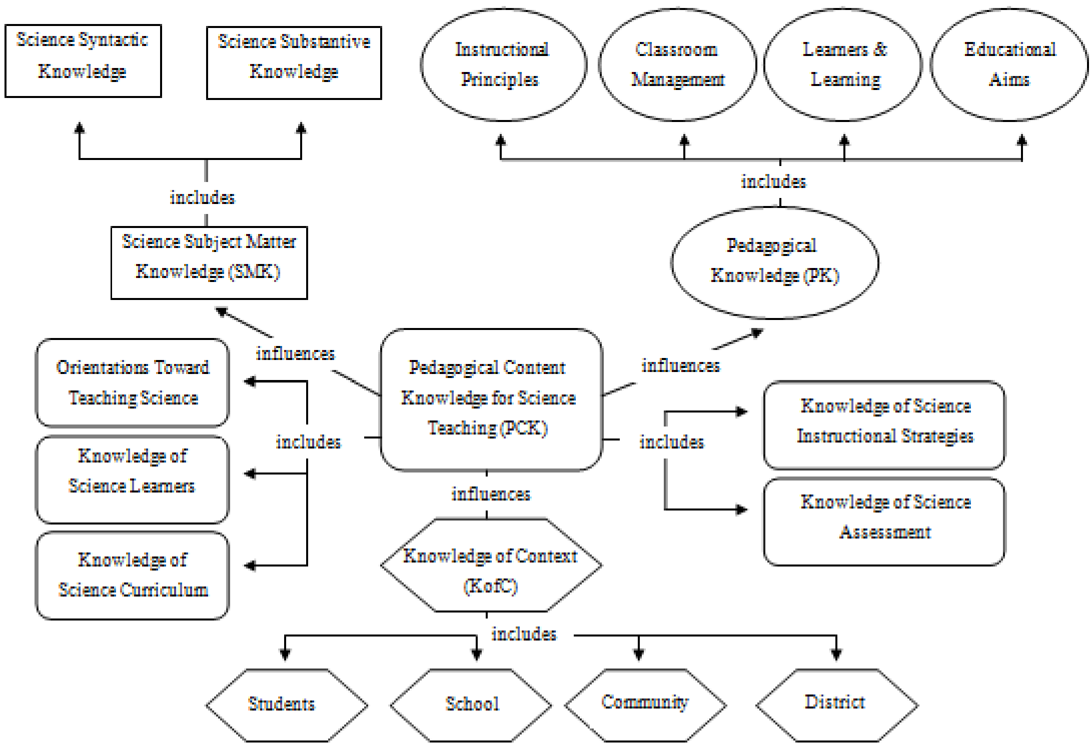


Figure 2.3. Abell's model of teacher knowledge.

Cochran, DeRuiter, and King (1993) criticized the term "knowledge" in pedagogical content knowledge because the word knowledge was too static. Thus, these researchers replaced the word knowledge in PCK with knowing, because construction of PCK was changing process rather than static knowledge. According to Loughran, Berry and Mulhall

(2012), PCK is a type of knowledge that teachers develop through experience and influenced by individual differences and the teaching context, content, and experience. In order to develop PCK, teachers firstly need to have a rich conceptual understanding of the subject content that they teach and this rich conceptual understanding is needed to be combined with expertise in using teaching procedures and strategies for use in particular classes. Lee and Luft (2008) indicated that prospective or beginning teachers usually had limited PCK, but experienced teachers developed an advanced understanding of teaching. De Jong and Van Driel (2004) also indicated that, teachers need experiences in teaching particular topics in practice in order to develop PCK.

According to Kind (2009), pedagogical content knowledge is a hidden concept. First of all, it is difficult to identify what it comprises and using this knowledge to support teacher education. Secondly, many professional teachers are not aware of the term. Kind (2009) suggested that prospective teachers should be encouraged to understand PCK as knowledge they themselves were learning so they would be more aware of the process they were undertaking.

In the following sections, the methods and findings of the research studies which were conducted to investigate PCK of science and/or chemistry teachers according to various aspects were summarized.

2.4.2.1. Research on Elements of PCK. Lee and Luft (2008) investigated components and specific elements of PCK according to experienced secondary science teachers and how experienced teachers organise these components. The participants of the study were four experienced teachers. Data were collected through interviews, classroom observations, lesson plans, and reflective summaries. During the interviews, teachers were expected to construct a diagram representing the components and elements of PCK. According to the analysis of the data, all four participants stated seven common components of PCK with slight variations in specific elements. These components were found to be knowledge of science, knowledge of goals, knowledge of students, knowledge of curriculum organization, knowledge of teaching, knowledge of assessment and knowledge of resources. All teachers stated that knowledge of science is the most important knowledge for science teaching and the components were connected to one another in different ways.

Ozden (2008) investigated the effect of content knowledge of prospective science teachers on their pedagogical content knowledge and 28 prospective science teachers participated in the study. Data were collected through lesson preparation task, content knowledge test and semi-structured interviews. In that study, firstly prospective science teachers were expected to write lesson plans for teaching the subject of phases of matters for the fifth grade . Then, the content knowledge test was administered to all participants. Finally participants were interviewed. The analysis of the lesson preparation, content knowledge test and semi-structured interviews indicated that prospective science teachers had inadequate knowledge and some misconceptions about phases of matters. Also, results indicated that content knowledge of prospective science teachers had positive effect on their pedagogical content knowledge. Moreover, the results showed that content knowledge influenced effective teaching practice.

<u>2.4.2.2. Research on the Effects of Professional Development Programs on PCK.</u> In the study of De Jong , Van Driel and Verloop (2005), the prospective chemistry teachers attended a program about the use of particle models and they are expected to deal with possible students' difficulties with using particle models. The teachers also practiced their planned teaching activities of particulate nature of matter in practice schools and analyzed their teaching. The data was collected through the written answers of each teacher to the questions on assignments, the reflective lesson reports written and the audiotape recordings of all discussions during the institutional workshops. In the first assignment, students were expected to write the difficulties in learning the relationship between particles and substances they remembered from their learning experiences or from their teaching practice. Then, prospective teachers were expected to analyse the subject of particulate nature of matter from school textbooks. In the second assignment, students were expected to write possible students' difficulties in understanding particulate nature of matter. They were also expected to give examples of instructional strategies to promote students' understanding of the issue. Then, teachers designed and taught a series of lessons on a topic focusing on the use of particle models. Each prospective teacher taught lessons at his or her practice school. In the third assignment, teachers were expected to write a report about the most important events and identified students' difficulties during their lesson. After the program, it was seen that prospective teachers had a better understanding of student difficulties with the use of particle models. Also, participants became more aware

of the characteristics of particle models. The results of the study indicated that the program improved participating prospective teachers' PCK in using particle models but the degree of development differed among prospective teachers.

De Jong and Van Driel (2004) investigated the development of prospective chemistry teachers' PCK in the context of multiple meanings such as the meanings of topics in different representational levels of chemistry. In terms of PCK, the knowledge of students' learning difficulties and teaching difficulties were emphasized. The participants of the study were eight prospective teachers who attended a teacher education program and the participants were also expected to teach in practice schools. The data was collected through individual interviews before and after the practice lessons of participants. During the pre-lesson interview, they were asked to show and explain their lesson plans and express their expectations regarding the students' conceptual difficulties and their own difficulties in teaching the topic. During the post-lesson interviews, they were invited to report and reflect on their teaching experiences with respect to teaching and learning difficulties. In the pre-lesson interviews, only three prospective teachers stated their expectation about teaching and students' learning difficulties. Yet, in the post-lesson interviews, other prospective teachers also reported teaching and students' learning difficulties. Four categories were identified regarding teaching difficulties and first three of them could be identified after teaching only. The first one was too fast reasoning between macro- and micro-meanings. All of the prospective teachers stated that they experienced teaching difficulties in terms of their too fast reasoning between the macro- and micro-meaning of topics because their students could often not follow their mental jumps. The second one was dominant orientation of the instruction towards micro-meanings. Six prospective teachers expressed that they generally explained scientific phenomena in terms of particles without any reference to relevant observations of phenomena. The third one was mixing together macro-meanings and micro-meanings. Six prospective teachers expressed teaching difficulties in terms of their confusing way of mixing together the macro-meaning and the micro-meaning of topics. Fourthly, a majority of prospective teachers stated handling confusing symbolic representations in textbooks as a teaching difficulty. Two categories of student-learning difficulties were identified before and after teaching. The first one was misunderstanding meanings of formulas and the second one was misunderstanding meanings of reaction equations.

Khourey-Bowers and Fenk (2009) investigated the relationship between teachers' participation in a chemistry professional development program and enhancement of content and pedagogical content knowledge related to representational thinking and conceptual change strategies and self-efficacy. 69 teachers participated in this study, majority of the prospective teachers were elementary teachers and minority of the participants were middle school or high school teachers. In the program, a university science educator, a chemistry professor, and two chemistry teachers constituted the instructional team and a variety of instructional methods were used to enhance content and pedagogical content knowledge. In the program, discussions were conducted for a variety of chemistry concepts and more discussions were on constructivism, historical development of scientific theories and models, inquiry strategies and alternative conceptions. Open-inquiry, guided inquiry, and problem-based laboratory activities were presented during the program. Moreover, participants were expected to apply conceptual change strategies in their own classrooms through assignments. Also, quantitative measures were used to assess content knowledge, PCK, and self-efficacy. According to the result of the study, the mean scores on content knowledge test increased significantly from pre-test to post-test for the total population and for the elementary teachers. Yet, the scores of middle/high school teachers did not change significantly. In addition, mean scores in representational thinking in both particulate and symbolic levels increased significantly from pre-test to post-test for the total sample and for the elementary teachers. The scores of middle/high school teachers increased slightly but the change was not significant. All participants had statistically significant gains in personal science teaching efficacy. Teachers' pedagogical content knowledge was also measured through the assignment about their classroom experiences, assignments evaluated whether they elicit alternative conceptions and use a bridging activity to help students develop more scientifically consistent ways of thinking. The analysis of selected assignments showed that elementary teachers advanced in pedagogical content knowledge by gains in implementation of conceptual change strategies and model development in their classrooms. The program enhanced PCK of high school teachers but they used different conceptual change strategies than elementary and middle school teachers.

Yakmaci-Guzel (2013) investigated the views and understandings of prospective chemistry teachers about the nature, diagnosis and remediation methods of misconceptions after they attended a course designed for that study. The course participants were 22 prospective chemistry teachers. During the course, participants read, and discussed with each other in order to design diagnostic questions and lesson plans, applied them in real classrooms, evaluated the effectiveness of their lesson to change target misconceptions, and reflected the effects of the course on them. Data were collected through self-reflection reports written by prospective teachers after they attended this course and diagnostic questions which prospective teachers posed to students before and after they applied their lessons. According to the results of the study, most of the participants realized the importance and variety of misconceptions, and also ways of dealing with them. Moreover, majority of the participants' lessons were found to be highly effective or partially effective to eliminate the target misconceptions, many of the high school students' misconceptions changed after the applied lessons.

2.4.2.3. Research on Pedagogical Content Knowledge Related to Understanding Student Misconceptions. Gomez-Zwiep (2008) investigated elementary teachers' perceptions of students' science misconceptions. Thirty teachers with at least one-year of experience were interviewed to question teachers' knowledge about the definition and sources of misconceptions, students' common science misconceptions, and their views about integrating misconceptions into their teaching and the effects of misconceptions on their teaching. The analysis of participants' responses showed that, 17% of the participating teachers could not give any definition of the term "misconception", and 33% of the teachers could not provide examples of students' science misconceptions. Most of the teachers perceived misconceptions as incorrect information that student got from different sources such as internet, parents, textbooks, etc. Only three of the teachers perceived misconceptions as student's own constructs. Also, several teachers believed that students did not have any scientific knowledge before formal science instruction. Nineteen teachers told that they did not take students' misconceptions into consideration while planning their instruction. Most of the interviewed teachers believed that they could easily correct a misconception with using various instructional strategies such as hands-on experiments, videos, inquiry, field trips, and questioning.

Morrison and Lederman (2003) investigated how science teachers diagnose their students' preconceptions. For this purpose, teachers were observed during their classes, indepth observations and interviews were conducted, and teachers' lesson plans and their students' written works were analyzed. Four secondary science teachers who had been teaching for at least five years participated in the study. Two of the participating teachers were biology teachers, one teacher was physics, and the other one was earth science teacher. Each teacher was interviewed twice prior to conducting classroom observations. Then, daily classroom observations were conducted for nine weeks. After classroom observations, stimulated recall interviews were conducted with teachers in which a short video segment of their teaching was shown and they reflected upon their teaching during that segment. After the stimulated recall interview, a short semi-structured interview was conducted with each teacher. According to the analysis of data, teacher's experience was found to be an important factor to explain teacher behavior. Helen had five years, Steve had 15 years, Bob had 24 years, and Bill had 34 years of experience in teaching. Helen was often hesitant and unclear when describing her teaching whereas Bill was always relaxed and confident in his manner. None of the four teachers used any type of instrument to identify students' preconceptions despite the fact that all of them stated it is important to know students' prior knowledge before teaching a new concept. All of the teachers stated that they attempted to find out their students' preconceptions through questioning or talking to students. Yet, classroom observations showed that three teachers mainly asked recall questions. Bill's questions were often of a more probing type, he tried to use students' ideas to create a discussion. When a student answered a question with an incorrect answer, Helen, Bob, and Steve rephrased the question for the same student or moved on to another student or they gave the student the correct answer. Bill, on the other hand, asked different questions about the topic and expected the students to express their ideas about the question. When the teachers were asked how they thought that the information about students' ideas could be used, Bob and Steve responded that they would use that information to reteach the concept. Helen mentioned that she would use the information as an example to other students in class. All of the teachers stated that they took care to explain the concepts carefully and made sure they spent adequate time on the topic to deal with common preconceptions.

2.4.2.4. Research on PCK Related to Teaching Particulate Nature of Matter. Boz and Boz (2008) investigated prospective chemistry teachers' knowledge about instructional strategies in particulate theory and 22 prospective chemistry teachers participated in the study. Prospective teachers were expected to design a lesson to introduce the particulate nature of matter to fifth-grade students and they were interviewed to investigate the factors affecting participants' decisions for selecting specific instructional strategies. Analysis of responses showed that majority of the prospective teachers preferred using concrete objects, some of them preferred computer animations and minority of the teachers preferred direct teaching. Prospective teachers preferred lecturing, questioning, using demonstration, animation and group work as teaching strategies to introduce particulate theory.

2.4.2.5. Research on PCK Related to Teaching Acids and Bases. Drechsler and Van Driel (2008) investigated pedagogical content knowledge of nine experienced chemistry teachers. The participants were volunteer upper secondary chemistry teachers that had participated in a teacher training course and the teachers were interviewed about two years after the course. During the interviews, the teachers were asked about their planning of an acid–base lecture sequence and about how they changed their teaching from year to year. Teachers mentioned the main difficulties for students' understanding as calculations, writing and interpreting equations and specifically bases rather than acids. The teachers' explanation of students' misunderstandings were found in four categories: (i) students' misinterpretations of acid/base reaction equations; for example, students have difficulty to understand equilibrium reaction of dissociation of some acids in water, (ii) students' preconceptions; for example, students think that only substances containing a hydroxide ion are bases, (iii) model confusion; students either confuse different models used in acid-bases or they do not recognize the limitations of each model, (iv) students' difficulties in distinguishing between explanations at the macroscopic level and at the microscopic level; students have difficulty to explain macroscopic level in terms of particles. Teachers stated that they changed how a topic was explained, the examples for calculation and laboratory works in their teaching within years. Teachers stated some factors for this change such as reflection on students' difficulties, collegial discussions, research, reflection on teaching, textbook and the media. Majority of teachers denoted an increasing satisfaction with teaching acids and bases within years.

2.5. Teaching Efficacy Beliefs of Teachers

Bandura (1997) described “self-efficacy” as beliefs in one’s capabilities to organize and execute the courses of action to attain designated performances. Self-efficacy of individuals affect the courses of action people choose, how much effort they put forth in a course of action, how long they will persevere in case of obstacles and failures. According to Bandura (1986), perceived self-efficacy of individuals is concerned with the beliefs of what one can do rather than the skills one has.

Despite the fact that, perceived self efficacy and self-esteem concepts are sometimes used interchangeably, according to Bandura (1997), these concepts are completely different. Perceived self efficacy is concerned with the beliefs of personal capability whereas self-esteem is concerned with the beliefs of personal-worth.

According to Bandura (1997), creating learning environments which results cognitive development of students rely on the talent and self-efficacy of teachers. Teachers’ beliefs in their efficacy affect both general orientation toward educational processes and specific instructional activities in their classrooms. Teachers’ efficacy beliefs also include ability to maintain effective classroom environment and using resources as well as ability to transmit subject matter knowledge.

Gibson and Dembo (1984) aimed to develop an instrument to measure teacher efficacy, identify dimensions of teaching efficacy and examine the relationship between teacher efficacy and observable teacher behaviours. According to the results, the researchers proposed two dimensions of teaching efficacy: personal teaching efficacy and general teaching efficacy. Personal teaching efficacy included teachers’ beliefs about their own skills and abilities whereas general teaching efficacy included also external factors such as home environment and family background. Personal teaching efficacy reflects Bandura’s self-efficacy component. Gibson and Dembo (1984) also indicated that teachers with low efficacy criticized more an incorrect answer of student, and showed less persistence when a student could not answer a question, compared to teachers with high efficacy. Harlen and Holroyd (1997) also indicated that teachers with low confidence levels tended to only teach minimum required subjects in science, rely their lessons on direct teaching, overemphasise prescriptive texts, and only do simplest practical work and with basic apparatus.

2.5.1. Factors Affecting Teaching Efficacy Beliefs of Teachers

Teachers' content knowledge has been found as an effective factor in teaching efficacy beliefs of teachers. According to Jarvis *et al.* (2005), a project that targeted problems related to prospective teachers' understanding in science can help them to increase their content knowledge and associated self-confidence. In their study, all of the participants' confidence for science was greatly increased at the end of a workshop that aims to enhance their understanding in science.

Khourey-Bowers and Simonis (2004) investigated the effect of a chemistry professional development program on personal science teaching self-efficacy, outcome expectancy, chemistry content, and pedagogical content knowledge of participating teachers. A total of 135 teachers participated in the study in four years. The program was implemented as a pre-test at the beginning of each day, and demonstrations, activities and discussions followed. Teachers worked in small groups during the activities and each day was completed with assignments and a post-test or reflections with new questions. The analysis of the results indicated that both personal science teaching efficacy and outcome expectancy were enhanced as a result of the professional development program. Mastery experiences of the participants during the activities, assessment strategies used in the program, oral and written feedbacks to participants' works helped participant increase science teaching efficacy. As a result, the professional development program enhanced self-efficacy of participants via increasing their science content knowledge and pedagogical content knowledge.

Schoon and Boone (1998) investigated the relationship between the number of misconceptions found in prospective elementary teachers and their science teaching efficacy. The results of the study showed that the relationship between the number of correct answers and teaching efficacy was significant but there was not found any relationship between the number of misconceptions and science teaching efficacy. Only holding certain misconceptions was found to be related to low self-efficacy.

According to Harlen and Holroyd (1997), there are other factors than content knowledge that affects self-confidence of teachers. In their study, male teachers, teachers who were more recently qualified, and, teachers of older pupils had a higher self-confidence compared with female teachers, teachers who were qualified more than 12 years ago, and teachers of younger pupils, respectively. Teachers' self-confidence seems to increase with greater teaching expertise and it is consistent with the research literature on self-confidence in teaching science, and science teaching self-efficacy (Appleton, 1999).

2.5.2. Research on Instruments to Measure Teaching Efficacy Beliefs

According to Enochs and Riggs (1990), beliefs are one of the foundations which behaviours are based on. In order to provide a reliable measure of self-efficacy beliefs of teachers, Enochs and Riggs (1990) developed a Science Teaching Efficacy Beliefs Instrument (STEBI) for elementary in-service teachers in the light of Bandura's social learning theory, and adapted the instrument as "Science Teaching Efficacy Beliefs Instrument Form B" (STEBI B) for prospective teachers. The instrument is a 5 points-Likert type scale and consisted of 23 items which prospective teachers indicated how much they agree or disagree with these statements.

Morgil, Seçken and Yücel (2004) measured teaching efficacy beliefs of prospective chemistry teachers with an instrument called "Kimya Öğretimine Yönelik Özyeterlilik İnanç Ölçeği". It has been found that prospective teachers have anxiety about teaching in a real class despite the fact that they have adequate theoretical knowledge and self-confidence about their subject matter knowledge. Moreover, the study showed that male prospective chemistry teachers had higher levels of teaching efficacy than females.

Yilmaz-Tuzun (2008) developed "Beliefs About Teaching" (BAT) scale to evaluate prospective elementary science teachers' self-reported comfort level with teaching methods, assessment techniques, classroom management techniques and science content. According to Yilmaz-Tuzun (2008), participants' confidence level with assessment techniques, classroom management, teaching methods, and science content were found to be correlated with the number of science methods and science content courses taken.

To sum up, the reviewed literature for this study indicated that prospective chemistry teachers might have similar misconceptions with students. Moreover, it was stated that several conceptual change strategies could be used to remediate misconceptions in different chemistry topics. It was also emphasized that knowledge and understanding of students' learning difficulties and instructional strategies to overcome them enhanced pedagogical content knowledge of teachers. Moreover, it can be concluded that teaching efficacy beliefs of teachers were found to be related to teachers' subject matter knowledge and seems an important factor that affects behaviours and choices of teachers in classrooms.

3. METHODOLOGY

The main purpose of this research study was to develop a training program for prospective chemistry teachers with the aim of improving their chemistry content knowledge, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. The study aimed to increase chemistry content knowledge of prospective teachers in the subjects of “particulate nature of matter”, “chemical equilibrium”, and “acid strength”. The other purpose of this study was to evaluate the impacts of this training program on participating prospective chemistry teachers in terms of content knowledge, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. For achieving this purpose, after the program, the change in participating prospective chemistry teachers’ chemistry content knowledge, their pedagogical content knowledge related to misconceptions, and their teaching efficacy beliefs were investigated and also their opinions about the training program were taken.

The current study was completed in two subsequent steps:

(i) Development of the training program

(ii) Evaluating the impacts of the training program on participants in terms of content knowledge, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs

As the purposes of the study were taken into consideration, it can be said that, this research study tried to answer the following four research questions:

(i) Is there any difference in prospective chemistry teachers’ chemistry content knowledge before and after attending the training program?

(ii) Is there any difference in prospective chemistry teachers’ pedagogical content knowledge;

- in terms of understanding the nature of misconceptions before and after attending the training program?

- in terms of strategies to identify and change student misconceptions before and after attending the training program?

(iii) Is there any difference in prospective chemistry teachers' teaching efficacy beliefs before and after attending the training program?

(iv) What are the prospective chemistry teachers' opinions about the training program?

In this chapter, first of all, a research project (Yakmaci-Guzel, 2012) that inspired this study was described. Secondly, the framework for the development of the training program was explained. In order to explain the impacts of the program, the participants of the study were introduced. The instruments used in the study and data collection procedures were explicated. Then, design and the procedure of the study were described. Finally, data analysis was explained.

3.1. A Research Project that Inspired the Current Study

A research project (Yakmaci-Guzel, 2012) about chemistry teachers' awareness and competency in recognizing common student misconceptions in chemistry was initiated in the first semester of the academic year of 2011-2012. In that study, a "Chemistry Concept Test" (CCT) (See Appendix A) was developed by Yakmaci-Guzel and Yigit. The misconceptions of 12th grade students were diagnosed as a result of administration of this test to 465 students from, a total of nine different, seven public and two private, high schools located in Istanbul.

When the misconceptions of 12th grade students were revealed with analysis of the data collected in that study, the researcher wondered whether prospective chemistry teachers had the similar misconceptions with the high school students and whether a training program would help prospective teachers to change their misconceptions. In order to develop such a training program, the researcher used the information collected from 12th grade students in that research project. The written responses of 12th grade students were integrated into the activities of the training program. In addition, "CCT" developed for that research project was used as an instrument in the present study to assess participants' content knowledge on these subjects.

3.2. Development of the Training Program

Each session of the training program started with a short presentation related to misconceptions and included a number of activities that target some specific misconceptions. The short presentations about the findings of the research literature related to misconceptions, the activities of the training program, the framework for the activities of the program and also the flow of any of the sessions were explained in detail in the following sub-sections.

3.2.1. Presentations of the Findings of the Research Literature Related to Misconceptions

The training program integrated short presentations related to misconceptions with the activities of the training program in order to enhance participants' pedagogical content knowledge related to misconceptions. The presentations were planned to take place at the beginning of each session of the program and take approximately 5-10 minutes. In these presentations, the findings of research literature related to misconceptions were explained. For the first session of the training program, the research studies concerning with the conceptions of "concept" and "misconceptions" were presented. The research studies that summarized the examples of common student misconceptions in chemistry were presented in the second session of the training program. For the third session of the training program, the research studies that indicated the sources of student misconceptions were introduced. For the fourth and the fifth sessions of the training program, the research studies that described some methods to identify student misconceptions and the methods to change student misconceptions in chemistry were introduced.

3.2.2. Activities of the Training Program

The misconceptions identified by administration of "CCT" to high school students as a part of aforementioned project formed the backbone for the activities of the present training program while developing it. The misconceptions included in the program and developed instructional activities for the subjects of “particulate nature of matter”, “chemical equilibrium”, and “acid strength” were described in the following paragraphs:

The training program included five activities about “particulate nature of matter”.

(i) The activity “*modelling particulate nature of matter*” emphasizes the modelling as a teaching strategy and targets the following misconceptions:

- The mixture of two pure substances is a pure substance
- The terms of element and atom always can be used interchangeably
- All polyatomic chemical species are compounds
- Pure substances are at the same time homogeneous mixtures

(ii) The activity “*animation of phase change of water*” emphasizes modelling and discussion as teaching strategies and targets the following misconceptions:

- There is air between the particles of matters
- There is not any space between the particles of solids
- When water evaporates, water molecules expand
- The space between the particles of ice is less than those of liquid water
- When water evaporates, water molecules decompose to H and O atoms

(iii) The activity “*mixing of different liquids*” emphasizes use of hands-on activities as a teaching strategy and targets the following misconceptions:

- There is no space between the particles of matters in liquid state
- There is air between particles of matters in liquid state
- The space between the particles of matters in liquid state is intermediate compared to solids and gases

(iv) The activity “*exploring the particles of diamond and graphite*” emphasizes discussion as a teaching strategy and targets the following misconception:

- The particles of a substance have the same properties with the bulk matter

(v) The activity "*comparing electrolysis and evaporation of water*" emphasizes discussion as a teaching strategy and targets the following misconception:

- It is hydrogen bonding that holds hydrogen and oxygen atom together within the water molecule

The training program included three activities about "chemical equilibrium".

(i) The activity "*ice-water equilibrium*" emphasizes use of hands-on activities as a teaching strategy and targets the following misconceptions:

- The concentration of reactants and products are equal at chemical equilibrium condition
- The concentration of reactants and products are proportional with stoichiometric coefficients at chemical equilibrium condition

(ii) The activity "*equilibrium analogy*" emphasizes analogies as a teaching strategy and targets the following misconceptions:

- Forward and reverse reactions are completed at the moment of equilibrium
- Only the products are found in the medium of chemical equilibrium

(iii) The activity "*limitations of Le Chatelier's principle*" emphasizes discussion as a teaching strategy and targets the following misconception:

- Le Chatelier's principle is valid in all chemical equilibrium conditions

The training program included two activities about "acid strength".

(i) The activity "*factors affecting acid strength*" emphasizes use of hands-on activities and discussion as teaching strategies and targets the following misconceptions:

- The strength of an acid is determined by the pH of the acid solution
- The strength of an acid is determined by the concentration of the acid solution
- Changing concentration of an acid solution does not affect its pH value

(ii) The activity "*the particles of acid solutions*" emphasizes modelling and discussion as teaching strategies and targets the following misconceptions:

- Acids do not dissociate in water
- Acids dissociate in different percentages in their concentrated and diluted solutions
- There is no water molecule in strong acid solutions
- In weak acid solutions, the concentration of acid molecules and ions are equal

3.2.3. The Framework of the Activities

While developing the activities of the training program, the conditions of conceptual change model proposed by Posner *et al.* (1982) were taken into consideration. Some of the high school students' responses to "CCT" collected during aforementioned research project were shown to participants at the beginning of the activities and prospective teachers were expected to evaluate the responses as scientifically correct or incorrect. Yet, all of these responses included one or more misconceptions in order to create cognitive conflict in prospective chemistry teachers. This step corresponds with the condition of "dissatisfaction". For the condition of "intelligibility", it was planned that new concepts were addressed by working on the activities of the program. For the "plausibility" condition of the conceptual change model, the activities included in the training program aimed to create learning environments in which prospective teachers will find out that new concepts provide more meaningful outcomes than their existing conceptions. For the "fruitfulness" condition of the conceptual change model, the discussion and practice questions were included for the participants to apply new knowledge at the end of the activities.

In the design of the present training program, recommendations of several researchers were taken into consideration. Vosniadou (1994) emphasized taking students' misconceptions into account in the design of instruction. For this reason, in order to achieve the aims of the training program, students' misconceptions were chosen as a starting point. Also, as indicated before, the actual responses of high school students on "CCT" were used in the program for making it more authentic and real.

According to Sarquis (2001), including a variety of instructional strategies is a more effective way than using a single instructional strategy to meet the needs of all students and learners have a better understanding when the content is presented in a number of ways. For this reason, various instructional strategies such as modelling, hands-on activities, discussion and analogies were included while designing the activities of the training program. According to Guskey (2003), creating collaboration among the participants, allocating adequate time and resources for activities were important characteristics of effective professional development activities for teachers. For this reason, the activities of the program were designed as the participants working in groups. Also, the duration of the activities was adapted according to the type of the activity.

3.2.3.1. Levels of Representation in Chemistry. In chemistry, matters may be represented in three levels: the macroscopic level, the microscopic level and the symbolic level (Johnstone, 1982). Macroscopic level is the observable and tangible level of representation of matter. Observable chemical phenomena such as "adding hydrochloric acid on zinc metal in a laboratory setting and observing the formation of hydrogen gas" are the macroscopic level. Microscopic level represents the inner world of matter that is not observable and understandable with senses. The behaviour and characteristics of non-observable particles such as "the structure of zinc atoms, hydrogen chloride molecules, zinc chloride lattice and hydrogen gas molecules" are the microscopic level. The "symbols, formulas and equations related to a chemical phenomenon such as Zn atoms, H_2 molecules or reaction equation ($Zn + 2HCl \rightarrow ZnCl_2 + ½\ H_2$)" constitutes the symbolic level of matter. When students and even teachers cannot scientifically connect and combine the three levels of matter, they may develop misconceptions about related chemical phenomena. Thus, in the training program, the representations of matter in all three levels were included in the activities.

The hands-on activities included in the training program represented the chemical phenomena in the macroscopic level. The training program included three hands-on activities: "mixing of different liquids" about the particulate nature of matter, "ice-water equilibrium" about the chemical equilibrium, "factors affecting acid strength" about the acid strength subjects. One of the hands-on activities, "mixing of different liquids" was designed according to predict-observe-explain approach. The other hands-on activities "ice-water equilibrium" and "factors affecting acid strength" was designed as inquiry-based.

According to White and Gunstone (1992), students are required to carry out three tasks in predict-observe-explain approach in order to understand a scientific phenomenon. Firstly, students have to predict the outcomes of some events and state their predictions. Secondly, they must observe the event and describe what they see. Finally, they must reconcile conflicts between their predictions and observation if there is any. In the "mixing of different liquids" activity, participants were expected to predict the final volume of two mixtures: (i) the mixture of water and alcohol, (ii) the mixture of water and oil. Secondly, participants were expected to mix certain volumes of water and alcohol and also mix certain volumes of water and oil and observe the final volume of each mixture. Finally, participants were expected to explain the event and resolve the conflicts between their prediction and observation.

Two of the hands-on activities of the training program; "ice-water equilibrium" and "factors affecting acid strength" are inquiry-based. National Research Council (1996) defines scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). According to Chiappetta and Adams (2004), inquiry is a way of scientific investigation in classrooms via observation, experimentation and reasoning and it promotes active learning of students. Classroom inquiry is described with five characteristics. Firstly, learners must be engaged in a scientific problem and collect data or analyze a given data to evidence in responding to the problem. Then, learners must formulate explanations from the evidence and evaluate their explanations through examining other sources in order to connect explanations to scientific knowledge. Finally, learners justify their explanations (National Research Council, 2000).

In the activities based on inquiry, participants were firstly presented a scientific problem and expected to design an experiment to solve this scientific problem. In the activity of "ice-water equilibrium", participants were expected to answer "What is the effect of the amounts of ice and water on the equilibrium temperature of ice-water mixture?" In the activity of "factors affecting acid strength", participants were asked to answer "Is the strength of an acid related to the concentration and the pH of the acid solution?" In order to solve these two scientific problems, participants were provided laboratory materials, expected to design a method and draw a conclusion.

The models included in the training program represented the chemical phenomena in the microscopic level of the matter. Gilbert, Boulter and Elmer (2000) defined "model" in science as "a representation of a phenomenon initially produced for a specific purpose" (p.11). According to Oversby (2000), modelling is "the action of representing an idea, an object, a process, an event or a system" (p.231). Modelling simplifies target concepts, it helps learners to visualize chemical phenomena and provide explanations for scientific phenomena. Thus, both of physical and conceptual/symbolic models have great value in understanding and communicating chemistry (Coll, 2006).

Three activities of the training program; "modelling particulate nature of matter", "animation of phase change of water" about the particulate nature of matter and "the particles of acid solutions" about the acid strength subjects emphasized the use of models. In the activity "modelling particulate nature of matter", the particles of elements, compounds and mixtures were represented in three phases of matters by models. The models in this activity were composed of spheres in different colours that represent different atoms and created by the researcher via Microsoft office program. In the activity "animation of phase change of water", water molecules were represented by molecular models on an internet website *(http://www.media.pearson.com.au/schools/cw/au_sch_ irwin_cc2_2/int/ch14/phases/0105.html)*. In the animation, the models of molecules have different arrangement and energy according to the phase of water. In the activity "the particles of acid solutions", the particles of acid molecules, water, hydronium ion, and acid anion were represented by molecular models. The models in this activity were composed of spheres and rectangles with different composition that represent different molecules and ions. Taber (2002) suggested these kinds of models to represent the particles of acid solutions.

3.2.3.2. Discussion. From social constructivist perspective, knowledge construction is a social process. Thus, social constructivists state that effective classroom environment promotes learning and suggest that teachers should support conceptual discussions in groups of students or whole class during instruction (Tytler, 2002). For this reason, in three activities of the training program; “exploring the particles of diamond and graphite”, “comparing electrolysis and evaporation of water” and “limitations of Le Chatelier’s principle”, “discussion” was used as the main teaching strategy. In the activity, “exploring the particles of diamond and graphite” participants were expected to share their ideas about the reasons of formation of allotropes from the same kind of atoms. In the activity, “comparing the electrolysis and the evaporation of water” participants were expected to discuss intramolecular and intermolecular forces in the case of the physical and chemical changes of water. In the activity, “limitations of Le Chatelier’s principle” participants were expected to share their ideas about several chemical equilibrium problems which Le Chatelier’s principle was not valid for. Furthermore, participating prospective teachers were expected to work and discuss as a group of two or three members in all activities of the training program. Participants were firstly expected to evaluate the presented student responses on “CCT” as a group. Moreover, they were expected to discuss their predictions and the results in an activity. They were also expected to discuss questions on activity sheets (Appendix B).

3.2.3.3. Analogies and Analogical Modelling. According to Turk, Ayas, and Karsli (2010) analogies involve the transfer of knowledge from a familiar domain to a target domain as a function of the structural correspondence between the two. For a student to learn new concepts meaningfully, it is necessary to connect new concepts with what he/she already knows. Thus, analogies are important teaching tools to enhance concept learning in science education (Harrison and Treagust, 2006). Even scientists use analogies to understand the concepts (Coll, 2006; Kikas, 2004).

In the activity “equilibrium analogy”, participants observed a model for an analogy in order to understand dynamic nature of chemical equilibrium. In this activity, some amount of water was transferred among two beakers continuously until the volume of water in both beakers did not change. This model was analogical to the proceeding of forward and reverse reactions even when chemical equilibrium was reached. Transferring water from the first beaker to second was analogical to forward reaction and from the second beaker to the first beaker was analogical to reverse reaction. Also, the volume of water transferred symbolized the rate of the reaction (*http://www.youtube.com/watch?v=C5jDmG4nVV8*).

Table 3.1. The activities and the teaching methods.

Activities	**Teaching Method**
Modelling particulate nature of matter	Modelling The particles of elements, compounds and mixtures in three phases of matter were represented by models
Animation of phase change of water	Modelling, discussion The particles of water in solid, liquid and gas phase were represented by models and the specific property of water resulted from hydrogen bonding was discussed
Mixing of different liquids	Use of hands-on activities, POE The participants were expected to predict the final volume of known amounts of two liquids, observe and explain the phenomena. The space between the particles of liquids and intermolecular forces between the particles of different matters were also discussed
Exploring the particles of diamond and graphite	Discussion The relationship between the particles of red and white phosphorus and the bulk matters were discussed
Comparing electrolysis and evaporation of water	Discussion The changes in electrolysis and evaporation events and intramolecular and intermolecular forces in water were discussed
Ice-water equilibrium	Use of hands-on activities, inquiry The participants were expected to find out that the amount of reactants and products did not have to be related to each other at chemical equilibrium
Equilibrium analogy	Analogy Tranferring some amount of water between two beakers is shown analogical to the dynamic nature of chemical equilibrium
Limitations of Le Chatelier's principle	Discussion The chemical equilibrium problems which the use of Le Chatelier's principle was not appropriate were discussed
Factors affecting acid strength	Use of hands-on activities , inquiry The participants were expected to find out that the strength of an acid was not related to pH and concentration of the acid solution
The particles of acid solutions	Modelling, discussion The particles of concentrated and diluted solutions of strong and weak acids were represented by models

3.2.4. Flow of Each Session of the Training Program

In this section, the flow of each session of the training program was explained to give an overall idea to the reader about implementation of the training program. It is important to note that each session had the similar flow with the others. The flow of each separate section was given in detail in Appendix A.

Before starting the activities of each session, a short presentation about the findings of the research literature on misconceptions was presented by the researcher to improve participants' pedagogical content knowledge related to misconceptions. After short presentation, the activities of the training program started with showing chosen 12th grade students' responses on "CCT" for discussion. Participants discussed the student responses from "CCT" as a group of two or three members and they were expected to decide whether the response was scientifically correct or incorrect. Then, participants were expected to suggest an activity or instructional strategy to remediate the misconceptions which they identified. The activities of the training program were developed by taking different instructional strategies into consideration according to the characteristics of the target misconceptions and demands of the subject to correct related misconceptions. Thus, these characteristics were explained before starting an activity. In all of the activities, prospective teachers actively participated. According to the demands of the activities, participants performed the activities, answered some questions, and, discussed related chemical phenomena and drew conclusions. At the end of an activity, participants were expected to evaluate the activity in terms of its effectiveness to change the target misconceptions and its contribution to their conceptual and pedagogical knowledge.

Table 3.2. Flow of the elements of a session.

Flow	Elements of a Session
1	Presentations about misconceptions
2	Showing selected 12th grade students' responses to "CCT"
3	Discussion of the student responses from "CCT" as a group
4	Suggestion of an activity or instructional strategy
5	Instructional strategies and rationale behind the activity
6	The implementation of the activity
7	Prospective chemistry teachers' evaluation of the activity

3.3. Evaluating the Impacts of the Training Program on Participants

3.3.1. Participants

A total of 22 prospective chemistry teachers (12 female, 10 male) with different levels of preparation in a chemistry teacher education program were the participants of this study. The sample consisted of two groups of prospective teachers having education in “teaching chemistry” department of a public university in Istanbul.

The first group was composed of 14 senior students who were attending an undergraduate course. These participants agreed upon to attend the training program as an integral part and additional requirement of the course. The second group of the participants was composed of a group of eight voluntary prospective chemistry teachers. Five of these prospective teachers were at the fourth year of their program, and three of them were at the second year of their program. The second group of the participants informed their willingness to participate in the study, when the training program was announced.

The training program for two groups of participants took place on two different days of the week. Yet, there was no difference in training program for two groups of participants other than the dates of the sessions.

3.3.2. Instruments and Data Collection

<u>3.3.2.1. Chemistry Concept Test (CCT) and Chemistry Concept Test Form B (CCT-B).</u> The content knowledge of prospective chemistry teachers in selected chemistry topics before the training program was evaluated with the “CCT” (Appendix C). This instrument (“CCT”) was developed during a research project by Yakmaci-Guzel and Yigit to identify student misconceptions in concepts of “particulate nature of matter”, “chemical equilibrium”, and “acid strength”. CCT and CCT-B were written data sources. One week before starting the intervention, the CCT was administered to all participants and it took more than one hour. One week after all interventions were finished, CCT-B was administered to evaluate the change in content knowledge of participants in three chemistry subjects.

To develop “CCT”, researchers reviewed the literature about misconceptions and wrote many items to identify student misconceptions about several chemistry subjects. Then, they decided to include three chemistry topics in which students have diverse misconceptions and selected seven items about these topics to include in “CCT”. Three experts analyzed the “CCT” and some parts of the test were modified according to the analyses of experts. After the pilot administration of “CCT” to students from different levels, one item was removed from the instrument in order to decrease the administration time of the instrument and make it administrable in a regular course period, 40-45 minutes in schools. The final form of “CCT” consists of six items (Yakmaci-Guzel, 2012).

The first item consisted of two parts, composing of a total of nine sub-items. For the first item, water was used as a case. In the first part of the first item, the respondents were expected to classify seven statements as true or false. Some of the statements, the false ones, included common student misconceptions about space and forces between particles of water in different phases and the relationship between the particles and the bulk matter; water. In the second part of the first item, the respondents were expected to draw the particles of ice and water vapour according to the given molecular representation of liquid water.

The second item consisted of six parts, each composed of two sub-items; so a total of twelve sub-items. Molecular representations of different matters were given in each sub-item. The molecular representations included in the order of: (i) a mixture of two compounds, (ii) a pure compound, (iii) a mixture of one element and one compound, (iv) a mono-atomic element, (v) a molecular element and (vi) a mixture of a mono-atomic element and a molecular element. The second item expected respondents to categorize the given substance as elements, compounds and mixtures according to their molecular representations and indicate what the matter was composed of. In their study, Stains and Talanquer (2007) also used similar categorization tasks; undergraduate chemistry students were asked to classify given molecular representations as elements, compounds or mixtures.

The third item consisted of three sub-items which were multiple-choice type. A chemical equilibrium reaction was introduced at the stem of the question and it was used for all three sub-items ($H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$). The distracters in multiple-choice were common student misconceptions in that subject. The first sub-item of the third item aimed to assess respondents' knowledge about the concentration of reactants and products in a chemical equilibrium condition. The second sub-item of the third item evaluated respondents' knowledge about the rates of forward and reverse reactions in a chemical equilibrium condition. The third sub-item of the third item assessed respondents' knowledge about the substances found in a chemical equilibrium condition.

The fourth item consisted of two sub-items. A chemical equilibrium was introduced at the stem of the question and participants were expected to consider the same reaction in two sub-items ($4HCl_{(g)} + O_{2(g)} \rightleftharpoons 2H_2O_{(g)} + 2Cl_{2(g)}$). The first sub-item of the fourth item aimed to assess respondents' knowledge about the effect of adding one of the reactants or products in a chemical equilibrium condition. The second sub-item of this item evaluated respondents' knowledge about the effect of adding a noble gas in a chemical equilibrium condition. Cheung (2009) also asked similar chemical equilibrium problems to chemistry teachers and concluded that teachers tended to use Le Chatelier's principle even when it was not valid.

The fifth item consisted of three sub-items. At the stem of the fifth question, a table of common acids that included the name and acidity constant of given acids and concentration and pH values of their solutions were given. The first sub-item of the fifth item expected the respondents to order given acids according to their acid strengths. The second and the third sub-items of this item aimed to understand whether respondents believed that the strength of an acid was affected when the concentration of acid solution was changed.

The sixth item consisted of two sub-items. The stem of the question introduced the reaction equations of dissociation of strong and weak acids in water and some representations for the particles of acid solutions under a magnifying glass. The sixth item expected the respondents to draw the particles in concentrated and diluted solutions of strong acids in the first sub-item and weak acids in the second sub-item. Taber (2002) suggested using molecular representations to understand the molecular nature of acidic solutions.

Table 3.3. The items of CCT and their content.

Item	Content
1a	Space and forces between particles of water , and the relationship between the particles of water and bulk matter
1b	Drawing particles of ice and water vapour according to the given molecular representation of liquid water
2	Identifying substances as elements, compounds and mixtures according to microscopic representations
3a	The relationship between the concentration of reactants and products at equilibrium condition
3b	The relationship between the rates of forward and reverse reactions at equilibrium condition
3c	The substances found in the medium at equilibrium condition
4a	The effect of adding one of the reactants to the system in equilibrium at constant pressure
4b	The effect of adding a noble gas to the system in equilibrium at constant pressure
5	Factors affecting acid strength
6	Drawing particles of strong and weak acid solutions

The chemistry content knowledge of prospective chemistry teachers after the training program was evaluated with the “Chemistry Concept Test Form-B” (CCT-B) (Appendix D). In order to form “CCT-B”, first of all, the numbers of all items were reorganized. Some of the items were retained as they were whereas some of the items were changed a little in terms of content. Items of “CCT-B” were explained in detail in the following paragraphs.

In order to write the first item of CCT-B, little changes were made on the third item of CCT. A different chemical equilibrium reaction equation was included in the stem of the question ($N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)}$). Yet, the stoichiometric coefficients were taken into consideration, the coefficients in both of the reaction equations were the same. The first and the second sub-items were not changed, only the names of the chemical substances in the third sub-item were changed according to reaction equation.

In order to write the second item of CCT-B, the fourth item of CCT was changed. A different chemical equilibrium reaction equation was included in the stem of the question

($2H_2S_{(g)} + CH_{4(g)} \rightleftharpoons 4H_{2(g)} + CS_{2(g)}$). In the first sub-item, the names of the chemical substances were changed according to the new reaction equation. In the second sub-item, a different noble gas, Argon, was added to the system and the name of the chemical substances were changed according to the new reaction equation.

In order to write the third item of CCT-B, little changes were made on the fifth item of CCT. At the stem of the question, the table included different acids with different acidity constants, and concentration and pH values. The first sub-item remained the same. The second sub-item included the names of different acids according to the changed version of the table.

The fourth item of CCT-B was the same with the sixth item of CCT. Also, the sixth item of CCT-B was the same with the second item of CCT.

In order to write the fifth item of CCT-B, some sub-items of the first item were conserved, on the other hand, some sub-items were changed. In the first part of the item, five of seven sub-items were the same with the ones in CCT. One statement of CCT which stated that "water molecules expand when water is evaporated" was replaced with another statement which stated that "water molecules shrink when ice melted". The other statement of CCT which stated that "there is air between the molecules of water vapour" was replaced with another statement which stated that "there is air between the molecules of ice". In the second part of the question, respondents had been expected to draw water molecules in solid and gas phase according to the given molecular representation of liquid water in CCT. On the other hand, respondents were expected to draw water molecules in solid and liquid phase according to the given molecular representation of water vapour in CCT-B.

3.3.2.2. Knowledge and Beliefs about Chemistry Misconceptions and Teaching Efficacy Questionnaire (KBCMTEQ). A questionnaire that consisted of eleven items was developed for this study by the researcher to measure prospective chemistry teachers' pedagogical content knowledge related to misconceptions and teaching efficacy beliefs before and after attending the training program (Appendix F). Eight of the questionnaire items (1-8) were adapted from the interview questions used in Gomez-Zwiep's (2008) study. KBCMTEQ was administered to all participants, in approximately one hour, both before and after the training program in order to see the difference in participants' pedagogical content knowledge related to misconceptions and teaching efficacy beliefs.

Four of this questionnaire items (1, 2, 3 and 8) aimed to evaluate prospective chemistry teachers' pedagogical content knowledge related to misconceptions in terms of understanding the nature of misconceptions. The first item expected respondents to define the term "misconception". The second item asked respondents to list examples of common student misconceptions in chemistry. The third item asked possible sources of student misconceptions. The eighth item asked respondents whether they thought that changing students' misconceptions was difficult or not.

Five of the questionnaire items (4, 5, 6, 7 and 11) aimed to evaluate prospective chemistry teachers' pedagogical content knowledge related to misconceptions in terms of strategies to identify and change student misconceptions. The fourth item investigated prospective teachers' preferences about taking misconceptions into consideration while preparing a lesson plan. The fifth item expected the respondents to list the methods to identify student misconceptions. The sixth item expected the respondents to list the methods to change student misconceptions. The seventh item composed of two parts. In the first part of the seventh item, respondents were expected to explain how they would change the flow of their lesson if they found out that their student have certain misconceptions during instruction. In the second part of the seventh item, respondents were expected to explain how they would change the lesson plan which they designed to teach this lesson in the future. The eleventh item expected the respondents to design a lesson flow in order to change a given specific misconception.

Two of the questionnaire items (9 and 10) were similar to the items of "Beliefs About Teaching" scale developed by Yilmaz-Tuzun (2008) and these items aimed to understand teaching efficacy beliefs of prospective chemistry teachers in terms of both instructional strategies and certain chemistry topics before and after attending the training program. The ninth item expected respondents to list the teaching methods which they believe that they could efficiently use with their current chemistry content and pedagogical knowledge and order these methods from the one which they could most efficiently use to the one which they could least efficiently use. The tenth item asked respondents which chemistry subjects they believed that they were able to teach efficiently, a three-point scale was given respondents to use while they were evaluating themselves.

Table 3.4. The items of KBCMTEQ, their construct and content.

Item	Construct	Content
1	PCK- Understanding nature of misconceptions	Definition of misconceptions
2	PCK- Understanding nature of misconceptions	Examples of misconceptions
3	PCK- Understanding nature of misconceptions	Sources of misconceptions
4	PCK- Strategies	Considering misconceptions while writing a lesson plan
5	PCK- Strategies	Diagnosis of misconceptions
6	PCK- Strategies	Remediation of misconceptions
7	PCK- Strategies	Remediation of misconceptions identified during the lesson
8	PCK- Understanding nature of misconceptions	Resistant nature of misconceptions
9	Teaching efficacy beliefs	Teaching strategies
10	Teaching efficacy beliefs	Teaching chemistry topics
11	PCK- Strategies	Writing a lesson flow designed to change a specific misconception

3.3.2.3. Program Evaluation Form (PEF). The "Program Evaluation Form" (PEF), developed by the researcher, consisted of 10 open-ended questions (Appendix G). It was administered to all participating prospective chemistry teachers after the training program in order to understand their opinions about the program. PEF was assigned to participants as a take-home paper.

The first item asked respondents whether they want to attend a similar training program after attending this program. The second item expected to see what the training program contributed to participants' teaching skills and knowledge. The third item asked the participants the most important thing which they learnt from the program. In the fourth item, respondents were expected to explain which characteristics of the training program they mostly liked and they mostly disliked. The fifth item asked respondents what should be added to/remove from the training program if it were repeated for some other groups of participants and what should be changed about the program. The sixth item asked the participants whether there were any misconceptions they noticed in themselves and corrected during the training program. In the seventh item, respondents were expected to explain how they would plan to benefit from the content and the methods of the program when they started to teach in a school. In the eighth item, respondents were expected to state the most unforgettable activity and most boring activity for them. In the ninth item, respondents were expected to explain the teaching methods they would use while teaching "particulate nature of matter," "chemical equilibrium" and "acid strength" subjects before the training program in the first part and explain the teaching methods they would use while teaching these subjects after the training program in the second part. The tenth item expected respondents to state their problems about a chemical phenomenon that they did not learn well during the training program, if any.

3.3.2.4. Interviews. The supplementary data sources; interviews, were auditory sources. Semi-structured interviews were conducted with the selected prospective teachers in order to understand what they were thinking about the change in their responses between pre- and post-measurements. In order to select the interviewees, the responses of participants on pre- and post-tests were analyzed. Preferably, the prospective teachers whose responses changed greatly from pre- to post-test were asked for interviewing and a total of 12 participants were interviewed. In the interviews, prospective teachers were expected to comment on their responses and explain the reason of change in their responses from pre- to post-measurement. The interviews were conducted individually and took approximately 30 minutes for each participant. The interviews were audio recorded and listened again during the analyses.

3.3.3. Design and Procedure

The design of this research study was "one-group pretest-posttest pre-experimental research design". Pre-experimental designs are for experiments with only one group. The one-group pretest-posttest research design involves a single group that is pre-tested, exposed to a treatment and post-tested. The effect of treatment is evaluated by comparing pre-tests and post-tests of participants (Gay, Mills and Airasian, 2006).

Before starting the training program, a questionnaire ("Knowledge and Beliefs about Chemistry Misconceptions and Teaching Efficacy Questionnaire", (KBCMTEQ)) consisting of items on pedagogical content knowledge related to misconceptions and teaching efficacy beliefs and also a concept test (“Chemistry Concept Test”, (CCT)) consisting of items about the “particulate nature of matter”, “chemical equilibrium” and “acid strength” subjects were administered to all participants.

Then, the developed training program was implemented by the researcher. During the intervention, activities took place and participants completed activity sheets (Appendix B). The intervention took five sessions long, each session of the training program was implemented in one and a half hour. The intervention took place on two different days of the week for two groups of participants. Each session was repeated for the second group of participants. Moreover, if a participant missed one session on one weekday, he/she had the chance to attend the session on the other weekday.

Three of the five sessions (Sessions 1, 2, and 5) of the training program consisted of two activities per session. After one activity finished, the following activity were performed with the same procedure. The third session consisted of three activities and the fourth session consisted of only one activity.

After the training program, for post-measurement, an equivalent form of the KBCMTEQ was administered to all participants in order to see the impacts of the program on participants’ understanding and pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. Moreover, after the training program, a similar form of CCT, “Chemistry Concept Test Form B” (CCT-B) was administered to all prospective teachers. Also, a “Program Evaluation Form” (PEF) was given to the participants as a take home work in order to understand their opinions about the impacts of the program on them.

After the training program, semi-structured interviews were conducted also with selected prospective chemistry teachers. The interview questions for each participant were designed according to his or her responses on pre- and post-instruments, thus, it can be said that, the interview questions of each participant was unique. The interviews were conducted to investigate the reasons why the responses of prospective teachers changed or did not change from pre- to post-tests. In the interviews, interviewees were expected to comment on their written responses and comment on why their prior concepts were changed or not changed after the training program.

3.4. Data Analysis

In the current research study, there are three different main instruments: the CCT, the KBCMTEQ, and the PEF. A mixture of quantitative and qualitative analysis methods was utilized for analyzing responses on the CCT, the KBCMTEQ and the PEF. As a supplementary tool, interviews were also used. The names of participants were not used, instead an ID number was assigned for each participant in order to ensure confidentiality of participants.

3.4.1. Coding and Scoring Chemistry Concept Test Responses

For the first research question, prospective chemistry teachers' conceptual understandings were evaluated by their performance on CCT. Abraham, Grzybowski, Renner and Marek (1992) used six categories to evaluate students' understanding in an open-ended question: Sound understanding, partial understanding, partial understanding with specific misconception, specific misconceptions, no understanding and no response. The responses of the prospective teachers on CCT in this study were categorized through similar five categories:

- Scientific Understanding (SU); a response that indicated a full and correct understanding of the chemical phenomena was categorized as SU category.
- Partial Understanding (PU); a response that indicated a scientific understanding of the chemical phenomena but having insufficient explanation was categorized as PU category.
- Partial Understanding with Specific Misconceptions (PUSM); a response that included both a correct understanding and misunderstanding together was categorized as PUSM category.
- Specific Misconceptions (SM); a response which indicated the participant has completely non-scientific understanding about the chemical phenomena was categorized as SM category.

- No Answer and No Explanation category was used for two cases: when the participant did not give any answer for an item and when the participant selected the correct or a wrong answer but did not explain his/her choice.

Evaluation rubrics for each item and sub-items of CCT were developed by the researcher. Evaluation rubrics for six items of CCT were listed as tables (Appendix E).

Numerical values were assigned to each type of conceptual understanding categories. “No Answer and No Explanation” category were not included in the analysis and treated as missing value. The numerical points given for other categories of responses on CCT were shown in Table 3.5.

Table 3.5. Numeric points of the categories of responses on CCT.

Numeric Point	**The Category of the Response on CCT**
0	Specific Misconceptions
1	Partial Understanding with Specific Misconceptions
2	Partial Understanding
3	Scientific Understanding

An increase in the numeric point of the categories of responses, from pre-test to post-test, among these four categories may or may not indicate prospective teachers’ enhancement of content knowledge. For example, a change from numeric point “0” to “2” will indicate the change of misconception, but, change from numeric point “0” to “1” will indicate the prospective teacher still have a misconception. In order to solve this conflict, the data was re-coded. The raw data was re-coded by assigning a numeric point 1 to the answers which were without any misconceptions and a numeric point 0 to the answers which included some misconceptions. Thus, change from numeric points “0” to “1” always indicated the change of misconception. Table 3.6 shows the numeric points given for the categories of recoded data.

Table 3.6. Numeric points for recoded data.

Numeric Point	Recoded Categories
0	Specific Misconceptions & Partial Understanding with Specific Misconceptions
1	Partial Understanding & Scientific Understanding

To check the reliability of the categorization of participants' responses, randomly selected 6 pre- and 5 post-test were categorized by another scorer according to evaluation rubrics. The Spearman rho correlation coefficients between two scorers; in other words inter-rater reliability; was found to be 0.799 for raw data and 0.884 for recoded data. The responses in which the scorers had disagreement were discussed and an agreement was tried to be reached. Thus, Spearman rho correlation between two scorers was found to be 0.832 for raw data and 0.991 after the discussion of scorers.

3.4.2. Wilcoxon Signed Rank Test

In order to analyze data with parametric tests, four basic assumptions must be met. Firstly, data must be get from normally distributed population. Secondly, variance must be homogeneous throughout the data. Thirdly, data should be measured at least in interval level. Finally, data from different subjects must be independent. On the other hand, non-parametric tests make no assumptions about the type of the data (Field, 2000). In the current study, participants were not selected randomly and the normal distribution of the participants was not considered. Additionally, data measured for the participants' content knowledge were at ordinal level. Bryman and Cramer (2005) described ordinal variables as classification according to categories, but categories can be ordered in terms of more or less of a construct.

The Wilcoxon signed rank test is used for situations in which there are two sets of scores to compare, but these scores come from the same subjects (Field, 2000). In the current study, there is one group of participants; prospective chemistry teachers, and there are two sets of scores; scores obtained from CCT and CCT-B . Thus, pre-test and post-test scores of participants were compared by Wilcoxon signed rank test.

In this study, recoded data was analyzed with Wilcoxon signed rank test. Thus, in the analysis, a change from the category with a numeric point "0" to the category with a numeric point "1" resulted a positive rank and indicated that the respondent corrected his or her misconception after the program. On the other hand, a change from the category with a numeric point "1" to the category with a numeric point "0" resulted a negative rank and indicated that the respondent had a misconception after the program whereas he or she did not have a misconception before the program. The ties in the analysis might result from two situations, it may indicate that prospective teachers did not have a misconception both before and after the program or had a misconception both before and after the program.

3.4.3. Analysis of KBCMTEQ and PEF

Gay *et al.* (2006) described qualitative data analysis as a process of breaking down data into smaller pieces, determining their import and putting pieces together in a more general and analytical form. For qualitative analysis, researchers frequently coded qualitative data which referred to the process of categorically marking units of texts, such as words, sentences, paragraphs, with codes and labels in order to indicate patterns and meaning.

In the analysis of KBCMTEQ, prospective chemistry teachers' responses on this instrument were examined, the main points which the participants mentioned were noted, these main points constituted the codes. Among these codes derived from different prospective teachers' responses, the common ones were combined in order to show how the trend changed from pre-measurement to post-measurement. Similarly, in the analysis of PEF, the main points in the participants' responses were identified and combined in order to show the percentage of participants which stated a particular opinion. Moreover, the participants' responses were also included as examples in the analyses of both KBCMTEQ and PEF.

3.5. Validity Issues

Gay *et al.* (2006) described threats to the validity of an experiment as any uncontrolled extraneous variables affecting performance on the dependent variable. How threats to validity were controlled in this study was explained in the following paragraphs.

3.5.1. History

History, as a threat to validity, refers to any event occurring the study and may affect the dependent variable (Gay *et al.*, 2006). The implementation of the training program took five weeks and there was not any extraordinary event that could affect the results of the current study.

3.5.2. Maturation

Maturation, as a threat to validity, refers to natural development of individuals physically, intellectually and emotionally over a period of time (Gay *et al.*, 2006). Since all intervention and testing took approximately two months, participants were not expected to be matured.

3.5.3. Testing

Testing, as a threat to validity, refers to possibility of improved performance on a post-test as a result of having taken a pre-test (Gay *et al.*, 2006). In order to decrease testing effect, a similar form of CCT was administered to participants after the training program.

4. RESULTS

This section included the analysis of the participating prospective chemistry teachers' responses on the instruments used in this study to answer the research questions.

The first research question examined whether participants' conceptual understanding related to concepts of "particulate nature of matter", "chemical equilibrium" and "acid strength" subjects after attending the program changed by conducting statistical analysis of the prospective chemistry teachers' responses on CCT.

The second research question investigated whether participants' pedagogical content knowledge related to misconceptions changed after attending the training program. The third research question investigated the difference in participants' teaching efficacy beliefs before and after attending the training program. In order to answer the second and the third research questions, participating prospective chemistry teachers' responses on KBCMTEQ were analyzed qualitatively and described in frequency percentages with exemplary quotations.

The fourth research question examined the opinions of the prospective chemistry teachers about the training program. The participants' responses on PEF were analyzed qualitatively to answer the fourth research question and the results were described in frequency percentages with exemplary quotations.

4.1. Findings Related to the Research Question 1

In order to evaluate the chemistry content knowledge of the prospective chemistry teachers, a concept test, CCT, that consists of six questions in "particulate nature of matter", "chemical equilibrium" and "acid strength" subjects was administered to the participants.

The first research question was: *"Is there any difference between prospective chemistry teachers' chemistry content knowledge before and after attending the training program?"* To answer the first research question, the change in the categories of prospective chemistry teachers' responses for each item of CCT before and after attending the training program was analyzed by using IBM SPSS Statistics 20 "Wilcoxon signed rank test".

4.1.1. The First Item of CCT

The first item of CCT includes two parts and a total of nine sub-items. "Wilcoxon signed rank test" indicated that the responses of the participants were significantly different before and after attending the training program in seven of these nine sub-items. The results indicated that, prospective chemistry teachers had significantly higher scores in six of nine sub-items and significantly lower scores in one of nine sub-items in post measurement.

The analysis of the first sub-item of the first item (1a1) showed that the training program elicited a statistically significant change in prospective chemistry teachers' understanding "the concept of empty space between the particles of matters" ($Z = -2.236$, $p = 0.025$, see Table 4.1). Before the training program, eight prospective teachers had a misconception that "there was air between the particles of matter".

After the training program, only one prospective teacher had the non-scientific idea that, "there was air between the particles of matter". Moreover, one prospective teacher had a misconception that "the particles of solids could not have any motion" and one prospective teacher stated the non-scientific view that "there was nothing between the particles of matter if the space between particles was little" after the program.

In the second sub-item of the first item (1a2), it was seen that there was a significant effect of the training program on increasing prospective chemistry teachers' understanding about "the space between the molecules of ice" ($Z = -3.162$, $p = 0.002$, see Table 4.1). When the misconceptions of prospective chemistry teachers were analyzed, before the program, eight prospective teachers stated that the space between the particles of ice is less than those of liquid water without considering exceptional property of ice resulted from crystalline structure of water molecules in solid phase. Furthermore, three participants had had the non-scientific view that there was no space between the molecules of water in solid phase. Moreover, one prospective teacher believed that there was space between the molecules of ice, but filled with air molecules. The prospective teacher stated that:

“Bu biraz aralık mesafe havadır. Buz moleküllerinin etkileşimi sırasında hava buzun içerisinde sıkışır.” (The space between molecules means air between molecules. The air sticks in ice because of the attraction between the molecules of ice) (Prospective teacher #02).

After the training program, only one participant stated the non-scientific idea that “the space between the particles of ice is less those of water in liquid form” whereas eight participants had had this misconception before the program. Also, two prospective teachers thought that there was no space between the molecules of water in solid phase whereas three participants had this misconception before the program. The prospective teacher who thought that there was space between the molecules of ice but filled with air molecules changed this non-scientific view and stated that:

“Elektrostatik bir etkileşim vardır ve bu etkileşimden kaynaklanan ve moleküllerin dizilişinden kaynaklanan bir boşluk vardır.” (There is an attraction force and there is space between molecules resulted from this attraction and the arrangement of molecules) (Prospective teacher #02).

The Wilcoxon signed rank test related to the third sub-item of the first item (1a3) indicated a significant difference which meant participants increased their understanding and corrected their misconceptions about “hydrogen bonding” (Z = -2.236, p = 0.025, see Table 4.1). Before the training program, seven prospective teachers stated that it was the hydrogen bond that kept hydrogen and oxygen atoms together within the water molecule. Moreover, one participant mentioned H_2 and O_2 molecules within the water molecule. After the training program, only two participants stated that it was the hydrogen bond that kept hydrogen and oxygen atoms together within the water molecule. Moreover, one participant confused intermolecular forces and intramolecular forces.

There was significant difference in the fourth sub-item of the first item (1a4). This result showed that participants had better understanding about “the relationship between the bulk matter and its particles” after the training program ($Z = -2.000$, $p = 0.046$, see Table 4.1). In pre-test, three participants thought that the particles of a matter might be hard or soft. In addition, one participant stated that water molecules were hard when water was in solid phase and they were soft when water was in liquid and gas phases. She stated that:

“Moleküllerdeki ısı miktarı arttıkça daha yumuşak hale gelebilirler.” (When the amount of heat energy in the molecules increase, molecules can get softer) (Prospective teacher #15).

After the training program, only one participant thought that the particles of a matter might be hard or soft whereas three participants thought in that way before the program. None of the participants had the misconception that the water molecules were hard when water was in solid phase and they were soft when water was in liquid and gas phases after the program whereas one participant had this misconception before the program.

The test results showed that there was a statistically significant difference between pre-test and post-test scores of the fifth sub-item of the first item (1a5) of CCT. Analysis showed that the training program increased participants’ understanding about “the amount of space between the molecules of water in liquid form” ($Z = -2.111$, $p = 0.035$, see Table 4.1). Before the training program, 11 prospective teachers stated that “the amount of space between the particles of liquid water was more than those of ice” without considering exceptional arrangement of water molecules in solid and liquid phases. Also, one prospective teacher had the non-scientific view that there was not any space between the molecules of water when it was in liquid phase, he stated that:

“Suyun sıvı halinde moleküller arasında boşluk yoktur. Olsaydı sıkıştırılabilirdi.” (There is no space between the molecules of liquid water. If there were some space, water could be compressed) (Prospective teacher #07).

After the program, five participants stated the misconception that "the space between the particles of liquid water was more than those of ice" whereas 11 participants stated it before the program. Furthermore, the participant who had a misconception that there was no space between the molecules of water when it was in liquid phase changed his view:

"Doğru. Moleküller katıya göre daha rahat hareket edebiliyorlar." (Right. The molecules of water in liquid state have a motion more freely than those in the solid state) (Prospective teacher #07).

There was no statistically significant difference between prospective teachers' responses to sixth and seventh sub-items of the first item (1a6 and 1a7). The sixth sub-item assessed whether participants had the misconception that "water molecules expand when water was evaporated". The seventh sub-item assessed participants' understanding about "conservation of mass during evaporation of water". Majority of the participants did not have a misconception about these sub-items both before and after the program.

In the eighth sub-item of the first item (1b1), a significant difference was found in participants' understanding of "the arrangement of molecules in ice" ($Z = -2.449$, $p = 0.014$, see Table 4.1). Before the training program, 19 participants stated that the space between the particles of ice was less than those of liquid water and one participant stated that there was no space between the particles of ice. In addition, seven participants drew water molecules in a disordered structure. Moreover, one participant had the misconception that the molecules of ice were smaller than the molecules of liquid water and water vapour.

After the training program, 15 participants stated that the space between the particles of ice was less than that of liquid water, whereas 19 participants had this misconception before the program. Also, five participants drew water molecules in a disordered structure, whereas seven participants indicated this misconception before the program. Moreover, one participant had the misconception that the molecules of ice could not have any motion.

In the ninth sub-item of the first item (1b2), negative ranks were higher than the positive ranks ($Z = -3.051$ (based on positive ranks); $p = 0.002$, see Table 4.1). For this sub-item, the participants were expected to draw “the particles of water vapour” in pre-test whereas they were expected to draw “the particles of liquid water” in post-test. In pre-test, one participant had the misconception that “when water was evaporated, the molecules decomposed to hydrogen and oxygen atoms”. Also, one participant had the misconception that the molecules of water vapour were larger than molecules of ice and liquid water. In post-test, 13 participants showed the misconception that the space between the particles of liquid water was more than those of ice.

Table 4.1. Results of the Wilcoxon signed rank test for the first item of CCT.

Number of Item		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
1a1	Negative Ranks	0	.00	.00	-2.236	**.025**
	Positive Ranks	5	3.00	15.00		
	Ties	17				
	Total	22				
1a2	Negative Ranks	0	.00	.00	-3.162	**.002**
	Positive Ranks	10	5.50	55.00		
	Ties	12				
	Total	22				
1a3	Negative Ranks	0	.00	.00	-2.236	**.025**
	Positive Ranks	5	3.00	15.00		
	Ties	17				
	Total	22				
1a4	Negative Ranks	0	.00	.00	-2.000	**.046**
	Positive Ranks	4	2.50	10.00		
	Ties	15				
	Total	19				
1a5	Negative Ranks	2	6.00	12.00	-2.111	**.035**
	Positive Ranks	9	6.00	54.00		
	Ties	10				
	Total	21				
1a6	Negative Ranks	1	1.50	1.50	.000	1.000
	Positive Ranks	1	1.50	1.50		
	Ties	18				
	Total	20				
1a7	Negative Ranks	1	2.00	2.00	-.577	.564
	Positive Ranks	2	2.00	4.00		
	Ties	18				
	Total	21				
1b1	Negative Ranks	0	.00	.00	-2.449	**.014**
	Positive Ranks	6	3.50	21.00		
	Ties	15				
	Total	21				
1b2	Negative Ranks	12	7.00	84.00	-3.051*	**.002**
	Positive Ranks	1	7.00	7.00		
	Ties	9				
	Total	22				

*Based on positive ranks

4.1.2. The Second Item of CCT

The second item of CCT includes six parts and twelve sub-items. In each part, molecular representation of a matter is given. Respondents are expected to classify the matter as a mixture, a compound or a pure substance and describe the constituents.

There was no sign difference between prospective teachers' responses for eleven of twelve sub-items. The only significant difference between pre- and post-measurement was found in the sixth sub-item of the second item (2c2).

The first and the second sub-items of the second item (2a1 and 2a2) investigated whether participants could identify a mixture of two compounds and describe its constituents. Majority of the participants did not have a misconception about these sub-items both before and after the program.

The third and the fourth sub-items of the second item (2b1 and 2b2) investigated whether participants could identify the particles of a pure compound and describe its constituents. The participants mainly did not have a misconception for the third sub-item (2b1) both before and after the training program. Prospective teachers could identify the substance as a pure compound. Yet, some prospective teachers had misconception of "using the terms atom and element interchangeably" both before and after the program, so there was no significant difference between pre- and post-measurement in fourth sub-item (2b2).

In the third part of the second item, the particles of a mixture that was consisted of a compound and a molecular element were represented. The fifth sub-item of the second item (2c1) investigated whether participants can identify a mixture of an element and a compound. Participants generally did not have a misconception for the fifth sub-item (2c1), and could state that it was a mixture both before and after the training program so there was no significant difference. Yet, the analysis showed that there was statistically significant difference between prospective chemistry teachers' responses between the pre-measurement and post-measurement in sixth sub-item (2c2). In the sixth sub-item, a significant difference between pre- and post-responses of the prospective teachers showed that participants increased their achievement in “identifying the particles of an element and a compound” (Z = -2.333, *p* = 0.020, see Table 4.2). Before the training program, six prospective teachers used the terms of element and atom, interchangeably. Also, three prospective teachers classified molecular elements as compounds. One of these prospective teachers stated that:

“Farklı atomlar farklı iki tane bileşik oluşturmuştur. Aynı tür atomlar da bileşik oluşturmuştur ve 2 farklı bileşik vardır.” (Different atoms form different compounds. Also, the same kind of atoms form a compound and so there are two different compounds) (Prospective teacher #19).

After the program, for the sixth sub-item (2c2), three participants used the terms element and atom interchangeably whereas six prospective teachers used these terms interchangeably before the program. In addition, three participants categorized molecular elements as compounds as in the pre-measurement.

The seventh and the eighth sub-items of the second item (2d1 and 2d2) investigated whether participants could identify a mono-atomic element from its representation and describe its constituents. Majority of the participants could identify the matter as a pure substance in the seventh sub-item (2d1) and stated that it was consisted of only one kind of element in the eight sub-item before and after the training program (2d2) .

The ninth and the tenth sub-items of the second item (2e1 and 2e2) investigated whether participants could classify the particles of a molecular element and describe its constituents. The results did not indicate a statistically significant difference because majority of the participants did not have a misconception about these sub-items both before and after the program.

Finally, the eleventh and the twelfth sub-items of the second item (2f1 and 2f2) investigated whether participants could identify the particles of a mixture of a mono-atomic element and a molecular element and describe its constituents. The results did not indicate a statistically significant difference because majority of the participants did not have a misconception about these sub-items both before and after the program.

Table 4.2. Results of the Wilcoxon signed rank test for the second item of CCT.

Number of Item		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
2a1	Negative Ranks	2	2.50	5.00	.000	1.000
	Positive Ranks	2	2.50	5.00		
	Ties	18				
	Total	22				
2a2	Negative Ranks	2	4.00	8.00	-1.134	.257
	Positive Ranks	5	4.00	20.00		
	Ties	15				
	Total	22				
2b1	Negative Ranks	0	.00	.00	-1.414	.157
	Positive Ranks	2	1.50	3.00		
	Ties	19				
	Total	21				
2b2	Negative Ranks	4	5.50	22.00	-.632	.527
	Positive Ranks	6	5.50	33.00		
	Ties	11				
	Total	21				
2c1	Negative Ranks	1	1.50	1.50	.000	1.000
	Positive Ranks	1	1.50	1.50		
	Ties	17				
	Total	19				
2c2	Negative Ranks	1	5.00	5.00	-2.333	**.020**
	Positive Ranks	8	5.00	40.00		
	Ties	10				
	Total	19				
2d1	Negative Ranks	1	1.00	1.00	-1.000*	.317
	Positive Ranks	0	.00	.00		
	Ties	19				
	Total	20				
2d2	Negative Ranks	0	.00	.00	.000	1.000
	Positive Ranks	0	.00	.00		
	Ties	20				
	Total	20				
2e1	Negative Ranks	0	.00	.00	-1.414	.157
	Positive Ranks	2	1.50	3.00		
	Ties	18				
	Total	20				
2e2	Negative Ranks	0	.00	.00	-1.732	.083
	Positive Ranks	3	2.00	6.00		
	Ties	16				
	Total	19				
2f1	Negative Ranks	1	2.00	2.00	-.577	.564
	Positive Ranks	2	2.00	4.00		
	Ties	17				
	Total	20				
2f2	Negative Ranks	0	.00	.00	-1.414	.157
	Positive Ranks	2	1.50	3.00		
	Ties	16				
	Total	18				

*Based on positive ranks

4.1.3. The Third Item of CCT

The third item of CCT includes three sub-items. The Wilcoxon signed rank analysis of the third item showed that prospective chemistry teachers had significantly better scores in two of the three sub-items. In the first sub-item of the third item (3a), there was a statistically significant change that showed that participants understanding about "the concentration of the reactants and products in a chemical equilibrium reaction" was increased (Z = -2.236, p = 0.025, see Table 4.3). When the responses of the participants were analyzed, it was seen that, 11 prospective teachers had believed that the concentrations of reactants and products were proportional with the coefficients in reaction equation before the program. Moreover, one prospective teacher stated that "concentration of a gas could not be calculated only liquids could have concentration". He stated before the program that:

"Molarite sıvılar için ölçülen bir değerdir." (Only concentration of liquids can be calculated) (Prospective teacher #17).

After the training program, five participants stated that the concentrations of reactants and products are proportional with the coefficients in reaction equation, whereas 11 participants believed this non-scientific idea before the program. Also, two participants stated that the concentrations of reactants and products would be the same at the chemical equilibrium condition after the program. The prospective teacher who had a misconception that only liquids can have concentration corrected this non-scientific view and stated after the program that:

"Tepkime dengededir ve dengeyi etkileyen diğer faktörler belirtilmediği için kesin bir yorum yapamıyoruz." (The reaction is at equilibrium and, since the factors affecting equilibrium are not explained, we cannot make a definite comment on this) (Prospective teacher #17).

The answers to the second sub-item of the third item (3b) showed that the training program also resulted a statistically significant change and enhanced participants' understanding of "the rates of forward and reverse reactions in a chemical equilibrium situation” (Z = -2.828, p = 0.005, see Table 4.3). Results of the analysis indicated that, before attending the training program, four prospective teachers in this study had a misconception that the rates of forward and reverse reactions were proportional to the coefficients in the reaction equation. In addition, two prospective teachers stated that the rates of forward and reverse reactions could not be calculated at the moment of equilibrium. Also, three prospective teachers had a misconception that the rate of forward reaction was higher in chemical equilibrium. One of these three participant stated that the rate of forward reaction would be higher than that of reverse reaction because the reaction has a tendency to produce products. She stated that:

“İleri reaksiyon daha hızlıdır çünkü maddeler birbirleriyle etkileşip yeni bir ürün oluşturmaya meyillidirler.” (The rate of forward reaction is higher, because reactants have a tendency to produce a new product) (Prospective teacher #20).

After attending the training program, only one prospective teacher had a misconception that the rates of forward and reverse reactions were proportional to the coefficients in the reaction equation whereas four prospective teachers had this misconception before the program. Also, only one prospective teacher had a misconception that the rates of forward and reverse reactions could not be calculated whereas two prospective teachers stated this misconception before the program. None of the prospective teachers had a misconception that the rate of forward reaction was higher in chemical equilibrium whereas three participants stated this before the program. After the program, the prospective teacher who stated the rate of forward reaction would be higher, corrected this misconception by stating that:

“Başlangıçta ileri tepkime daha hızlıdır ancak dengeye ulaştığında ileri ve geri tepkimelerin hızları eşitlenir.” (At the beginning of the reaction, the rate of forward reaction is higher. When the equilibrium is reached, the rates of forward and reverse reactions become equal) (Prospective teacher #20).

On the other hand, there was no statistically significant difference in pre-test and post-rest responses of participants in the third sub-item of the third item (3c) as can be seen in Table 4.3. The third sub-item of the third item investigated participants’ knowledge about the substances found in the medium at chemical equilibrium. A high number of participants did not have a misconception about this sub-item before and after the program so no significant difference was found.

Table 4.3. Results of the Wilcoxon signed rank test for the third item of CCT.

Number of Item		**N**	**Mean Rank**	**Sum of Ranks**	**Z**	**Asymp. Sig. (2-tailed)**
3a	Negative Ranks	0	.00	.00	-2.236	**.025**
	Positive Ranks	5	3.00	15.00		
	Ties	15				
	Total	20				
3b	Negative Ranks	0	.00	.00	-2.828	**.005**
	Positive Ranks	8	4.50	36.00		
	Ties	11				
	Total	19				
3c	Negative Ranks	0	.00	.00	-1.000	.317
	Positive Ranks	1	1.00	1.00		
	Ties	20				
	Total	21				

4.1.4. The Fourth Item of CCT

The fourth item of CCT included two sub-items. In the analysis of the fourth item, it was seen that the pre-test and post-test responses of prospective chemistry teachers were not statistically significant in none of two sub-items. The first sub-item of the fourth item aimed to assess prospective teachers' knowledge about "chemical equilibrium conditions when Le Chatelier's principle was not valid". The results showed that all of prospective teachers had misconceptions about this subject before the program; they applied Le Chatelier's principle despite the fact that the use of that principle was not appropriate for this problem. The majority of the participants also had this misconception after the program, so no significant difference was found between participants' understanding before and after the training program. The second sub-item of the fourth item aimed to assess prospective teachers' knowledge about adding a noble gas to a system of chemical equilibrium at constant pressure. The results showed that majority of the prospective teachers had a misconception of "adding a noble gas to a system of chemical equilibrium at constant pressure did not disturb the equilibrium" without considering the effect of adding noble gas on final volume before the program. Majority of the participants still had this misconception after the program, so no significant difference was found. It can be concluded that, the training program did not significantly affect participants' understanding about adding substances to chemical equilibrium systems at constant pressure.

Table 4.4. Results of the Wilcoxon signed rank test for the fourth item of CCT.

Number of Item		**N**	**Mean Rank**	**Sum of Ranks**	**Z**	**Asymp. Sig. (2-tailed)**
4a	Negative Ranks	0	.00	.00	-1.414	.157
	Positive Ranks	2	1.50	3.00		
	Ties	20				
	Total	22				
4b	Negative Ranks	1	3.50	3.50	-1.633	.102
	Positive Ranks	5	3.50	17.50		
	Ties	15				
	Total	21				

4.1.5. The Fifth Item of CCT

The fifth item of CCT included three sub-items. The analysis of the fifth item showed that prospective chemistry teachers had significantly higher scores in all of these three sub-items after attending the program. In the first sub-item of the fifth item (5a), analysis indicated a statistically significant change that the training program enhanced participants' understanding about "the factors affecting the strength of acids" ($Z = -3.162$, $p = 0.002$, see Table 4.5). Results of the analysis of participants' misconceptions indicated that, before attending the training program, 10 prospective teachers believed that only pH value of an acid solution determined the strength of an acid. Also, two prospective teachers believed that both acidity constant of an acid and the pH of an acid solution determined the strength of an acid. Moreover, one prospective teacher believed that both of the concentration and the pH of an acid solution determined the strength of an acid.

After the training program, only one prospective teacher had the misconception that the strength of an acid was depended on pH value of the acid solution, whereas 10 participants had this misconception before the program. Also, similar to pre-test, one prospective teacher had the misconception that both of the concentration and the pH of an acid solution determined the strength of an acid. No prospective teachers believed that both acidity constant of an acid and the pH of an acid solution determined the strength of an acid, whereas two participants had this misconception before the program. Different from pre-test, one prospective teacher had the misconception that both of the acidity constant of an acid and the concentration of the acid solution determined the strength of an acid.

A significant difference in pre- and post-responses of the participants in the second and third sub-items of the fifth item (5b and 5c) indicated an increase in prospective chemistry teachers' understanding about "the relationship between the concentration of an acid solution and the strength of the acid" (Z = -3.742, p = 0.000, and Z = -2.828, p = 0.005 respectively, , see Table 4.5). Analysis of misconceptions of participants showed that, 11 prospective teachers had a misconception that the strength of an acid would increase if the concentration of the acid solution was increased before the training program. Moreover, two prospective teachers stated that pH of an acid solution would not change if the concentration of the solution was increased. Also, one prospective teacher stated that the strength of an acid was depended on the pH value of the acid solution. In addition, one prospective teacher stated that the percentage of an acid found in water would decrease if the concentration of the acid solution were increased. Also, one prospective teacher stated that the pH of an acid solution would increase, if its concentration were increased. Moreover, one prospective teacher stated that the hydrogen bonding in HNO_3 increases its acid strength. Furthermore, three prospective teachers believed that increasing the concentration of an acid solution would increase the acidity constant. One of these prospective teachers stated that:

"Ka değeri artar ve asidikliği artar yani asitlik kuvveti artar" (The value of acidity constant increases, I mean, the strength of the acid increases.) (Prospective teacher #19)

After the training program, four prospective teachers had the misconception that the strength of an acid would increase if the concentration of the acid solution was increased whereas 11 participants had this misconception before the program. None of the prospective teachers stated other misconceptions mentioned in the previous paragraph. One of the participants who stated that increasing the concentration of an acid solution would increase the acidity constant before the program corrected his conceptions after the program and stated that:

"Asitlik kuvveti değişmez. Asitlik kuvveti molaritelere göre değişmez." (The strength of the acid does not change. The strength of an acid is not related to the concentration of the acid solution) (Prospective teacher #19).

Table 4.5. Results of the Wilcoxon signed rank test for the fifth item of CCT.

Number of Item		**N**	**Mean Rank**	**Sum of Ranks**	**Z**	**Asymp. Sig. (2-tailed)**
5a	Negative Ranks	0	.00	.00	-3.162	**.002**
	Positive Ranks	10	5.50	55.00		
	Ties	7				
	Total	17				
5b1	Negative Ranks	0	.00	.00	-3.742	**.000**
	Positive Ranks	14	7.50	105.00		
	Ties	5				
	Total	19				
5b2	Negative Ranks	0	.00	.00	-2.828	**.005**
	Positive Ranks	8	4.50	36.00		
	Ties	8				
	Total	16				

4.1.6. The Sixth Item of CCT

The sixth item of CCT included two sub-items. For the first sub-item (6a), participants were expected to draw "the dissolution of strong acids in water". Some of the prospective teachers had misconceptions about this subject before and after the training program and so no significant effect of the program on the participants' understanding for this subject was observed.

The analysis of the sixth item also showed that prospective chemistry teachers had significantly higher scores in the second sub-item of the sixth item (6b). In this item, the analysis showed that participants' understanding about "the dissolution of weak acids in water" increased (Z = -2.449, p = 0.014, see Table 4.6). When prospective teachers were expected to draw the particles of weak acid solutions, some prospective teachers tended to draw the particles of ions and water in the same ratio in both of concentrated and diluted solutions. It can be seen from these drawings that these prospective teachers had a misconception about the concept of concentration. Before the training program, five prospective teachers drew the particles of ions and water with the same ratio in concentrated and diluted weak acid solutions. Also, three participants drew a representation with different amounts of H_3O^+ and A^- ions that was not correct according to the reaction equation. Also one participant stated that the ionization percentage of weak acids in concentrated and diluted solutions were different.

After the training program, two participants drew the particles of ions and water with the same ratio in concentrated and diluted weak acid solutions whereas five prospective teachers had this misconception before the program. Also, only one participant drew different amounts of H_3O^+ and A^- ions in his/her representation after the training program whereas three participants had this misconception before the program. None of the participants had the misconception of “the different ionization percentage of weak acids in concentrated and diluted solution” whereas 1 participant had this misconception before the program. In addition, one prospective teacher indicated a hundred percent dissociation of a weak acid in water.

Table 4.6. Results of the Wilcoxon signed rank test for the sixth item of CCT.

Number of Item		**N**	**Mean Rank**	**Sum of Ranks**	**Z**	**Asymp. Sig. (2-tailed)**
6a	Negative Ranks	4	6.00	24.00	-.905	0.366
	Positive Ranks	7	6.00	42.00		
	Ties	9				
	Total	20				
6b	Negative Ranks	0	.00	.00	-2.449	**0.014**
	Positive Ranks	6	3.50	21.00		
	Ties	13				
	Total	19				

4.1.7. Analysis Done by Collecting Items Related to Same Subjects

CCT included two items for each of three different chemistry subjects; “particulate nature of matter”, “chemical equilibrium”, and, “acid strength”. Table 4.7 shows the numbers of items and corresponding subjects.

Table 4.7. Item number and corresponding subjects in CCT.

Item #	Subject
1	Particulate nature of matter
2	Particulate nature of matter
3	Chemical equilibrium
4	Chemical equilibrium
5	Acid strength
6	Acid strength

A score for an item was calculated via adding points that a respondent obtained from all sub-items of corresponding item. Then, the scores of two items about the same subject were summed up and so the total points that the prospective chemistry teachers obtained in each subject was calculated. The rankings of the participants according to total points of the subjects before and after the program were compared in order to see "the change in prospective chemistry teachers' understanding in terms of these three subjects". A Wilcoxon signed rank test indicated that prospective chemistry teachers had significantly higher scores in all of three subjects: "particulate nature of matter" (Z = -3.226, p = 0.001), "chemical equilibrium" (Z = -3.611, p = 0.000), "acid strength" (Z = -3.856, p = 0.000).

Table 4.8. Results of the Wilcoxon signed rank test for the subjects of CCT.

Number of Item		N	Mean Rank	Sum of Ranks	Z	Asymp. Sig. (2-tailed)
1+2	Negative Ranks	3	6.33	19.00	-3.226	**.001**
	Positive Ranks	17	11.24	191.00		
	Ties	2				
	Total	22				
3+4	Negative Ranks	0	.00	.00	-3.611	**.000**
	Positive Ranks	16	8.50	136.00		
	Ties	6				
	Total	22				
5+6	Negative Ranks	0	.00	.00	-3.856	**.000**
	Positive Ranks	19	10.00	190.00		
	Ties	1				
	Total	20				

4.2. Findings Related to the Research Question 2

The second research question was: "*Is there any difference in prospective chemistry teachers' pedagogical content knowledge related to misconceptions before and after attending the training program?*" In order to understand whether prospective chemistry teachers' pedagogical content knowledge related to misconceptions enhanced, the KBCMTEQ was administered to the participants before and after attending the training program. The participating prospective chemistry teachers' responses on four items of KBCMTEQ were analyzed in order to understand PCK in terms of understanding the nature of misconceptions. The participants' responses on five items of KBCMTEQ were analyzed in order to understand PCK in terms of strategies to identify and change student misconceptions. The results of the findings related to PCK in terms of understanding the nature of misconceptions and strategies to identify and change were described in the following sub-sections.

4.2.1. PCK in terms of Understanding the Nature of Misconceptions

4.2.1.1. The First Item of KBCMTEQ. The first item of the KBCMTEQ expected the participating prospective teachers *"to define the term misconception"*. Before the training program, 21 of 22 participants could provide a definition of misconception. Participants generally described misconceptions as misunderstanding a science concept. After the training program, 21 of 22 participants gave a definition. Yet, one of the participants stated how she would explain a chemistry subject if a student had misconception about the related topic rather than defining the term. When she was expected to define misconception, in the interview conducted with her at the end of the study, she described the misconception as:

"Kavram yanılgısı bir [konseptin] bilinen bilimsel gerçeklerinin veya ifadelerinin yanı sıra çocukların kafasında oluşturduğu onunla ilgili kendi açıklamaları.. Bunlar bilimsel değil tabii onlara göre bilimsel bize göre değil. Bilimsel gerçekle çakışıyor" (Misconception means children's own explanation about a concept which they formed in their mind and it is beyond the scientific explanations. Misconceptions are not scientific, it may seem scientific for children but it is not scientific, in fact. They contradict with the scientific facts) (Prospective teacher #06).

The prospective teacher who could not give any definition of misconceptions before the program described the term after the program as:

"Kavram yanılgısı öğrencilerin bilimsel kavramı yanlış bilmeleri" (Misconception is knowing a scientific concept in a wrong way) (Prospective teacher #07).

The number of prospective chemistry teachers who stated some sources and examples of misconceptions while they were defining misconceptions before and after attending the training program were shown in Table 4.9 with exemplary excerpts.

Table 4.9. The results of the first item of KBCMTEQ.

The Components of PCK		**#**	**Exemplary excerpts**
Before	Participants who included a source in definition	3	*"Kişinin öğretilen bir kavramı kendi kişisel deneyim ve eski öğrendiklerine göre, kavramın gerçek anlamı dışında anlam yüklenerek öğrenilmesi" (One's learning a concept with a meaning different than its real meaning according to his personal experiences and previous learning)(Prospective teacher #12).*
	Participants who included an example in definition	1	*"Örneğin katı ve sıvı maddelerin molekülleri arasındaki boşlukların katılarda hiç yok sıvılarda ise aradaki boşluğun çok olduğunun düşünülmesi bir kavram yanılgısıdır" (For example, 'there is no space between particles of solids' and 'there is a considerable space between the particles of liquids' are misconceptions) (Prospective teacher #20).*
After	Participants who included a source in definition	7	*"Kavram yanılgıları öğrenciler tarafından genellikle doğru olduğuna inanılan ama gerçekte yanlış olan bilgilerdir. Öğrenciler bunları ders esnasında öğretmenin yeteri kadar konuya hakim olmamasından kaynaklı oluşturabilir veya gözlemlerine dayanarak tek başlarına da oluşturabilir" (Misconception is non-scientific knowledge but students generally believe that they are true. Students form this non-scientific knowledge because of poor content knowledge of their teachers or their observations)(Prospective teacher #13).*
	Participants who included an example in definition	3	*"Kavram yanılgısı bir [conceptin] anlamının dışında ve yanlış yerde kullanılması. Bunu anlatmak için bir örnek de verebilirdim örneğin şekerin suda çözünmesi olayı kavram yanılgısıdır; öğrenciler bunu çözünme değil şeker suda eridi şeklinde söyler. Çözünme ve erime kavramları aynı anlamdaymış gibi kullanılır" (Misconception means using a concept with a wrong meaning. To exemplify it, dissolution of sugar in water may result a misconception, students generally describe this as sugar melted. Dissolution and melting concepts are used as if they mean the same thing) (Prospective teacher #08).*

4.2.1.2. The Second Item of KBCMTEQ. The second item in KBCMTEQ instrument expected the participating prospective teachers *"to give examples of common student misconceptions in chemistry"*. When the examples of common student misconceptions given by the participants were analyzed, before the program, it was seen that, seven prospective teachers gave the misconception of "gases do not have weight" as an example. Also, four prospective teachers gave the misconception "a solid disappears when it is dissolved in water" as an example. In addition, four prospective teachers gave students' using melting and dissolution concepts interchangeably as an example of misconceptions.

Prospective teachers generally preferred to give examples of misconceptions in the particulate nature of matter subject, 10 participants stated some student misconception in this subject as examples. For example, three participants stated the misconception of "space between the particles of liquids is intermediate compared to solids and gases" as an example. Also, two participants stated the misconception of "the particles of a matter have the same properties with the bulk matter" and one participant gave the misconception of "there is air between the particles of matters" as examples.

In the subject of chemical equilibrium, one prospective teacher gave one misconception example. He wrote the misconception of "the concentrations of reactants and products are equal in at a chemical equilibrium condition". Other than these two subjects, prospective teachers gave misconception examples in the subjects of the dissolution, chemical reactions, and gases. None of the prospective teachers stated misconception examples about the subjects of acids and acid strength.

After attending the training program, when prospective chemistry teachers' misconception examples were analyzed, it was found that, participants generally stated the misconceptions covered in the training program as examples, 15 prospective teachers gave examples of student misconceptions which were discussed during the program. For example, seven prospective teachers gave the misconception of "there is air between the particles of matters" whereas only one participant stated this misconception as an example before the program. In addition, five prospective teachers listed the misconception "the particles of a substance have the same properties with the bulk matter" whereas two participants stated this misconception as an example before the program. Different from pre-measurement, two prospective teachers listed "classifying molecular elements as compound" as an example for misconception and three prospective teachers stated the misconception "the structure of particles change in phase changes of matter". A total of 12 prospective teachers stated some student misconception in particulate nature of matter, however, 10 participants stated some student misconception in this subject as examples before the program.

For chemical equilibrium, two prospective teachers stated examples of student misconceptions after the program whereas only one participant stated an example about this subject before the program. One participant stated the misconception "the concentrations of reactants and products are equal in at a chemical equilibrium condition" and the other participant stated the misconception "the reverse reaction starts when the forward reaction finishes" as examples.

For acid strength, seven prospective teachers stated examples of student misconceptions after the program whereas none of the participants had stated misconception examples about this subject before the program. Different from pre-test, five prospective teachers stated "acid strength depends on the pH of the acid solution" and three prospective teachers stated "acid strength depends on the concentration of the acid solution" as examples of student misconceptions in chemistry.

Table 4.10. The results of the second item of KBCMTEQ.

	# participant - gave examples in particulate nature of matter	# participant - gave examples in chemical equilibrium	# participant - gave examples in acid strength
Before	10	1	0
After	12	2	7

<u>4.2.1.3. The Third Item of KBCMTEQ.</u> The third item in KBCMTEQ expected the participants *"to list possible sources of misconceptions"*. Before the training program, participants mostly listed "teachers" as the reason of students' misconceptions, 13 prospective teachers stated that student misconceptions might result from "teachers' own misconceptions and wrong teaching strategies and materials used in the instruction such as

inappropriate directions, illustrations, etc". Among 13 participants, nine participants stated that students' misconceptions resulted from teachers' insufficient and misleading instruction. Other participants mentioned teachers' own misconceptions, teacher-oriented instruction, and, inappropriate teaching materials as teacher-based sources of misconceptions.

According to 6 participants, students' insufficient learning in the previous courses causes misconceptions in subsequent learning. Furthermore, six participants stated that "students drew their own conclusion when they entered a new situation, so they might construct non-scientific knowledge in their mind" and it caused misconceptions. One prospective teacher stated that:

"Öğretmen kaynaklı olabilir. Öğretmen öğrencide [misconceptionlar] yaratmış olabilir. Ya da öğrencinin [scientific] olmayan deneyimlerini yanlış yorumlamış olması olabilir. Öğrenciler ders dışındaki deneyimlerini kendilerine gore yanlış yorumluyor olabilirler. Bazı yanlış gözlemler kavram yanılgısına yol açabilir." (It may result from teachers. Teachers could have caused misconceptions in students. Students may draw wrong conclusions from their daily experiences. Students may misinterpret their out-of-school experiences according to their own thinking. Some misinterpretation of students' observations may result misconceptions) (Prospective teacher #04).

Moreover, six prospective teachers stated that students' misconceptions could result from "their daily life experiences" before the program. Also, minority of prospective teachers listed students' inability to connect between macroscopic and microscopic levels of matter, textbooks as sources of misconceptions.

After attending the training program, the number of participants who stated "teachers" as a major source of misconceptions was increased from 13 to 17, 17 prospective teachers stated that students' misconceptions might be resulted from their teachers by some means. Among these prospective teachers, 11 participants denoted that if teachers did not instruct the subject in a way that their students could understand, it would result misconceptions in students. In addition, two participants stated that teachers' misconceptions and lack of advanced chemistry content knowledge could possibly cause misconception in their students. Moreover, two participants explained that teachers' using inappropriate teaching materials might lead to misconceptions. Moreover, three prospective teachers expressed that "teacher-oriented, direct instruction" which emphasized memorization of knowledge rather than understanding might cause misconceptions in students. One of these three participants stated that:

"Kimyanın görsel öğelerle ve pratikle ilgili örnekler verilerek anlatılması gereken bir ders olduğunu ve sadece teori ve ezberci bir eğitime dayanarak verilen bir eğitimin yanılgıya yol açabileceğini düşünüyorum." (I think, chemistry is a course which should be instructed with visual teaching materials and daily life examples, direct teaching based on memorization may results misconceptions in students) (Prospective teacher #21).

Similar to the pre-measurement, seven participants stated that students drew their own conclusion when they entered a new situation so it caused their misconceptions and five prospective teachers listed students' incorrect and insufficient learning in previous courses as a source of misconceptions after the program. Moreover, three participants expressed that the use of scientific terms in daily language might be a source of misconceptions.

<u>4.2.1.4. The Eighth Item of KBCMTEQ.</u> The eighth item of the KBCMTEQ was *"In your opinion, is changing students' misconceptions difficult?"* Before the training program, 15 participants stated that changing students' misconceptions was a difficult process. Participants mainly stated that changing student misconceptions was a difficult process because students accepted these misconceptions for a long time. According to four participants, changing students' misconceptions was not a difficult process. In sum, these participants stated that if a teacher presented concrete examples, introduced proofs that challenge misconceptions and had necessary experience and preparation for this issue; it would not be difficult to change students' misconceptions. According to three prospective teachers, changing students' misconceptions may or may not be difficult process depending on the students and/or the type of the misconceptions. The number of participants who stated that changing students' misconceptions was difficult or not before and after attending the training program were shown in Table 4.11 with exemplary excerpts.

Table 4.11. The results of the eighth item of KBCMTEQ.

The Components of PCK		#	Exemplary excerpts
Before	Participants who thought that changing students' misconceptions was a difficult process	15	*"Evet. Uzun bir süredir bunların doğru olduğuna inandıysa, yanlış olduklarını göstersek bile bu durumu hemen kabullenmeyebilir." (Yes. If the student has been accepting a non-scientific knowledge as true for a long time, even if we show that the knowledge is wrong, he may not believe that) (Prospective teacher #13).*
	Participants who thought that changing students' misconceptions was not a difficult process	4	*"Öğrencilerin kavram yanılgılarını değiştirmek eğer aksini ispat eden iyi bir kanıtınız varsa çok zor olmaz." (Changing students' misconceptions will not be difficult if you have a proof that proves the related scientific knowledge) (Prospective teacher #10).*
	Participants who thought that changing students' misconceptions may or may not be a difficult process	3	*"Bazı öğrencilerin zordur. Öğrenciye göre değişir. Öğrencilerin önceden edindikleri yanlış bilgiler, günlük hayatta kabul gören kavram yanılgıları varsa bu tür öğrencilerde kavram yanılgılarını değiştirmek zor olabilir." (It is difficult for some students. It depends on students. If students have non-scientific previous knowledge or misconceptions that are accepted as true in daily life, it will be hard to change these students' misconceptions) (Prospective teacher #05).*
After	Participants who thought that changing students' misconceptions was a difficult process	13	*"Öğrencinin kavram yanılgısını değiştirmek zordur hele ki öğrenciler bu kavram yanılgısıyla sorularını rahatlıkla cevaplıyorsa. Öğrenciler sorun çıkarmayan bilgiyi değiştirmek istemeyecektir. Bu noktada bu bilgiyi değiştirmek daha da zor olur." (It is difficult to change students' misconceptions especially if students can solve their questions without any problem despite the presence of misconceptions. Students do not want to change their knowledge if they do not encounter a problem. Thus, it is more difficult to change misconceptions) (Prospective teacher #08).*
	Participants who thought that changing students' misconceptions was not a difficult process	6	*"Hayır zor değildir. Sonuçta kavram yanılgılarının ortadan kaldırılmasına yönelik çok fazla yöntem, öğretim metodu geliştirilebilir. Özellikle kimyada daha fazla olduğunu düşünüyorum bu metodların." (No it is not difficult. Because a high number of teaching methods and strategies can be developed to remediate misconceptions. Specially, there are lots of methods in chemistry) (Prospective teacher #19).*
	Participants who thought that changing students' misconceptions may or may not be a difficult process	3	*"Öğrenciye ve bu yanılgılara ne kadar inandığına göre değişir. Etkili bir metodla ortadan kaldırılabilir . Bazıları ise oldukça zor değiştirilir. Doğru olanı hazmetse bile zamanla unutup yine eski bilgisini hatırlayabilir. Kalıcı olması için zaman harcamak gerekir." (It depends on the students and how much students believe in these misconceptions. Misconceptions can be changed with an effective method. Changing some misconceptions may be difficult. Even if a student understands the correct conception, he or she may remember previous non-scientific concepts. For a concept to be permanent, time is needed) (Prospective teacher #13).*

4.2.2. PCK in terms of Strategies to Identify and Change Student Misconceptions

The fourth item of the KBCMTEQ was *“Do you think that the possible student misconceptions should be taken into consideration when you prepare a lesson plan? How do you do that?”* Before the training program, 21 of 22 prospective teachers stated that while preparing a lesson plan, possible student misconceptions should be taken into consideration. Only one participant stated that since there were a variety of student misconceptions, we could not know all of these misconceptions so we could not include them in lesson plans. After the training program, all of the prospective teachers suggested that while preparing a lesson plan, possible student misconceptions should be taken into consideration.

Before the training program, seven prospective teachers emphasized designing the lesson plan according to the student misconceptions indicated in research literature on misconceptions. On the other hand, after the program, 15 prospective teachers mentioned taking the student misconceptions which was found in research findings into consideration while writing a lesson plan. These prospective teachers stated that teachers needed to add teaching activities and tools such as experiments, counter-examples and visualization materials which targeted possible misconceptions. One of 15 participants stated that:

“Evet. Arşivden tarama yapılarak olası kavram yanılgıları tespit edilmeli. Bunlara karşı meydan okuyucu aktiviteler yapılmalı” (Yes. Possible student misconceptions should be searched from archives. Some teaching activities that target these misconceptions should be performed) (Prospective teacher #14).

The same number of participants, 9 participants, focused on asking pre-questions or administering a pre-test before starting the instruction to take possible student misconceptions into consideration before and after the training program.

The fifth item of KBCMTEQ expected the respondents *“to list the methods in order to identify student misconceptions”*. Before the training program, majority of prospective teachers, 13 of 22 participants stated “asking questions at the beginning of instruction of a subject” when they were expected to suggest a method to identify student misconceptions.

Among these 13 participants, four prospective teachers emphasized that it was required to ask “open-ended questions which expected the explanation for answers and targeted the misconception” to identify student misconceptions. One of these four participants stated that:

“Tespit aşamasında, kavram ile alakalı dersin ilk başlarında öğrencilere sorulacak açık uçlu sorular bu yönde bize fikir verecektir” (Asking open-ended questions to students at the beginning of the instruction will give us an idea about identifying their misconceptions) (Prospective teacher #12).

Moreover, 11 participants stated “administering a pre-test before instruction” as a misconception identification method. In addition, four participants mentioned that interviews could be conducted with students to identify their misconceptions. A few prospective teachers listed classroom discussions, expecting students to draw concept maps, homework, and observing students when they were requested to list methods to identify student misconceptions.

After the training program, similar to the result before the program, majority of prospective teacher, 15 prospective chemistry teachers stated asking questions at the beginning of the lesson as a method to identify student misconceptions. Different from the pre-measurement, eight of 15 prospective teachers suggested asking open-ended questions which targeted a misconception whereas 4 participants emphasized it before the training program. One of these eight prospective teachers stated that:

“Özellikle bunu ölçmek için ders planını hazırlarken açıklama talep eden sorular hazırlayarak” (Via including questions that expect explanations in answers for this purpose) (Prospective teacher #14)

Similar to the pre-measurement, 12 participants mentioned applying a pre-test before instruction as a method. In addition, three participants stated that classroom discussion might be a method to identify misconceptions. Moreover, three participants mentioned that interviews could be conducted with students to identify their misconceptions. A few prospective teachers listed journal writing, reviewing the research literature related to misconceptions, and surveys as methods to identify student misconceptions.

The sixth item of the KBCMTEQ expected the respondents *"to list the methods to change student misconceptions"*. Before the training program, nine prospective teachers stated that presenting discrepant events and counter examples that would challenge students' existing knowledge might be a good way to change student misconceptions. Moreover, five participants stated that laboratory works would be another method to change misconceptions. Furthermore, five participants mentioned that teachers could correct student misconceptions via integrating different visual teaching materials into their lessons. In addition, four prospective teachers stated that teachers could change student misconceptions by the help of appropriate questions that would lead students to think about the subject. Prospective teachers also mentioned analogies, classroom discussions and daily life examples as methods to change student misconceptions. One of the prospective teachers who stated only one method to change misconceptions stated that:

"Öğrenciler kavram yanılgısı yaşıyorsa bazen bu kavramı değiştirmez. Bazen doğru bilgiyi kabul eder bazen doğru bilgiyi kabul etmez ama derslerinde doğru kavramı dersler dışında bildiği kavramı kullanmaya devam edebilir. Bence öğrenciye kabul ettirirken onun da yanlışlığının nereden geldiğini anlayabileceği hatta kavram yanılgısı yaşadığını ve yanlışlığını kendi farkedebileceği yöntemler seçilebilir. Mesela öğrencinin kafasındaki tanımla cevaplayamayacağı örnekler verilebilir". (If a student has a misconception, sometimes he does not change it. He may accept the scientific knowledge or may not, he may use scientific meaning of the concept in science lessons and his misconception about that concept in daily life. I think, students should find out and understand their misconceptions while we are trying to change them. For example, we can present examples that contradict their understanding and they cannot explain) (Prospective teacher #08).

After the training program, the number of participants who suggested that supplementary visual teaching material such as animations, molecular models, videos in order to change student misconceptions was highly increased. After the program, 14 participants indicated that teachers could correct student misconceptions via integrating different visual teaching materials into their lessons whereas five participants stated it before the program. Moreover, 12 prospective teachers stated laboratory works as a method to change student misconceptions whereas five participants mentioned it before the program.

Similar to pre-test, eight prospective teachers stated that discrepant events and counter examples would challenge students' existing knowledge and change student misconceptions. Prospective teachers also mentioned analogies, classroom discussions and daily life examples as methods to change student misconceptions similar to pre-measurement. The prospective teachers who stated only one method before the program stated three different methods to change student misconceptions after the program. She stated that:

"Kavram yanılgılarını değiştirmek için deney yaptırılabilir olayı gözlemlerse bunu ortadan kaldırabilirler çünkü öğrenciler somut olarak sunulan şeyleri daha çabuk benimsiyorlar. Animasyon-simülasyon kullanılabilir. Kendi aralarında tartışmaları sağlanabilir bunda da öğrencilerin birbirlerinin takıldıkları noktaları birbirlerine iyi ifade ettiklerini düşünüyorum." (Experiments may be conducted to remediate students' misconceptions because when students observe the phenomena and see concrete examples, they accept it more easily. Animations and simulations may be used. Class discussions may help students to explain the points which they do not understand to each other) (Prospective teacher #08).

The seventh item of the KBCMTEQ was *"Suppose that you identified a misconception in some of your students. a) Do you change the flow of your lesson? If your answer is yes, what kind of change would it be? b) Do you change the lesson plan which you will design to teach this lesson in the future? If your answer is yes, what kind of change would it be?"* Before the training program, 17 prospective teachers stated that they would change the flow of their lesson if they identified a misconception in some of their students. Three participants expressed that they would change the flow of a lesson, if the number of students having certain misconception is high. One of these three participants stated that:

"Eğer kavram yanılgısı olan öğrenci sayısı az ise bir değişiklik yapmam ama çok ise kavram yanılgısı yaşanan konuyla ilgili daha fazla bilgi, daha fazla somut örnek vererek o konunun üzerine biraz daha fazla yoğunlaşırım" (If the number of students who have a misconception is small, I would not change the lesson. Yet, if the number is high, I would concentrate the lesson more on that subject with additional explanations and more concrete examples) (Prospective teacher #05).

One prospective teacher stated that she would change the flow of the lesson, if her students have misconceptions related to the content of that lesson. She stated that:

"Dersin gidişatında değişiklik yapmam dersin içeriğine bağlıdır. Örneğin dersin konusu gazlarda basınç-sıcaklık ilişkisi ise ve bir öğrencide taneciklerle ilgili bir kavram yanılgısı varsa dersi bölüp maddenin tanecikli yapısı konusuna geri dönmem konu akışını bozar ve diğer öğrencilerin motivasyonu bozulabilir. Ama farklı bir derste ya da aktivitede söz konusu kavram yanılgısı üzerine odaklanırım. Çünkü bir öğrencideki kavram yanılgısı diğer öğrencilerde de aynı kavram yanılgısının olma olasılığını gösterir bence" (It depends on the content of the lesson, for me, to change the flow of the lesson. For example, if the subject were pressure-temperature relationship in gases, and a student had a misconception about particulate nature of matter I would not return the subject of particulate nature of matter because the flow of the lesson and student motivation would be disturbed. Yet, I focus on that misconception in another lesson or another activity. Because a misconception of one student shows the possibility that other students also have that misconception) (Prospective teacher #16).

One prospective teacher stated that he would change the flow of the lesson, if the misconceptions had potential to block subsequent learning. He stated that:

"Yanılgı çalışılan grubun ileriki kavramları anlamasını etkileyecekse mutlaka akış değişmelidir. Fakat daha izole bir konu üzerinde çalışılıyorsa daha sonra planlı bir şekilde geri dönülmek üzere derse devam edilebilir." (If the misconception had potential to affect the understanding of the following concepts, the flow of the lesson must be changed. If the subject was very specific, I would not change the flow of the lesson, I would revisit this misconception in the future) (Prospective teacher #18).

When prospective teachers explained how they would change the flow of the lesson if they found out that their students have certain misconceptions before the program, six participants stated that they would just try to remediate misconception. In addition, five prospective teachers indicated that they would give concrete examples during the instruction to change students' misconceptions. Moreover, four prospective teachers stated that they would perform activities that targets to change students' misconceptions. Also, three participants expressed that when they identified misconceptions in their students, they would conduct experiments about the related subject. Moreover, three participants emphasized asking questions that will challenge students' misconceptions.

When the prospective chemistry teachers were asked whether they would change the lesson plan designed to teach this lesson in the future before the program, 18 prospective teachers expressed that they would change the lesson plan. One prospective teacher stated that he would assess their future students understanding and check whether they had the same misconceptions.

"Bu duruma göre değişebilir. Aynı kavram yanılgısının daha sonraki öğrencilerimde olup olmadığına bakarım genel olarak rastladığım bir kavram yanılgısı olursa ders planımı değiştirirdim." (It depends on the case. I would check whether my students in future had the same misconception. If I saw that students commonly had this misconception I would change my lesson plan) (Prospective teacher #02).

One prospective teacher expressed that if she observed a misconception in majority of her students, she would also change the lesson plan designed to teach this lesson in the future. Furthermore, one prospective teacher expressed that she would change the lesson plan designed to teach this lesson in the future if she identified a misconception related to that lesson. One of the 22 participants did not make any comments for this part of the question.

When prospective teachers explained how they would change the flow of the lesson plan designed to teach this lesson in the future if they found out that their students have certain misconceptions, five participants stated that they would add an activity to the lesson plan that would help remediate the misconception. Also, four participants expressed that they would add an experiment to the lesson plan. Moreover, four prospective teachers stated that they would add concrete examples to the lesson plan. In addition, three prospective teachers stated that they would add questions that aimed to challenge students' misconceptions. Furthermore, three prospective teachers stated that they would add the identified misconception into the lesson plan. Also, three prospective teachers stated that they would emphasize and clarify the basic concepts in their lesson plans designed to teach this lesson in the future.

After the training program, 21 prospective teachers stated that they would change the flow of their lesson if they identified a misconception in some of their students whereas 17 prospective teachers stated it before the program. Only one participant stated that:

"Eğer bu bir kişide ortaya çıkmışsa dersi kesmem ama eğer daha fazla kişideyse dersin akışı değişmelidir" (I would not interrupt the lesson if only one student had this misconception. Yet, if more than one student had this misconception, the flow of the lesson must be changed) (Prospective teacher #17).

When prospective teachers explained how they would change the flow of the lesson if they found out that their students have certain misconceptions, the number of prospective teachers who stated that they would just try to remediate misconception from six to three. Moreover, seven prospective teachers stated that they would ask questions to challenge students' misconceptions after the program whereas three participants stated it before the program.

Similar numbers of prospective teachers, four participants and three participants stated that they would perform activities that targets to change students' misconceptions before and after the training program, respectively. Also, similar to pre-measurement, three participants expressed that when they identified misconceptions in their students, they would conduct experiments about the related subject.

When the prospective chemistry teachers were asked whether they would change the lesson plan designed to teach this lesson in the future, after the program, 21 prospective teachers expressed that they would change the lesson plan whereas 18 prospective teachers stated it before the program. Only one prospective teacher expressed that he would try not to change the lesson plan prepared for the future lessons.

When prospective teachers explained how they would change the lesson plan designed to teach this lesson in the future, if they found out that their students have certain misconceptions, after the program, five prospective teachers stated that they would take misconceptions into consideration while writing a lesson plan, however, three participants expressed it before the program. Different from the pre-measurement, a total of five prospective teachers stated that they would include visual teaching materials such as simulations, animations and videos into lesson plan.

Similar to pre-measurement, four participants and three participants stated that they would add concrete examples to the lesson plan before and after the training program. Also, three participants stated that they would add an activity to the lesson plan that would help remediate the misconception after the program. Yet, five participants stated it before the program.

The eleventh item of the KBCMTEQ expected the respondents *"to write a lesson flow for two lesson hours in order to change a specific misconception"*. The specific misconception in this item is "intra-molecular bonds are broken in melting and evaporation of covalent compounds". Despite the fact that participants were expected to write a detailed lesson flow, the same number of prospective teachers, eight participants, just wrote the name of teaching strategies rather than describing a flow of steps before and after the training program. Yet, it was seen that some prospective teachers who poorly described a lesson flow before the training program, elaborated their writing and wrote more successful and descriptive lesson flows after the program. The lesson flows of two prospective teachers are included as examples in the following paragraphs.

The summary of lesson flow which a prospective teacher wrote (#03) before the program, which was composed of only the name of teaching strategies:

"Bu kavram yanılgısını ortadan kaldırmak için [Audiovisual Instructional Model] kullanılabilir. Yani kavram yanılgısının aksini gösteren bir animasyon kullanılabilir.

Kovalent bağ yapmış bir bileşiğin katı halinden sıvı haline geçerken moleküller arası etkileşimlerin zayıfladığı moleküller arası bağların kopmadığını gösteren animasyonlar rahatlıkla bulunabilir. [Eriyen ve buharlaşan moleküller] tek tek gösterilerek molekül yapısının bozulmadığı, bunu sağlayan etkenin kovalent bağ olduğu gösterilir. Gaz molekülündeki kovalent bağlar gösterilerek pekiştirilebilir." (In order to eliminate this misconception, audiovisual instructional model can be used. I mean, an animation that disproves this misconception can be used. One can easily find an animation which shows that the inter-molecular forces are broken in melting of a covalent compound but intra-molecular bonds are not broken. Melting and evaporating molecules should be shown one by one, indicating that the structure of a molecule does not change, the covalent bond is the agent that causes it. Understanding can be reinforced by showing the molecules of covalent compound in gaseous state) (Prospective teacher #03).

The lesson flow which the prospective teacher wrote (#03) after the program, showed elaboration of his thinking:

"Suyun elektrolizi olayının reaksiyonunu verip öğrencilerle olayın nasıl gerçekleştiğini konuşuruz. Konu ile ilgili bir animasyon kullanımı. Suyun buharlaşması olayının denklemi konuşulup moleküllerin nasıl davrandığı konuşulur. Konu ile ilgili bir animasyon kullanımı.İki durumda su moleküllerinin geçirdiği değişiklikler ayrıntılı bir şekilde çizilerek anlatılır. Birinci durumda etkili olan kuvvetlerin [intramolecular forces], ikinci durumda etkili olan kuvvetlerin [intermolecular forces] olduğu söylenir.İkinci durumu daha iyi açıklamak için sıvı halden gaz haline geçen bir su kütlesindeki bir su molekülünün diğer su molekülleriyle olan etkileşimini gösteren bir animasyon kullanılır. Gaz hale geçmiş sudaki bir molekülün içindeki kovalent bağlar gösterilip, bu bağların kaynama esnasında koparılmadığı gösterilir. Dersin sonunda öğrencilerin bu derste ne öğrendikleri sorulup özetleyecek şekilde arkadaşlarına anlatmaları istenir. Konu hakkındaki kavram yanılgısının ortadan kalkıp kalkmadığını ölçmek için kısa bir değerlendirme (quiz) yapılır." (Firstly, we talk about electrolysis of water and how this phenomenon occurs and use of an animation about the subject. Secondly, we talk about the behaviour of water molecules in evaporation of water and use of an animation about the subject. The change of water molecules in these two events are explained by drawing in detail. It should be told that, in the first event, the effective forces are intra-molecular

forces, in the second event the effective forces are inter-molecular forces. In order to better explain the second event, an animation which shows the interaction of water molecules in the phase change of water from the liquid state into gaseous state can be used. During the animation, it should be showed that the intra-molecular forces in a water molecule in the gaseous state are not broken during boiling. At the end of the lesson, students are asked what they have learned in this lesson and expected to summarize it to their friends. A quiz can be administered to students in order to evaluate whether their misconceptions are changed)(Prospective teacher #03).

The lesson flow which the prospective teacher wrote (#05) before the program, only included the name of teaching methods not integrated to the specific misconception:

"5E modelini uygularım. Bu modelde en uygun kısım [exploration] kısmıdır. Bu bölümde deney kullanarak öğrencilerin bu konudaki kavram yanılgısını kırmaya çalışırım. Ayrıca [elaboration] kısmında değiştirilen kavram yanılgısını başka bir bilgiyle birleştirip kullanılması kavramın daha iyi anlaşılmasını ve pekiştirilmesini sağlar." (I would apply 5E model. The most appropriate part of the model is exploration part. In this part, I try to eliminate student misconceptions by the help of experiments. Moreover, in elaboration part, integration of new concepts with other knowledge provides better understanding and reinforcement of understanding of the concept) (Prospective teacher #05).

The prospective teacher (#05) introduced a more elaborated lesson flow that targeted the specific misconception after the program :

"Molekül içi bağlar ve moleküller arası bağlar kavramları açıklanır. Kovalent bağlar açıklanır (görsel kullanılarak, animasyon) H_2O yapısı görseller kullanılarak anlatılır, molekül içi bağları, moleküller arası bağları gösterilir. Analoji kullanılarak bu bağların nasıl kırılabileceği anlatılır. Erime, donma ve kaynama kavramları açıklanır. Bu olaylar sırasında moleküllerde nasıl değişiklikler olabileceği öğrencilere sorulur. Gelen cevaplara göre bu olaylar sırasında nasıl değişiklikler meydana gelebileceği öğrencilere açıklanır. [Sonra su molekülünün erime, kaynama, donma sırasında moleküller arası ve molekül içi bağlarının] nasıl etkilendiği animasyon yardımıyla gösterilir ve açıklanır. Sonuç olarak H_2O molekülü erime ve kaynama olaylarında, sadece moleküller arası

bağların kırılacağı moleküller arası bağlarda bi değişiklik olmayacağı açıklanır. " (The concepts of intra-molecular forces and inter-molecular forces are explained. Covalent bonds are described (by using visual teaching materials, such as animation) and the structure of H_2O is explained with using visuals and the intra-molecular bonds and intermolecular bonds regarding water are shown. How to break these bonds are explained with an analogy. The concepts of melting, freezing and boiling concepts are explained. Students may be asked what changes in molecules during these events. According to the responses from the students, the changes occurred during these events are described. Then, how the inter- and intra-molecular bonds of water molecule change during melting, boiling, freezing are shown with the help of an animation. As a result, in the melting and boiling of H_2O, it is explained that only the inter-molecular bonds are broken and the intermolecular bonds would not change)(Prospective teacher #05).

Before the training program, two prospective teachers stated their hesitation about deciding how to change the specific misconception. These prospective teachers stated they did not know how to change this misconception. One of these prospective teachers only wrote objectives of the lesson before the training program and she wrote the only name of teaching strategies that she planned to use after the program. The other prospective teacher wrote only two teaching strategies rather than a flow of instruction before the training program and she wrote a description of flow of steps after the program. Before the training program, she wrote:

"Kovalent bağın nasıl oluştuğuna dair bir video izletirdim. Tüm bağların elektrostatik etkileşimler olduğunu ifade eden bir etkinlik yaptırırdım.Çok da bir fikrim yok açıkçası" (I would show a video about how covalent bond was formed. I would lead students to perform an activity which indicated that all types of bonds were electrostatic attractions. In fact, I have no more idea) (Prospective teacher #16).

After the training program, she wrote:

"Derse az miktarda yapılacak suyun hal değişimlerini gösteren bir aktiviteyle başlayıp aktivite sonunda öğrencilerin fikirlerini tartışmasını isterim ve düşüncelerini tahtaya yazarım. Faz değişimi olayını atomik seviyede canlandıran bir video izletirim ve

sonrasında suyun 3 halinin atomik seviyede kartonlara çizilmesini bir grup aktivitesi olarak yaptırır bu çizimleri sunmalarını ve bu hal değişimlerinin nasıl gerçekleştiğini anlatmalarını isterim." (I would start the lesson with an activity that showed the phase change of little amount of water and, at the end of the activity, I would expect the students discuss their ideas and I would write their ideas on the board. I would show a video that represented the process of phase change in atomic level and I expect students to represent water in three phases on carton papers as group activity. Then I want students to present their representations and explain how these phase changes occurred) (Prospective teacher #16).

Before the training program, one participant made comment on non-scientific understanding about the misconception rather than suggesting a lesson flow to change it. He stated that:

"Faz değişiminin fiziksel bir olay olduğunu ve fiziksel değişimlerde maddenin kimyasal yapısının değişmeyeceğine hemfikir olacağımızı düşünüyorum. Molekül içi bağların kırılması da kimyasal olduğuna göre faz değişiminde kovalent bağlar etkilenmez." (I think, we agree on that phase changes are physical changes and the chemical structure of a matter does not change in physical changes. Since, breaking intra-molecular forces is a chemical change, covalent bonds are not affected by the phase changes)(Prospective teacher #18).

After the training program, the prospective teacher described a few steps in instruction in order to change the misconception. He stated that:

"Kimyasal ve fiziksel değişim kavramları tanımlanıp farklarının tartışılmasından sonra, faz değişimlerinin tanecikli yapı üzerindeki etkileri tartışılması. Sınıf içi tartışmalardan sonra moleküler maddelerin faz değişimi sırasında tanecik davranışlarını gösteren bir animasyon gösterimi ve sonrasında, önceki tartışmanın tekrar edilmesi." (The discussion of the effect of phase changes on the particle nature of matter, after describing physical and chemical changes and discussion of the difference between these concepts. Showing an animation that represents particles of molecular substances at phase

change after classroom discussions, and then repeating the previous discussion) (Prospective teacher #18).

Furthermore, when the participants were expected to write a detailed lesson flow before the program, only 10 participants could write a flow of instruction. On the other hand, one participant only wrote sub-titles of the topic and one participant could not write any lesson plan. After the training program, the number of participants who wrote a flow of instruction in their answers increased from 10 to 14. Table 4.11 summarizes the number of participants who wrote a detailed lesson flow before and after the program.

Table 4.12. The results of the eleventh item of KBCMTEQ.

	only name of strategies	write a flow	comment on misconception	write sub-titles	write objectives	no lesson plan
Before	8	10	1	1	1	1
After	8	14	-	-	-	-

Prospective teachers included predict-observe-explain, multi-representational instruction, inquiry, experimental works and analogies in their lesson plan. Among these teaching strategies, the number of participants who preferred to use of microscopic representations of matter and direct teaching was increased after the training program. The number of prospective teachers who wrote a lesson which included lecturing increased from six in pre-test to 10 in post-test. Moreover, two prospective teachers suggested using teaching materials that focused on microscopic level before the training program, and the number increased to eight participants after the program. One of the prospective teachers who suggested using microscopic representations of matter in pre-test stated that:

"Öncelikle katı, sıvı, gaz maddeleri [sub-microscobic] düzeyde göstermelerini isterim. Her öğrenci bunu gösterebildiğinde iki atom arasında oluşan bağın bir etkileşim sonucunda oluştuğunu, etkileşim kaybolduğunda da eski konumlarına geri döndüklerini gösteren bir animasyon kullanırım." (First of all, I would expect students to represent solid, liquid and gaseous matters in sub-microscopic level. When each student succeed to represent it, I would show an animation which indicate that a bond between two atoms is

resulted from an attraction, and when the attraction is absent, they would have their previous positions) (Prospective teacher #02).

After the training program, he also suggested using microscopic representations of matter and elaborated his lesson plan. He stated that:

"Önce [intermolecular forces] ve [intramolecular forces] hakkında giriş yaparak derse başlarım ve bu kavramlara dair bir yanılgı var mı onu tespit etmeye çalışırım. Daha sonra ["intermolecular forces"]ın fiziksel özelliklere etkisinden bahsederim ve görsel materyaller kullanarak erime ve kaynama olaylarının moleküller arası etkileşimle alakalı olduğu, kovalent bağ yapan elementlerin birbirleriyle olan etkileşiminin çok daha güçlü olduğu ve erime kaynama olaylarında bu kovalent bağın bozulmadığını göstermeye çalışırım." (I would start the lesson with an introduction about inter-molecular forces and intra-molecular forces and try to identify student misconceptions if they have any. Then, I mention the effect of inter-molecular forces on physical properties of matter, I would try to show melting and boiling of an event is related to inter-molecular forces with visuals, the attraction between the atoms forming a covalent bond is very strong and this covalent bond is not broken in melting and boiling processes) (Prospective teacher #02).

4.3. Findings Related to the Research Question 3

The third research question was: *"Is there any difference in prospective chemistry teachers' teaching efficacy beliefs before and after attending the training program?"* In order to answer this research question, the responses of participating prospective chemistry teachers on the ninth and tenth item of KBCMTEQ before and after attending the training program were analyzed. Common responses of the prospective teachers were combined together and the results of the analyses of these items were given in detail in the following paragraphs.

4.3.1. The Ninth Item of KBCMTEQ

The ninth item in the KBCMTEQ was *"List the teaching methods which you believe that you can efficiently use with their current chemistry content and pedagogical* *knowledge. Please order the methods from the one which you can most efficiently use to the one which you can least."* In the analysis of this item of KBCMTEQ, the order of teaching methods was omitted since majority of the prospective teachers did not indicate an order of teaching methods in their responses.

When the pre-tests and post-tests of the participants were compared, it was found that prospective teachers wrote a higher number of teaching methods which they believe they could efficiently use after the training program. Table 4.12 describes the number of prospective teachers and how many teaching methods they listed before and after the training program.

Table 4.13. The results of the ninth item of KBCMTEQ.

	no method	1 method	2 methods	3 methods	4 methods	5 or more methods
Before	2	9	8	3	-	-
After	-	1	5	6	7	3

When the methods that the participants listed in pre-test were analyzed, six participants stated that they would successfully use scientific inquiry as a teaching method. Also, five participants stated that they would efficiently use experimentation and four participants stated that they could efficiently use predict-observe- explain teaching methods. Moreover, four prospective teachers listed constructivism as a teaching method rather than a learning and teaching approach. Furthermore, three participants stated they believed themselves to efficiently use classical teaching methods. Minority of prospective teachers listed argumentation, 5E teaching model, use of visual teaching materials as molecular models they could successfully use.

After the training program, the majority of the prospective teachers, 13 participants stated their belief that they would successfully use methods utilizing molecular models in instruction despite the fact that only a few teachers listed this teaching method before the program. Moreover, the number of participants who believed that they would efficiently use experimentation as a teaching method greatly increased from five to 12. Furthermore, eight participants stated their belief that they would be able to successfully use scientific inquiry as a teaching method whereas six participants had this belief it before the program. In addition, the number of participants who believed that they would efficiently use classical teaching methods slightly increased from three to five.

Different from pre-measurement, seven participants stated that they would efficiently use questioning and also seven participants stated that they would efficiently benefit from analogies as teaching methods after the program, despite the fact that participants did not state these methods in pre-test.

4.3.2. The Tenth Item of KBCMTEQ

The tenth item of KBCMTEQ was "*Which chemistry subjects do you believe that you are able to teach efficiently? Use the evaluation scale while you are evaluating yourself.*" For this question, a numeric point 1 indicated that the respondent believed he/she was not able to teach corresponding subject efficiently. A numeric point 2 indicated that the respondent was undecided about his/her beliefs. A numeric point 3 indicated that the respondent believed he/she was able to teach corresponding subject efficiently.

In this item, 21 of 22 participants assigned a numeric point for their belief that they were able to teach corresponding subject efficiently or not, according to the scale given in the item before the program. Yet, one prospective teacher commented on her belief about teaching efficacy instead of assigning a numeric point, she stated that:

"Asitler ve bazlar, elektrokimya, radyoaktivite ve elektrokimya bunlar arasında anlatmadığım tek 4 konu olduğu için biraz tedirginim yani bunlarda çok etkin olabileceğimi şu an için düşünmüyorum. Diğerleri için de kimya bilgim var. Ancak pedagojik olarak nasıl olduğumu bilmiyorum çünkü bunu anlayabilecek bir mentor öğretmenim yoktu." (I have not instructed acids and bases, electrochemistry, radioactivity and organic chemistry subjects yet, so I am nervous, I think that I am not able to efficiently instruct these subjects now. For the other subject, I have chemistry content knowledge but I do not have an idea about my pedagogical knowledge since I do not have a mentor teacher who can evaluate that) (Prospective teacher #06).

For particulate nature of matter, before the training program, no prospective teachers assigned a numeric point 1, four prospective teachers assigned a numeric point 2, and 17 prospective teachers assigned a numeric point 3 for their belief that they are able to teach the particulate nature of matter. Similar to pre-test, no prospective teachers assigned a numeric point 1, five prospective teachers assigned a numeric point 2, and 17 prospective teachers assigned a numeric point 3 after the training program. Table 4.13. summarizes the analysis of the tenth item of KBCMTEQ for particulate nature of matter.

Table 4.14. The results of tenth item of KBCMTEQ for particulate nature of matter.

Items	**Before**	**After**
1	-	-
2	4	5
3	17	17
Total	21	22

For chemical equilibrium, before the training program, four prospective teachers assigned a numeric point 1, eight prospective teachers assigned a numeric point 2, and nine prospective teachers assigned a numeric point 3 for their belief that they are able to teach this subject. On the other hand, no prospective teachers assigned a numeric point 1, eight prospective teachers assigned a numeric point 2, and 14 prospective teachers assigned a numeric point 3 after the training program. Table 4.14. summarizes the analysis of the tenth item of KBCMTEQ for chemical equilibrium.

Table 4.15. The results of tenth item of KBCMTEQ for chemical equilibrium.

Items	**Before**	**After**
1	4	-
2	8	8
3	9	14
Total	21	22

For acid strength, before the training program, five prospective teachers assigned a numeric point 1, nine prospective teachers assigned a numeric point 2, and seven prospective teachers assigned a numeric point 3 for their belief that they are able to teach this subject. On the other hand, two prospective teachers assigned a numeric point 1, 14 prospective teachers assigned a numeric point 2, and six prospective teachers assigned a numeric point 3 after the training program. Table 4.14. summarizes the analysis of the tenth item of KBCMTEQ for acid strength.

Table 4.16. The results of tenth item of KBCMTEQ for acid strength.

Items	**Before**	**After**
1	5	2
2	9	14
3	7	6
Total	21	22

4.4. Findings Related to the Research Question 4

The fourth research question was: *"What are the prospective chemistry teachers' opinions about the training program after they attend the program?"*. The PEF included 10 open-ended items. All participants' responses to the items of PEF were evaluated and categorized in order to understand their opinions regarding improvement of the training program. For the analysis of PEF items, common responses of participants to each item were listed and similar responses were combined by the researcher. In the following paragraphs, prospective chemistry teachers' responses to each item of PEF and some quotations from their responses were included.

4.4.1. The First Item of PEF

The first item asked participants "*whether they want to attend a similar training program after attending this program"*. For this item, 21 of 22 participants stated that they would like to attend a similar training program after attending this program. Only one participant stated that he would not attend a similar program because of already having heavy school curriculum.

4.4.2. The Second Item of PEF

The second item was *"In your opinion, what did the training program contribute to your teaching skills and knowledge? Explain with sharing your experiences"*. It was seen from participants' responses that the most important contribution of the program was seen as learning teaching methods and activities to cure common student misconceptions. Half of the prospective teachers, (11 participants) stated that the training program contributed to their teaching skills and knowledge through teaching how to correct common student misconceptions. Moreover, nine prospective teachers stated that the training program contributed their teaching knowledge through enhancing their chemistry content knowledge and correcting their own misconceptions in chemistry. According to six prospective teachers, it was very helpful to see the examples of common student misconceptions during the program. One of the prospective teachers stated that :

"Olası kavram yanılgılarını öğrenmek ders planı hazırlarken onları da göz önünde bulundurmam gerektiğini bir kez daha hatırlatmış oldu. Ve bu kavram yanılgılarının ne tür etkinliklerle giderilebileceğini görmemi sağladı." (Learning common student misconceptions reminded me to take misconceptions into consideration while designing a lesson plan. Also, it showed me which activities would be helpful to decrease these misconceptions) (Prospective teacher #16).

4.4.3. The Third Item of PEF

The third item asked the participants "*the most important thing that they have learnt from the program"*. Similar to the second item, 10 prospective teachers stated that the most important thing which they learnt from the program was learning how to correct common student misconceptions. Similarly, according to five participants, correcting their own misconceptions was the most important thing that they have learnt from the program. Furthermore, four prospective teachers listed some chemical phenomena such as understanding the reason of higher volume of ice than water or finding out chemical equilibrium situations when using Le Chatelier's principle was invalid or understanding the particulate nature of concentrated and diluted solutions of strong and weak acid as their most important learning during the program. One of these four prospective teachers stated that:

"Öğrenmiş olduğum en önemli şey Le Chatelier prensibinin her zaman geçerli olmadığı. Ama programda öğrendiğim en önemli şey artık rituel işlenen derslerin değişmesi gerektiğidir. Çünkü programdaki gibi işlenirse bütün okullarda dersler çok daha faydalı olur diye düşünüyorum." (Learning Le Chatelier principle not to be valid in all chemical equilibrium situations was my most important learning. Also, I learnt that the direct teaching methods should be changed. If the teaching methods used in the training program were applied in all schools, the lessons would be more helpful for students) (Prospective teacher #19).

4.4.4. The Fourth Item of PEF

The first part of the fourth item expected the participating prospective teachers to explain "*which characteristics of the training program they mostly liked*". When the prospective teachers' responses were analyzed, it was seen that eight prospective teachers stated that they mostly liked the "inclusion of actual students' responses on CCT" aspect of the program. One of these eight prospective teachers stated that:

"Genel olarak programın en beğendiğim özelliği önce konuyla ilgili bir giriş yapılması ve daha sonra tek tek öğrencilerin cevapları üzerinde tartışmamız oldu. Bu bence çok [efektif] bir yöntem. Böylece hangi kavram yanılgısına nasıl yaklaşmamız gerektiğini öğrendik. Bazen doğru sorular sormamız gerekti bazen de deney yaptırmamız." (In general, I mostly liked our discussion of students' responses one by one after a introductory part about the subject. I think it is a very effective method. So we learnt different approaches for different types of misconceptions. Sometimes the right method is seen as questioning, sometimes the method is conducting experiments) (Prospective teacher #02).

Similar to the second and the third item, four participants stated that they mostly liked learning student misconceptions during the program. Similarly, four prospective teachers stated that they mostly liked "the emphasis given to learning how to change student misconceptions" in the program. Minority of prospective teachers mentioned "encouraging classroom environment", "learning some findings of research literature about misconceptions", "group discussion during the activities" when they were expected to explain what they mostly liked about the program.

The second part of the fourth item expected the participating prospective teachers to explain *which characteristics of the training program they mostly disliked*. For this part of the item, five participants stated that they did not like "the limited time left for the activities". One of these five participants stated that:

"Ancak bunların yanında tek olumsuz gördüğüm yanı zamanın kısıtlı olması diye düşünüyorum. Belki daha çok tartışabilsek ya da öncesinden öğretmen adayı olarak bizlerden yani grup olarak bir yöntem bulsaydık, alternatif olabilecek yolları keşfeder ve çeşitliliğe ulaşırdık." (I think, limited time is the negative side of this program. If we had chance to discuss more or we suggest some methods as teacher candidates, we would find alternative and a variety of methods to change student misconceptions) (Prospective teacher #06)

For the second part of the fourth item, four participants listed "early meeting time of the sessions in mornings" as a property of the program they disliked. A few prospective teachers mentioned "the lack of break time between the activities", "being familiar with some activities of the program from previous educational courses" and "limited space left for the questions on the activity sheets" when they were expected to explain what they mostly disliked about the program. On the other hand, five participants stated that there was nothing they disliked about the program.

4.4.5. The Fifth Item of PEF

The fifth item was *"In your opinion, what should be added to/remove from the training program if it is repeated for some other groups of participants? What should be* *changed about the program."* According to seven participants, "new chemistry subjects should be added to the program". Moreover, seven participants suggested "the rearrangement of the time planned for each activity of the program". Also, three prospective teachers suggested "the discussion part of the participants should be increased". Furthermore, "removing evaluation of the activity part at the end of each activity"," increasing the number of student responses from CCT", "informing the participants about the content of the session before the sessions", etc. were suggested by a few participants.

*"Bu program başka gruplar için tekrar yapılırsa bence neye ne kadar zaman ayrılması üzerinde bazı değişiklikler yapılabilir. Ayrıca maddenin tanecikli yapısı, kimyasal denge ve asitlere ilave olarak başka kavram yanılgılarına yönelik farklı konular programa eklenebilir." (If this program is repeated for some other groups, I think some changes could be made about the time which was planned for each parts of the program. Moreover, some other chemistry subjects may be added to the program in addition to the particulate nature of matter, chemical equilibrium and acids) (Prospective teacher #11)***.**

4.4.6. The Sixth Item of PEF

The sixth item asked the participants "*whether there were any misconceptions they found out in themselves and corrected during the training program"*. Majority of the prospective teachers, 15 prospective teachers stated they had misconceptions about the factors affecting the strength of an acid and corrected during the program. In addition, seven participants declared that they had had misconceptions about using Le Chatelier's principle in every chemical equilibrium situation before the program and changed it during the program. Also, three prospective teachers commented on finding out their misconceptions about classifying molecular elements as compounds.

4.4.7. The Seventh Item of PEF

The seventh item expected the participating prospective teachers "*how they would plan to benefit from the content and the methods of the program when they started to teach in a school"*. To this item, seven prospective teachers stated that they planned to use similar teaching tools included in the program such as modelling, group discussion etc., and 10 prospective teachers wrote the names of the same activities included in the training program. One of these 10 prospective teachers said that:

"Evet düşünüyorum.Kullandığımız bazı videolar özellikle ileri-geri tepkimeyle ilgili olan çok etkiliydi. Yapılan deneylerde yine kullanabileceğim ve basit düzenekle hemen anlaşılabilecek deneyler vardı. Asitliği ölçtüğümüz deney örneğin gayet güzel ve etkili bir deneydi."(Yes, I think. Some videos that we used, specially the one about forward and reverse reactions were very effective. Among the experiments performed, I could use some experiments which required simple apparatus and were easily understandable. The experiment that we measured acidity was a fine and effective experiment) (Prospective teacher #20).

4.4.8. The Eighth Item of PEF

The first part of the eighth item was *"Which activity was the most unforgettable for you?"* The analysis of participants' responses showed that the most unforgettable activity was acid strength laboratory work, 10 prospective teachers chose the acid strength activity as the most unforgettable activity. Moreover, four prospective teachers informed that the video that showed an analogical modelling in chemical equilibrium was unforgettable for them. In addition, three participants selected modelling acid solutions activity as the most unforgettable one. Several prospective teachers mentioned mixing different liquids, discussion of allotropes of carbon, ice-water equilibrium, concept map of hydrogen bonding as unforgettable activities.

The second part of the eighth item was *"Which activity was boring one for you?"* According to three prospective teachers, the first activity modelling particulate nature of matter was a boring activity. Also, two prospective teachers selected ice-water equilibrium as a boring activity. According to four prospective teachers, none of the activities of the training program was boring. Minority of prospective teachers mentioned mixing different liquids and modelling acid solutions as boring activities.

4.4.9. The Ninth Item of PEF

The first part of the ninth item expected the participating prospective teachers to explain "*which teaching methods they would use while teaching the particulate nature of matter, the chemical equilibrium and the acids subjects before attending the training program*". Without considering three subjects separately, seven prospective teachers stated that they would use visual teaching tools such as animations, simulations etc. and three prospective teachers stated that they would use experimentation. Also, four prospective teachers stated that they would use direct teaching methods. Moreover, three prospective teachers stated their lack of knowledge about teaching methods for the particulate nature of matter, the chemical equilibrium and the acids topics.

For the particulate nature of matter subject, four prospective teachers stated they would prefer visual teaching tools such as molecular drawings, animations, simulations etc. For chemical equilibrium subject, three prospective teachers stated that they would use analogical modelling activity that was also included in the program. Three prospective teachers stated that they would use direct teaching methods to teach chemical equilibrium. Two prospective teachers stated that they had no idea about which teaching methods they would use for chemical equilibrium before the program. For acids subject, five prospective teachers stated that they had no idea about the teaching methods which they would use for chemical equilibrium before the program. Also, one prospective teacher stated that she would solve problem to teach acids.

The second part of the ninth item expected the participants to explain "*how the methods which they were planning to use while teaching the particulate nature of matter, the chemical equilibrium and the acids subjects changed after the program*". Without considering three subjects separately, 10 prospective teachers stated that they would use visual teaching tools such as molecular representations, animations, simulations etc. and seven prospective teachers stated that they would use experimentation. Also, two prospective teachers stated that they would use analogies while teaching these subjects.

For the particulate nature of matter subject, three prospective teachers stated they would prefer visual teaching tools such as molecular drawings, animations, simulations etc.

Also for chemical equilibrium subject, two prospective teachers stated that they would use visualization tools. In addition, one participant stated that he would use the analogical modelling activity included in the program. Moreover, one prospective teacher stated that he would use ice-water equilibrium activity. For acids subject, two prospective teachers stated that they would use hands-on activities while teaching. Also, three prospective teachers stated that would use visualization tools to teach acids.

4.4.10. The Tenth Item of PEF

The tenth item was *"Do you have any problems about a chemical phenomenon that you did not learn well and could not ask during the training program?"* For the last item, 21 of 22 prospective teachers stated they did not have a problem about chemical phenomena included in the training program. One of the 22 teachers said that:

"Le Chatelier prensibinin uygun olmadığı durumların örneklerinin daha fazla verilmesini beklerdim. Bu konu çok netliğe kavuşmadan geçildi diye düşünüyorum." (I would expect more examples about the situations which the use of Le Chatelier's principle was not appropriate. I think, this subject was passed without sufficient clarification) (Prospective teacher #08).

5. CONCLUSION AND DISCUSSION

This research study had two main objectives. Firstly, the study aimed to develop a training program in order to increase prospective chemistry teachers' chemistry content knowledge in "particulate nature of matter", "chemical equilibrium" and "acid strength" subjects, pedagogical content knowledge related to misconceptions and teaching efficacy beliefs. While developing the training program, the suggestions from the research literature on misconceptions, conceptual change, teaching strategies, and professional development activities for teachers were taken into consideration. Secondly, the study aimed to evaluate the effectiveness of the developed training program. Twenty-two prospective chemistry teachers constituted the participants of the study. The effects of the training program were investigated by analyzing the change in these prospective teachers' responses on the instruments used in the study; "CCT" and "KBCMTEQ" and by the opinions of the participants about the program which they stated on "PEF". The responses of participants in interviews were also included in discussion and conclusion of the results.

5.1. Change in Prospective Chemistry Teachers' Content Knowledge

In order to determine the effect of the training program on participants' chemistry content knowledge in the subjects of "particulate nature of matter", "chemical equilibrium" and "acid strength", the categories of participants' responses on "CCT" before the program and the categories on "CCT-B" after the program were compared by Wilcoxon signed rank test. The analysis of the responses of participants on CCT showed that prospective chemistry teachers had a variety of misconceptions about "particulate nature of matter", "chemical equilibrium" and "acid strength" subjects before attending the training program. Also, the analysis of the responses showed that participants retained some of these misconceptions after the program. According to the results, it can be concluded that, participants' content knowledge increased and some of their misconceptions decreased in "particulate nature of matter", "chemical equilibrium" and "acid strength" subjects during the training program.

Research literature on misconceptions indicated that misconceptions of students were found to be very resistant to change (Driver, 1983). In this study, some prospective chemistry teachers' misconceptions retained even if these concepts were discussed in the training program. Thus, it can be said that the findings of this study also confirmed the resistant nature of misconceptions.

The training program included five activities about "particulate nature of matter", three activities about "chemical equilibrium" and two activities about "acid strength". The concepts about one chemistry subject were also included in other activities about the same subject. Yet, new concepts in a completed activity were not discussed in the activities of other subjects. For the items in which prospective chemistry teachers did not change their misconceptions, majority of the participants, who were interviewed, stated that they forgot new concepts and turned their non-scientific thinking a few weeks later. Thus, in order to increase the effect of the training program on participants' content knowledge and achieve long-term learning, it can be said that new concepts should be repeated in and integrated into the following sessions of the training program.

For some items of CCT, majority of prospective chemistry teachers did not have misconceptions before attending the training program. It was also found that, in these items, participants did not hold any misconceptions after the training program. Thus, for these items the training program did not change the content knowledge of participants because of the fact that the participants have had already a scientific understanding related to these subjects.

On the other hand, for the items in which prospective chemistry teachers changed their misconceptions, participants, who were interviewed, stated some characteristics of the activities included in the training program. The results of analysis of items and sub-items of CCT and participants' comments on their responses were summarized in the following paragraphs. The comparison of the findings with the results of other research studies that were conducted to investigate corresponding misconceptions were also included in these paragraphs.

5.1.1. Change in Prospective Chemistry Teachers' Content Knowledge about Particulate Nature of Matter

In the first sub-item (1a1) of the first item of CCT, prospective teachers misconception that "there was air between the particles of matters" decreased after the training program. In a research study (Novick and Nussbaum, 1978), eight grade students' understanding of the particulate nature of matter was investigated. The results of that study showed that eight grade students also thought that the space between the particles of a matter was filled with something such as air, dust, oxygen gas, nitrogen gas, etc. Thus, it can be said that, prospective teachers in this study had the same misconceptions with eighth-grade students before the training program. In the interviews, some participants stated that "the animation of phase change of water" and "the discussion of the concept of empty space between particles of matters" in the second activity helped them change their misconceptions.

In the second, fifth and eighth sub-items (1a2, 1a5, and, 1b1) of the first item of CCT, the space between the particles of ice and liquid water and the structure of ice were investigated. Prospective teachers had misconceptions about relative spacing between particles of ice and liquid water before the training program. Prospective teachers stated these misconceptions in some sub-items, but at the same time, they gave scientific responses on other items after the training program. This result might show that prospective teachers learnt some properties of ice but did not successfully change their misconceptions. This result may indicate that conceptual change was a slow and gradual process as Vosniadou (2007a) stated. Moreover, in the second and fifth sub-items (1a2 and 1a5), some prospective teachers mentioned that they had difficulty to correctly answer these sub-items because of the word "some" in the statement. According to these prospective teachers, the term of "some distance" confused them and could not imagine how much distance is some distance. According to the comments of these participants, it can be said that, more clear and comparative statements such as "more distance than those in the liquid form or the minimum distance among three phases" could be helpful for those teachers to answer these questions correctly.

In the third sub-item (1a3) of the first item of CCT, the number of prospective teachers who stated that "it was the hydrogen bond that kept hydrogen and oxygen atoms together within the water molecule" was significantly decreased after the training program. Some participants expressed that comparison of evaporation and electrolysis of water in macroscopic, microscopic and symbolic levels in the tenth activity of the training program helped them understand the intra-molecular forces in a water molecule and inter-molecular forces between water molecules.

The fourth sub-item (1a4) of the first item of CCT showed that only a few prospective teachers believed that "the atoms or molecules of a matter might be hard or soft" and "water molecules were hard when water was in solid phase and they were soft when water was in liquid and gas phases" before the training program. Ben-Zvi, Eylon and Silberstein (1986) showed that10th grade students believed that one single, isolated atom had the same properties with the bulk matter. Thus, it can be seen that, prospective teachers in this study had similar misconceptions with high school students before the training program. In the fourth sub-item (1a4), the number of prospective teachers who thought that "the atoms or molecules of a matter might be hard or soft" and "water molecules were hard when water was in solid phase and they were soft when water was in liquid and gas phases" was significantly decreased after the program. For this sub-item, participants stated that discussion of allotropes of carbon in the fourth activity of the training program helped them understand the relationship between the particles of a matter and the bulk matter.

The sixth and seventh sub-items (1a5 and 1a6) of the first item of CCT showed that majority of the prospective teachers already had a correct understanding about the fact that the nature of particles and mass of substances did not change in phase changes. Thus, it can be said that participants' content knowledge in these sub-items did not change since they already had a scientific understanding before the training program.

In the ninth sub-item (1b2) of the first item of CCT, participants were expected to draw the particles of water vapour in pre-test and the particles of liquid water in post-test. The particles of water vapour have the same arrangement and properties with the particles of any other matters in gas phase. Thus, most of the prospective teachers successfully drew the microscopic representation of water vapour and only a few prospective teachers had misconceptions about water vapour before the program. On the other hand, the space between the particles of liquid water is less than that of ice, so water is different from other liquids and has an exceptional property as a liquid resulted from hydrogen bonding. Thus, most of the prospective teachers failed to draw the microscopic representation of liquid water correctly compared to ice after the program.

The second item of CCT showed that majority of the prospective chemistry teachers in this study incorrectly used the terms atom and element interchangeably and a few prospective teachers wrongly classified molecular elements as compounds before the training program. This finding is consistent with the findings of the research study, conducted by Stains and Talanquer (2007), which showed that undergraduate chemistry students categorized microscopic representations of molecular elements as compounds. In the second item of CCT, there was significant difference between prospective teachers' ranks in only sixth sub-item (2c2) of twelve sub-items after the program. In this sub-item, a few participants used the terms element and atom interchangeably after the training program. The difference in this sub-item was found significant by statistical analysis, but, this misconception was not changed in the fourth sub-item of this second item (2b2). Thus, it can be concluded that attending the training program did not change the misconceptions of prospective teachers in the second item. These results was found to be consistent that Zirbel's study (2004) which indicated that students can hold their misconceptions while accepting and using the new concepts. Moreover, this misconception might be resulted from participants' lack of understanding in differentiation of macroscopic and microscopic levels. Some additional activities that target macroscopic and microscopic levels of matter should be integrated into the training program.

To sum up, the responses of participants on some items of CCT showed that prospective chemistry teachers had a variety of misconceptions about particulate nature of matter before attending the training program. Attending the training program, developed for this study, successfully changed prospective chemistry teachers' misconceptions for some items of this subject but not for some others. Moreover, in some sub-items, prospective teachers already had a scientific understanding before the training program. Thus, prospective teachers' content knowledge was not changed in these items. As a conclusion, when the subject was considered as a whole, it can be said that the content knowledge of prospective teachers in particulate nature of matter was increased after the training program.

5.1.2. Change in Prospective Chemistry Teachers' Content Knowledge about Chemical Equilibrium

In the third item of CCT, there was sign difference between prospective teachers' responses in the first and the second sub-items (3a and 3b). The third item of CCT showed that, a high number of prospective chemistry teachers who participated in this study thought that the concentrations of reactants and products were proportional with the coefficients in reaction equation before attending the training program. In their study, Hackling and Garnett (1985) also found that high school students believed that there was an arithmetical relationship between the concentrations of reactants and products at chemical equilibrium. Moreover, prospective chemistry teachers who participated in this study had misconceptions "the rates of forward and reverse reactions cannot be calculated at the moment of equilibrium" and "the rate of forward reaction would be higher than that of reverse reaction at the moment of equilibrium". The study conducted by Sepet, Yilmaz and Morgil (2004) showed that high school students thought that "the forward and reverse reactions were completed when one of the matters were consumed" and "the rate of forward reaction was higher than that of reverse reaction at equilibrium". Thus, it can be concluded that, the prospective teachers in this study had similar misconceptions with the high school students before the training program, and changed these misconceptions after the training program. Furthermore, before the training program, majority of the prospective teachers already had a correct understanding about the substances found in medium at chemical equilibrium. Thus, it can also be said that, participants' content knowledge in this sub-item did not change since they already had a scientific understanding before the training program.

The fourth item of CCT showed that, before the training program, majority of the prospective teachers tended to apply Le Chatelier's principle even when the use of the principle was not appropriate. They also thought that adding a noble gas to a chemical equilibrium system at constant pressure did not disturb the equilibrium. These results of this study were consistent with the results of the study conducted by Cheung (2009). In that study, Cheung (2009) also found that secondary school teachers tended to use Le Chatelier’s principle even when the principle could not solve the problem. Also, majority of the secondary school teachers predicted no change when argon was added to an equilibrium system at constant pressure because argon did not react with the chemicals in the medium. In the fourth item, after the training program, most of the prospective teachers tended to apply Le Chatelier’s principle as in the pre-test. Also, some prospective teachers tried to write reaction quotient, but they failed either to write the reaction quotient correctly or to draw correct conclusions from the quotient. Furthermore, participants retained their misconceptions that adding a noble gas to a chemical equilibrium system at constant pressure would not affect the equilibrium after the program. These results indicated that participants’ misconceptions retained after the program. Thus, it can be concluded that the training program did not affect prospective teachers’ content knowledge in cases of adding a matter to a equilibrium system at constant pressure and the limitations of Le Chatelier’s principle. In the interviews, the participants were asked that why their misconceptions in this subject did not change after the training program and, they mainly listed the limited time for the activity of “discussion of limitations of Le Chatelier’s principle” and limited number of exercise questions as the reason. Some of the prospective teachers also suggested to solve equilibrium problems with numerical values.

To sum up, the responses of participants on some items of CCT showed that prospective chemistry teachers had a variety of misconceptions about chemical equilibrium before the training program. Attending the training program successfully changed prospective chemistry teachers’ misconceptions for some items of this subject but not for some others. Also, in one sub-item, prospective teachers already had a scientific understanding before the training program. Thus, prospective teachers’ content knowledge was not changed in the corresponding item. As a conclusion, when the subject was considered as a whole, it can be said that the content knowledge of prospective teachers in chemical equilibrium was increased after the training program.

5.1.3. Change in Prospective Chemistry Teachers' Content Knowledge about Acid Strength

The fifth item of CCT showed that, before the training program, majority of the prospective chemistry teachers believed that "the strength of an acid was determined by the pH of acid solution". Sheppard (2006) showed that some of the high school students who attended that study related the strength of an acid or base to the pH value of their solutions similar to the prospective chemistry teachers in this study. Moreover, most of the prospective chemistry teachers who participated in this study believed that "the strength of an acid would change if the concentration of acid solution was changed". Boz (2009) also showed that majority of prospective teachers who attended that study could not differentiate concentration and strength of an acid. The results of that study were found to be consistent with the current study. In the fifth item, majority of the participants' misconceptions changed after the training program. Most of the prospective teachers understood that "the strength of an acid was dependent on the percentage of its dissociation in water" after the program. Only one participant thought that the strength of an acid was determined by the pH of acid solution. Indeed, it was found that this prospective teacher did not attend the session in which the factors affecting acid strength were discussed. Prospective teachers generally stated that inquiry laboratory activity about acid strength was a very effective method to change these misconceptions. According to participants, designing an experiment to solve the inquiry question and observing the chemical phenomena challenged their knowledge and helped them to change their non-scientific beliefs.

The sixth item of CCT indicated that prospective chemistry teachers had misconceptions in dissociation of strong and weak acids in water before the training program. This result was found to be consistent with the study conducted by Ekiz *et al.* (2011), none of the prospective chemistry teachers participated in that study could represent and explain the ionization of HCl in water, correctly. After the training program, there was statistically significant difference between prospective teachers' pre- and post-drawings in the second sub-item (6b). Thus, it can be concluded that participants' understanding in dissociation of weak acids in water was increased during the training program. Prospective teachers stated that they practiced drawing the particulate nature of matter but they only drew the particles of elements, compounds and mixtures in different phases so it was interesting to draw the particles of acid solutions, thus this activity helped them change their misconceptions. Also, one of the prospective teachers stated that she considered only the ratio of ions when drawing the microscopic representation of concentrated and diluted solutions of weak acid without taking the number of water molecules into account before the program, but developed her understanding during the program.

To sum up, the responses of participants on some items of CCT showed that prospective chemistry teachers had various misconceptions about acid strength before attending the training program. Attending the training program developed for this study, successfully changed prospective chemistry teachers' misconceptions for some items of this subject, but not for some others. Yet, when the subject was considered as a whole, it can be said that the content knowledge of prospective teachers in acid strength was increased after attending the training program.

5.2. Change in Prospective Chemistry Teachers' PCK in terms of Understanding the Nature of Misconceptions

In order to determine the effect of the training program on participants' understanding related to misconceptions, participants' common responses in four items of "KBCMTEQ" before the program and after the program were compared. The results indicated an enhancement of participants' PCK in terms of understanding the nature of misconceptions, after the training program, in some aspects that was explained in detail in the following paragraphs.

For the items in which prospective chemistry teachers wrote more developed responses, they mostly mentioned the effect of the training program. On the other hand, some of the prospective teachers gave shorter responses on post-administration of KBCMTEQ. As the reason, prospective teachers stated, in the interviews that, they were reluctant to write a response in detail because they had the same test twice.

When prospective teachers were asked to define a misconception in the first item of KBCMTEQ, participants enriched their definitions, integrated more sources and examples of misconceptions into their definitions after the program. Thus, it can be concluded that prospective teachers more internalized the concept of “misconception” after the training program.

In the second item of KBCMTEQ, prospective teachers mainly listed the examples of student misconceptions in basic chemistry subjects, generally in the subject of “particulate nature of matter” and no participants stated examples of student misconceptions in the subject of “acid strength” before the training program. It is important to note that majority of prospective teachers had several misconceptions about the subject of “acid strength” before the training program. Some prospective teachers stated in the interviews, that they were not aware of their misconceptions, so they could not think this misconception as a misconception example before training program. Most of these prospective teachers changed this misconception during the program. After the training program, prospective teachers also stated misconception examples in more advanced chemistry concepts such as acid strength.

In the third item of KBCMTEQ, the number of participants who stated that teachers might be a source of misconceptions was increased after the training program. For this change, it can be said that, when the prospective teachers found out that they had certain misconceptions in basic chemistry subjects, they thought that they would teach this misconceptions as if they were scientific concepts if they did not attend to this training program.

For the eighth item of KBCMTEQ, a little decrease in the number of participants who stated “changing students’ misconceptions was a difficult process” was observed after the training program. Prospective teachers stated that if teachers knew effective ways to change student misconceptions, it was not difficult to change these misconceptions.

To sum up, the results showed that the prospective chemistry teachers participating in the study, already had advanced PCK in terms of understanding the nature of misconceptions before attending the training program. In addition, attending the training program increased prospective chemistry teachers' pedagogical content knowledge in terms of understanding the nature of misconceptions in some more aspects.

5.3. Change in Prospective Chemistry Teachers' PCK in terms of Strategies to Identify and Change Student Misconceptions

In order to determine the effect of the training program on participants' pedagogical content knowledge in terms of strategies to identify and change student misconceptions, participants' common responses in five items of "KBCMTEQ" before the program and after the program were compared. The results indicated an enhancement of participants' pedagogical content knowledge in terms of strategies to identify and change student misconceptions after the training program.

In the fourth item of KBCMTEQ, the number of prospective teachers who expressed the importance of designing the lesson plan according to the student misconceptions increased after the program. Moreover, in the seventh item of KBCMTEQ, a higher number of prospective teachers stated that would change the flow of their lesson and the lesson plan designed to teach this lesson in the future, if they identified a misconception in some of their students, after the training program. As a result, it can be concluded that, prospective chemistry teachers more emphasized preventing and changing student misconceptions in instruction after the training program.

In the fifth item of KBCMTEQ, a higher number of prospective teachers emphasized asking open-ended questions in order to identify students' misconceptions after the training program compared to the number of prospective teachers before the program. According to these prospective teachers, a question that asked only right answer could not identify student misconceptions, students might select the correct choice despite the fact that they had certain misconceptions. Thus, teachers should question the reasons behind student responses. Bergquist and Heikkinen (1990) also indicated that, high marks on an examination could be interpreted as an indication that students understood the material, but it was likely that these students would assimilate some misunderstandings. It can be concluded that, training program led prospective teachers to ask more open-ended questions in instruction.

For the sixth item of KBCMTEQ, prospective teachers were expected to suggest teaching methods in order to change student misconceptions. After the training program, especially, the number of participants who suggested to use supplementary visual teaching materials and who suggested laboratory works was highly increased. It might be resulted because of the fact that these teaching methods were commonly used in the training program.

In the eleventh item of KBCMTEQ, participants were expected to write a lesson flow to change a specific misconception. Prospective teachers who wrote just wrote the name of teaching strategies before the training program, elaborated their lesson flows after the program. It can be concluded that, enhancement of the lesson flows of participants could be thought as an evidence for improvement of the participants' pedagogical content knowledge related to misconceptions in terms of teaching strategies. In the interviews, prospective chemistry teachers were expected to enhance their lesson plans. Most of the prospective teachers could more elaborate their lesson plans in the interviews. Yet, these prospective teachers stated that they could write a limited plan because of their decreased motivation at the last item of the questionnaire and the time restrictions. Different instruments could be administered to better assess PCK related to misconceptions. As a result, it can be concluded that, prospective chemistry teachers' pedagogical content knowledge in writing a lesson flow which targeted a specific misconception was enhanced after attending the training program.

To sum up, all of these results showed that attending the training program enhanced prospective chemistry teachers' pedagogical content knowledge in terms of strategies to identify and change student misconceptions. Yet, it can be sait that, the instrument used in this study had limitations to assess the actual effectiveness of the training program on pedagogical content knowledge related to misconceptions.

5.4. Change in Prospective Chemistry Teachers' Teaching Efficacy Beliefs

In order to determine the effect of the training program on participants' teaching efficacy beliefs, participants' common responses in two items of "KBCMTEQ" before the program and after the program were compared. Participants' teaching efficacy beliefs were evaluated in terms of both teaching methods which they believed that they could efficiently use and certain chemistry subjects which they believed that could teach efficiently.

In terms of teaching methods, prospective teachers wrote a higher number of teaching methods which they believe they could efficiently use after the training program and listed some new teaching methods which they did not mention before the training program. Thus, it can be concluded that, the training program enhanced prospective chemistry teachers' teaching efficacy beliefs in terms of using these teaching methods.

In terms of chemistry subjects, prospective teachers assigned similar numeric points before and after the training program in the subject of "particulate nature of matter". A higher number of prospective teachers indicated that they believed they were able to teach "chemical equilibrium" efficiently after the training program. Finally most prospective teachers were undecided about their beliefs about teaching "acids and bases" before and after the training program. It can be concluded that, teaching efficacy beliefs of prospective teachers did not change for the subjects of "particulate nature of matter" and "acid strength", but enhanced for the subject of "chemical equilibrium".

Prospective teachers quite changed their misconceptions about acid strength after the training program, but it was found that their teaching efficacy beliefs about this subject were still not changed much. It may be resulted from the fact that a more general term "acids and bases" rather than "acid strength" were used in the item. Prospective teachers were generally unsure about their efficacy beliefs about this subject, and it might result from the fact that they could not be sure about their knowledge in other aspects of this subject which was not covered during the program such as bases, titration, neutralization, etc.

5.5. Limitations of the Study

The main limitation in this research study was the number of the participants, only 22 prospective chemistry teachers attended the training program. Also, the participants of the study were not chosen by random selection but conveniently. Moreover, all of the participants were from the same university, participants from different universities may result different findings. In addition, majority of the participants were at the fourth and fifth year of their university program, prospective teachers at different years of their university program may cause different results. Thus, the results of the study cannot be generalized to all prospective chemistry teachers.

The training program was implemented in five sessions. Thus, there was limited time for each activity. Thus, it was difficult to spend much time for discussions, it would be better, if participants had more time for discussions. Moreover, the training program was developed before the pre-measurement, so only some changes were conducted in the training program according to the results of pre-measurement. It might be better to design the activities according to the responses of participants in pre-tests.

In this study, similar forms of instruments were administered as pre-tests and post-tests. Thus, participants were less motivated to respond in post-tests because they have already answered similar questions before. Furthermore, the items in KBCMTEQ had limitations to measure the change in participants' pedagogical content knowledge related to misconceptions. These factors may prevent to show actual improvements of participants on the investigated variables. It is another limitation of the study.

5.6. Recommendations for Further Research

Based on the findings of the current research study, following recommendations may be helpful for future studies.

This study can be conducted with a larger number of prospective chemistry teachers in order to generalize the results. It would be better to choose the participants with random selection from different levels and different universities. Further research can be conducted to compare the effects of the training program on two different groups of participants; for example prospective and in-service chemistry teachers. Moreover, the number of chemistry subjects can be increased by including different subjects. In addition, some other constructs could be added to the study such as anxiety, job satisfaction etc. Thus, other effects of the training program could be investigated.

On the other hand, this study can be conducted with some changes in the structure of the training program. Firstly, the time for each activity may be increased, so there would be more time for discussion of participants during the activities. In addition, the time allocated for the activities may be organized according to the results of pre-measurement. The activities which the participants do not have any misconception could be removed from the program and the time for the activities which majority of the participants have several misconceptions could be increased. Also, additional activities may be integrated to the training program especially for the chemistry subjects that the content knowledge of participants was not found significantly different after attending the program. For example, participants observed the molecular representation of water in three phases by the help of an animation in the training program, but the participants retained their misconceptions about the specific structure of water. It is recommended for participants of further studies to draw the specific structure of water during the activity in order to change their misconceptions. Furthermore, the concepts which were adressed in one session of the training program may be discussed in the following sessions, so learning would be more permanent.

In this study, the same instrument (KBCMTEQ) was used in order to evaluate the change in participants' pedagogical content knowledge related to misconceptions, so respondents were less motivated to respond it in post-measurement. In addition, the items in this instrument had limitations to measure participants' pedagogical content knowledge. Thus, different items which increase respondents' motivation to answer and also more clearly show the change in participants' pedagogical content knowledge can be added to the instruments to better evaluate the effect of the program on participants. For example, items which include some teaching scenarios or vignettes can be presented to respondents. Respondents can be asked to add or change some parts in these scenarios or vignettes for enhancing students' comprehension or resolving the confusion presented. Furthermore, a number of propective teachers who attended this study stated that the statement of "some distance" in the items of "1a2 and 1a5" confused them while they were thinking about the answer. Thus, it would be better to use more structured and clear directions in the instruments of further research studies.

In this study, activity sheets were used as a teaching tool during the training program and they were not analysed to evaluate the change in participants' content and pedagogical content knowledge after attending the training program. Activity sheets can be used as the main instruments in further studies for formative evaluation of the effect of the training program on participants rather than administering a post-test at the end. Moreover, whole data can be collected by interviewing the participants before and after attending the training program to better understand the change in participants.

APPENDIX A : FLOW OF THE SESSIONS

FLOW of the 1st SESSION

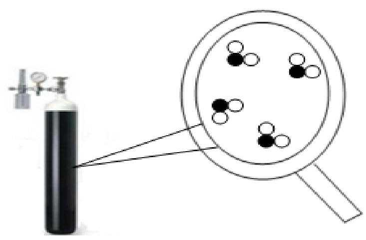
In the short presentation related to misconceptions part of the first session before starting the activities, the term “concept” was defined and the role of students’ existing conceptions in their learning was explained. Moreover, it was stated that students might have scientific and non-scientific conceptions before starting instruction. Then, misconceptions were described and different terminologies to describe misconceptions were summarized. After the presentation about misconceptions, the first and the second activity were performed in the first session as described below.

Flow of the 1st Activity : Modelling Particulate Nature of Matter

Target Misconceptions
1. The mixture of two pure substances is a pure substance
2. The concepts of element and atom always can be replaced with each other
3. All polyatomic chemical species are compounds.
4. Pure substances are at the same time homogeneous mixtures

1. In the first activity, the chosen student responses which were given to the second question of the CCT were shown to the prospective teachers. One example response (Student#025) from student responses was given below:

2b) The matter:



- Mixture ( )
- Pure substance (X)
- Compund (X)

Because; It is a pure substance because it consists of only one kind of molecules. Since the molecules consist of two different atom, it is a compound.

- It consists of only one element ( )
- It consists of two different elements (X)
- It consists of an element and a compound ( )
- It consists of only one compound (X)
- It consists of two different compounds ( )

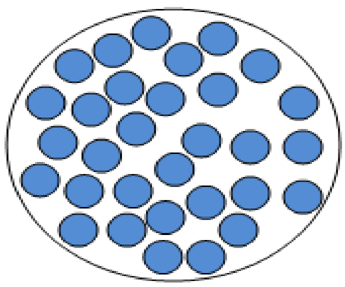
Because; There is two different atoms in the molecules. Thus, the matter consists of two different elements. Yet, the matter consists of only one compound because all of the molecules in the demonstration are the same.

2. Participating prospective teachers were expected to discuss the students' responses to the second question of CCT as a group and evaluate the student response as correct or incorrect.

3. Participants were asked to suggest an activity or instructional strategy to remediate misconceptions about the particulate nature of matter which they identified.

4. The misconceptions of 12th grade students indicated that students did not have a correct and complete understanding of the concepts of element, compound and mixture. Furthermore, students might have difficulty to differentiate the particles of elements, compounds and mixtures, mostly probably due to the fact that it is not possible to observe the molecular level.

5. The activity started with the definition of concepts "element", "compound" and "mixture". In the definitions, it was emphasized that molecular elements have covalent bonds. The particle models for the terms element, compound and mixture were introduced. In the particle models, different colours meant different atoms and colours and organization of particles changed according to the composition and phases of corresponding matter. In the particle models, models of molecular elements such as O_2, N_2, O_3 were emphasized as they were not compounds. For example, the particles of a liquid element was described and drawn as the following model:



Particles of a Liquid Element

It is composed of only one kind of atoms

It is a pure substance

It is monoatomic

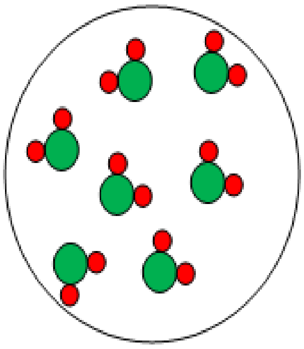
Particles are disordered

The space between particles is litttle

There is nothing between particles

The intermolecular forces between particles are weaker

During the activity, the prospective teachers also discussed the concepts of atoms and elements with a demonstration.



Which statement is true?

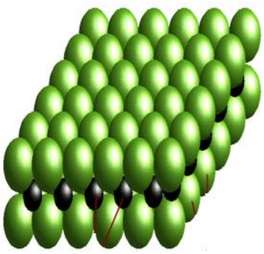
This matter consists of only one compound

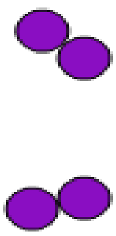
OR

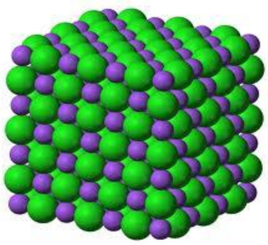
This matter consists of two different elements

Both macroscopic pictures and microscopic representations for the reaction of sodium metal and chlorine gas to form sodium chloride were presented and it was explained that sodium chloride consisted of sodium atoms, but not elemental form of sodium.

$2Na_{(k)} \quad + \quad Cl_{2(g)} \quad \rightarrow \quad NaCl_{(k)}$

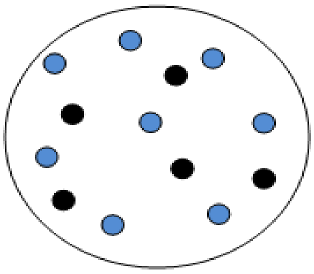




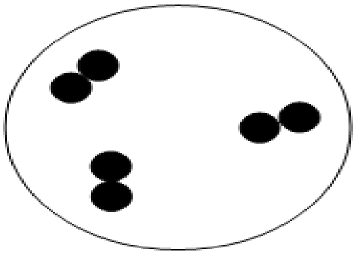


Also, a modelling activity with modelling clays was planned as modelling the particles of given matters such as iron metal, oxygen gas, the mixture of HCN and He and the mixture of NH_3 and water, but the activity could not be taken place because of time restrictions.

6. Participating prospective teachers discussed the particle models of some example substances, as the two representations given below, in terms of its composition, purity and homogeneity. They were asked which of the terms can be used for the substance given in the representation.

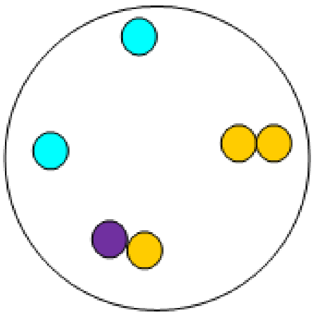


Is the matter
An element?
A compound?
A mixture?
Homogeneous ?
A pure substance?



Is the matter
An element?
A compound?
A mixture?
Homogeneous ?
A pure substance?

Prospective teachers also did similar categorization tasks given in the Activity Sheet I (Appendix B).



The matter is

a. An element   b. A compound   c. A mixture

Because
………………………………………………
………………………………………………
………………………………………………

The matter consists of ………………………………

7. After the activity was finished, the participants were expected to evaluate the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

Flow of the 2nd Activity : Animation of Phase Change of Water

Target Misconceptions
1. There is air between the particles of matters
2. There is not any space between the particles of solids
3. When water evaporates, water molecules expand
4. The space between the particles of ice is less than that of liquid water
5. When water evaporates, water molecules decompose to hydrogen and oxygen atoms

1. In the second activity, the chosen student responses which were given to the first and the second part of the first question of the CCT were shown to the prospective teachers. One example response (Student#244) from student responses was given below:

	True	False	Explanation
There is some distance between the molecules of ice		X	Ice is a solid so there is no space between the particles of ice. It has ordered structure. The particles can only have vibrational motion.

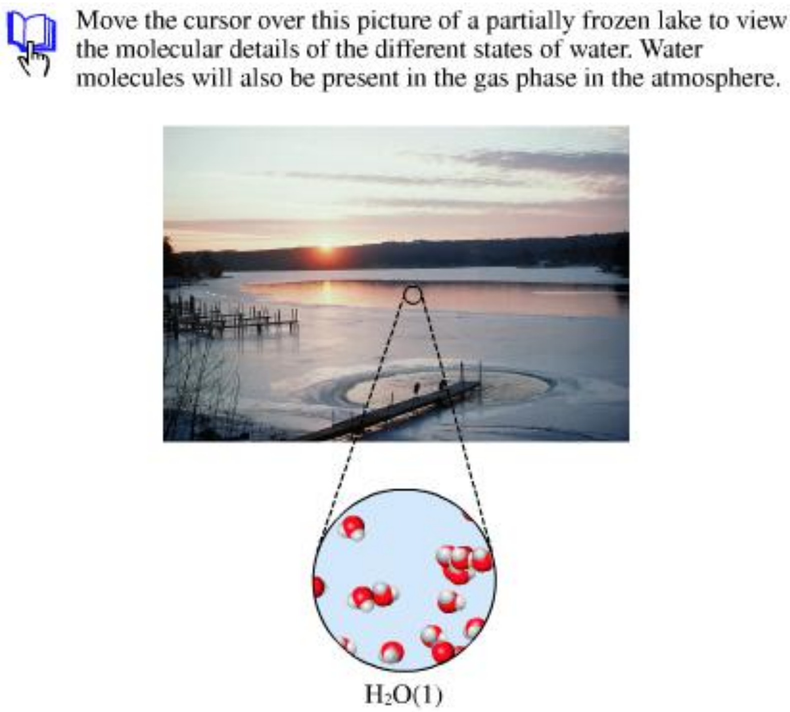
2. Prospective chemistry teachers were asked to discuss and evaluate the presented student responses as a group.

3. Prospective chemistry teachers were asked to suggest instructional strategies to change the misconceptions about the particulate nature of matter which they identified.

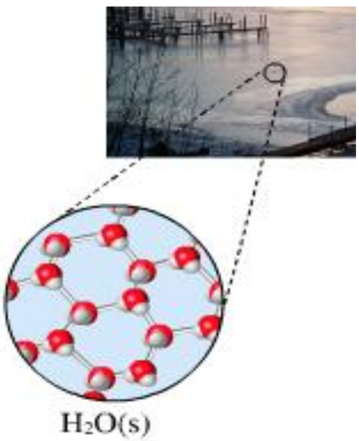
4. The target misconceptions of 12th grade students indicated that students did not have a correct understanding of the particulate nature of matter. Students could not visualize how the structure of the matter and the space and intermolecular forces between particles changed when a matter changed phase. Furthermore, students might have difficulty to understand the unique properties of matter resulted from hydrogen bonding.

5. The activity started with questioning technique to attract prospective teachers' attention. The participants were asked the name of attraction forces between the molecules of water and in which phase these forces are stronger. Since, it was easier to expect stronger intermolecular forces cause the particles of ice to be closer, it was questioned that why a glass bottle filled with water cracked after it left in a freezer.

Prospective chemistry teachers watched the animation and while they were watching the animation, arrangement and properties of water molecules in three phases was explained by the researcher.



(http://www.media.pearson.com.au/schools/cw/au_sch_irwin_cc2_2/int/ch14/phases/0105.html)



In the solid phase of water**,** water molecules have ordered lattice structure

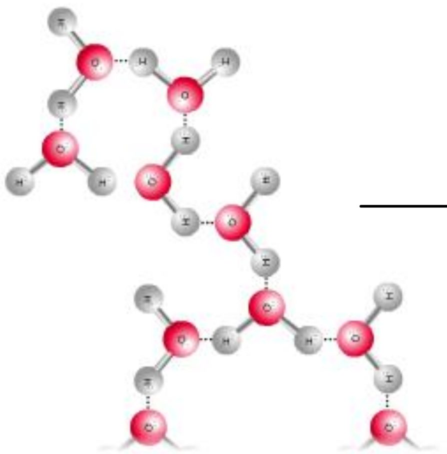
Intermolecular forces between the water molecules are the strongest

Each water molecule forms hydrogen bonds with adjacent water molecules

Hydrogen bonds hold water molecules in a fixed three dimensional pattern

Thus, ice has a lower density than water different from ordinary liquids

6. Prospective teachers were expected to predict and write the related characteristics of water molecules according to the given molecular representations in the Activity Sheet I (Appendix B).



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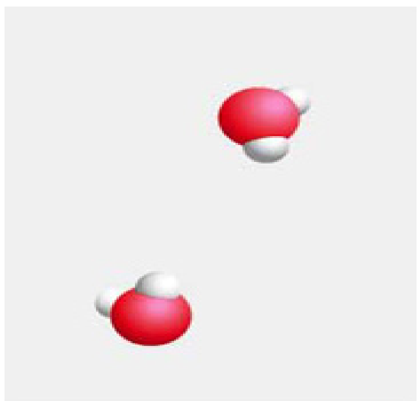

→ ....
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Finally, the changed and conserved properties of water molecules were discussed.

7. After the activity was finished, the prospective chemistry teachers were expected to evaluate the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

FLOW of the 2nd SESSION

In the short presentation related to misconceptions part of the second session before starting the activities, examples of student misconceptions about several chemistry topics were presented to prospective teachers. To exemplify misconceptions, misconceptions from solubility, vaporization and vapour pressure and ionization energy concepts were given and discussed. From solubility, several misconceptions about dissolution and melting concepts, concentration and saturation terms, boiling point of solutions were summarized. The misconceptions about vaporization and vapour pressure concepts, the relationship between equilibrium vapour pressure and the amount of liquid or the volume of the vapour were given to prospective teachers about vaporization and vapour pressure subject. Furthermore, the prospective teachers were informed about misconceptions about stability of atoms and their ions, the changes when an atom lost an electron.

Flow of the 3rd Activity : Mixing of Different Liquids

Target Misconceptions
1. There is no space between the particles of matters in liquid state
2. There is air between particles of matters in liquid state
3. The space between the particles of liquids is intermediate compared to solids and gases

1. In the third activity, example student responses from the first question of the CCT were shown to the prospective teachers. One example response (Student#282) from student responses was given below:

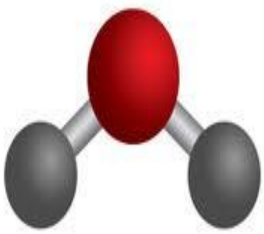
	True	False	Explanation
There is some distance between the molecules of water when it is in liquid form		X	Since hydrogen bond exists between water molecules, there is no distance between the molecules of water when it is in liquid form. For example, even a little amount of water stick together as a drop

2. Participants were expected to discuss student responses as a group and evaluated them as scientifically correct or incorrect.

3. Prospective chemistry teachers were asked to suggest instructional strategies to change the misconceptions about the particulate nature of matter which they identified.

4. The target misconceptions of 12th grade students about liquids indicated that students had difficulty to understand the concept of empty space and how much distance was present between the particles of liquids.

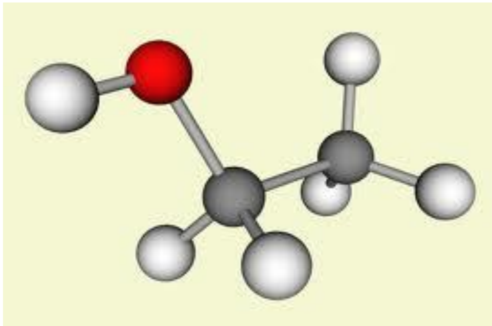
5. In this activity, prospective teachers performed a hands-on activity and mixed different liquids; namely, water, ethyl alcohol and oil. Before starting the activities, the participants were expected to predict the final volume when known amount of liquids were mixed. Then, they produced ethyl alcohol-water and oil-water mixtures in separate cylinders and observed the volume changes. After mixing liquids, the terms polarity, electronegativity and the effect of intermolecular forces in a liquid on dissolution were discussed. Moreover, the role of spacing in liquids was emphasized to explain decrease of volume when two liquids dissolved in each other.



Water

It has polar molecular structure

There is hydrogen bonding and dipole-dipole attractions between water molecules



Ethyl Alcohol

It has polar molecular structure

There is hydrogen bonding and dipole-dipole attractions between ethyl alcohol molecules

When water and ethyl alcohol is mixed

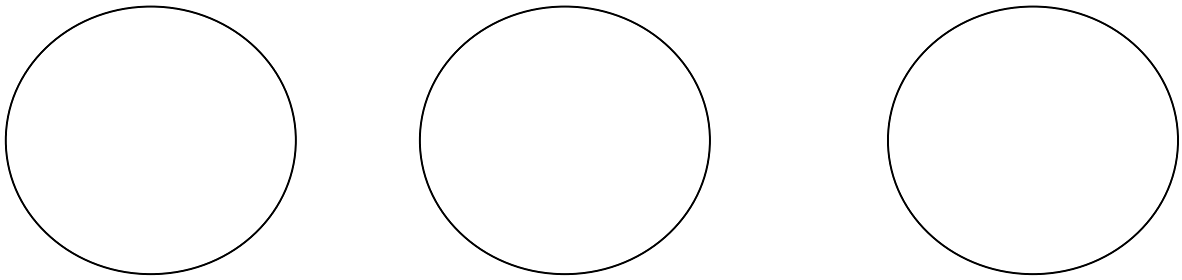
There is also hydrogen bonding and dipole-dipole attractions between molecules of water and ethyl alcohol

Thus, water and ethyl alcohol dissolve in each other and mix homogeneously

6. Prospective teachers were expected to draw how the particles of ethyl alcohol-water and oil-water mixtures appear under a magnifying glass on Activity Sheet II (Appendix B).

Draw the molecules of water and ethyl alcohol before and after they are mixed

Before Mixing **After Mixing**



Ethyl Alcohol Water Ethyl Alcohol & Water

7. The participants were expected to evaluate the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge after the activity was finished.

Flow of the 4th Activity : Exploring Particles of Diamond and Graphite

Target Misconception
1. The particles of a substance have the same properties with the bulk matter

1. In the fourth activity, example student responses from the first question of the CCT were shown to the prospective teachers. One example response (Student#392) from student responses was given below:

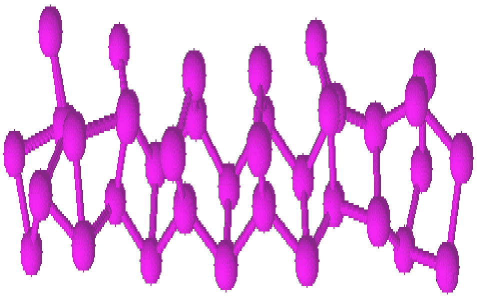
	True	False	Explanation
Water molecules are hard when water is in solid phase and they are soft when water is in liquid and gas phases	X		Because ice is a hard substance, water molecules in ice should also be hard. The properties of matter results from its molecules.

2. Participants were requested to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Prospective chemistry teachers were asked to suggest instructional strategies to change the misconceptions about the particulate nature of matter which they identified.

4. The target misconceptions of 12th grade students about an atom and corresponding matter indicated that students might attribute the properties of observable matter to individiual atoms because they could not observe the molecular world.

5. In this discussion activity, first of all, the concept of allotropy was described as property of some elements to be found in different forms via having different arrangement of its atoms. It was emphasized that different configuration of the same atoms might result completely different physical properties. Then, examples of two allotropes of phosphorus were presented to prospective teachers and characteristics of each allotrope were explained in detail.



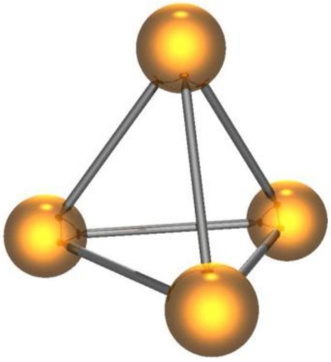
Red Phosphorus

Phosphorus atoms are in poylmeric structure in red phosphorus.

It is flammable but it does not ignite in air below 240 °C

It can ignite through rubbing, because of this property, it is used in matchbook strike plates.

It is not toxic.



White Phosphorus

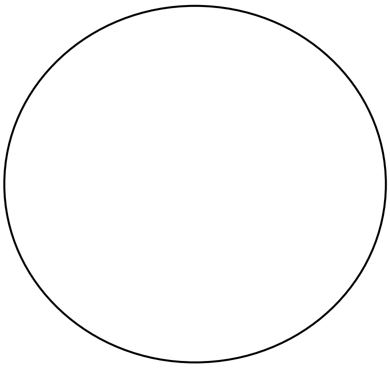
Phosphorus atoms in white phosphorus exists as molecules in tetrahedral arrangement made up of four atoms.
Because of its structure, white phosphorus is highly unstable.
It is flammable and it can ignite spontaneously in air at 50 °C. Because of this property, white phosphorus is used as a weapon.
It is toxic.

6. After talking about allotropes, the macroscopic pictures of two allotropes of carbon; diamond and graphite were demonstrated to the participants and they were expected to predict and draw microscopic representations of diamond and graphite according to pictures of these substances.

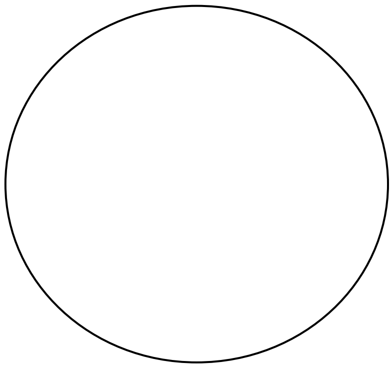
Diamond

Graphite

Draw the arrangement of carbon atoms in diamond and graphite on the Activity Sheet II taking the pictures of these substances into consideration (Appendix B).



Diamond



Graphite

Then, prospective chemistry teachers discussed whether the statement “The atoms of diamond are colorless and shiny whereas the atoms of graphite are black and dull” was scientifically correct or not according to the molecular models they drew.

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants’ conceptual and pedagogical knowledge.

FLOW of the 3rd SESSION

The starting presentation about misconceptions was about the sources of misconceptions in the third session. The prospective teachers were warned about that the language used may cause misconceptions in students. For example, the name of the term “neutralization” may cause students to infer that neutralization processes always yield neutral products. Furthermore, using anthropomorphic terms to explain chemical phenomena results students to understand atom as living things. Prospective teachers were also informed that analogies may result misconceptions if the analogical and target models and the limitation of the analogies were not well explained. Moreover, it was emphasized that some terms that have different meanings in daily life and science like concept of “force” may cause misconceptions in students. It was also stated that students understanding like generalization or miscategorization of concepts create misconceptions.

Also, prospective teachers were shown that representations in chemistry textbooks may result in misconceptions.

Flow of the 5th Activity : Ice-Water Equilibrium

Target Misconception
1. The concentration of reactants and products are equal at chemical equilibrium condition
2. The concentration of reactants and products are proportional with stoichiometric coefficients at chemical equilibrium condition

1. Before starting the fifth activity, the chosen student responses which were given to the first part of the third question of the CCT were shown to the prospective teachers. One example response (Student#002) from student responses was given below:

(3rd Question)

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ reaction is at equilibrium in a closed-container.

3a) Which of the following statements is correct about the concentration of reactants and products? Explain your reasoning.

a) The concentration of reactants is higher than the concentration of products.
b) The concentration of products is higher than the concentration of reactants.
+c) The concentration of reactants and products are equal.
d) There is not enough information to compare the concentration of reactants and products.

Because; the molarity of a solution is calculated with the formula of n/V. There is 2 moles of reactants and 2 moles of products. Thus, the concentration of reactants and products are equal.

2. Prospective chemistry teachers were asked to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were asked to suggest instructional strategies to change the misconceptions about the chemical equilibrium which they identified.

4. The target misconceptions of 12th grade students about the concentration of reactants and products at the moment of equilibrium indicated that student perceived "equal concentration of reactants and products" as a criterion for a system to reach chemical equilibrium. Moreover, it might result from students' generalization of the fact that the concentration of reactants and products were constant at the moment of equilibrium.

5. At the beginning of the activity, the prospective teachers were introduced an inquiry question: “What is the equilibrium temperature of ice and water mixture and what is the effect of the amounts of ice and water on the equilibrium temperature of ice-water mixture?”. Then, prospective teachers tried to design an experiment to identify the equilibrium temperature and determine the effect of amounts of matters on equilibrium temperature. Some groups took the same amount of water in different beakers, added the different amount of ice to the beakers and measured the temperature at the moment of equilibrium. Similarly, some other groups took the same amount of ice in different beakers, added the different amount of water to the beakers and measured the temperature at the moment of equilibrium. During the activity, prospective teachers had the opportunity to observe different amount of ice and water had no effect on the physical equilibrium of ice and water. Finally, both groups performed the results and discussed whether the concentration of reactants and products affected equilibrium. It was concluded that the concentration of reactants and products had no effect on equilibrium. In the activity, it was emphasized that this activity presented a physical equilibrium condition but it was also valid for chemical equilibrium.

6. After the hands-on activity, prospective teachers were asked to compare the concentration of reactants and products at different equilibrium conditions. (Activity Sheet III in Appendix B)

$\mathbf{N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}}$ if the reaction is at equilibrium in a closed-container, what can you tell about the concentration of reactants and products?

7. The participants were asked to evaluate the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants’ conceptual and pedagogical knowledge.

Flow of the 6th Activity : Equilibrium Analogy

Target Misconceptions
1. Forward and reverse reactions are completed at the moment of equilibrium
2. Only the products are found in the medium of chemical equilibrium

1. Before starting the sixth activity, the chosen student responses which were given to the second and third part of the third question of the CCT were projected for the prospective teachers. One example response (Student#042) from student responses was given below:

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ reaction is at equilibrium in a closed-container.

3b) Which of the following statements is correct about the rates of forward and reverse reactions? Explain your reasoning.

a) The rate of forward reaction is higher than the rate of reverse reaction.
b) The rate of reverse reaction is higher than the rate of forward reaction.
c) The rates of forward and reverse reactions are equal.
+**d)** There are no rates of forward or reverse reactions since all reactions are completed at the moment of equlibirum.

Because; when equilibirum is reached, there is no formation of compounds and elements. It means the reactions are completed.

2. Prospective chemistry teachers were requested to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were expected to suggest instructional strategies to change the misconceptions about the chemical equilibrium which they identified.

4. The target misconceptions of 12th grade students about the rates of forward and reverse reactions at the moment of equilibrium indicated that student had difficulty to understand dynamic nature of chemical equilibrium.

5. Participating prospective teachers watched the video that shows an analogical model for dynamic nature of chemical equilibrium (*http://www.youtube.com/watch?v=C5j*

DmG4nVV8). In the video, a teacher transferred some water from one beaker to another until the volume of water in both beakers did not change. This event was analogical to the phenomena that chemical equilibrium was reached when the rates of forward and reverse reactions become equal and reactions continued after the equilibrium was reached. During the video, the attributes of the analogical and the target models were explained such as what volume of water represented or what transferring water from one beaker to another was analogical.

6. After watching video, prospective teachers drew a graph that showed how volumes of water in two beakers changed with number of trials and interpreted these graphs in terms of the relationship between the rates of forward and reverse reactions. Then, prospective teachers answered the questions on the Activity Sheet III (Appendix B) such as;

$\mathbf{N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}}$ if the reaction is at equilibrium in a closed-container, what can you tell about the rates of forward and reverse reactions? Which matters are found in the reaction medium?

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

Flow of the 7th Activity : Discussion of Limitations of Le Chatelier's Principle

Target Misconception
1. Le Chatelier's principle is valid in all chemical equilibrium conditions

1. The example student responses which were given to the fourth question of the CCT were shown to the prospective teachers. One example response (Student#010) from student responses was given below:

(4th Question)

$4HCl_{(g)}$ + $O_{2(g)}$ $\rightleftharpoons$ $2H_2O_{(g)}$ + $2Cl_{2(g)}$ reaction is at equilibrium in a container with a movable piston at constant pressure and temperature.

4b) How does the number of O_2 molecules change if some amount of He (Helium) gas is added to the container? Explain your reasoning.

Because; Since He is a noble gas, it will not take place in the reaction, so it will not affect O_2 gas.

2. Prospective chemistry teachers were asked to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were expected to suggest instructional strategies to change the misconceptions about the chemical equilibrium which they identified.

4. The target misconceptions of 12th grade students showed that student believed that Le Chatelier's principle was valid in every equilibrium condition.

5. In the activity, firstly, the prospective teachers were expected to describe Le Chatelier's principle. Then, findings of the studies that showed the limitations of Le Chatelier's principle were discussed and some alternative methods such as calculation of reaction quotient to decide whether the rate of the forward or the reverse reaction would increase to reach the equilibrium. Some chemical equilibrium problems were solved and the methods about how to solve these problems were explained.

6. After the researcher solved and explained chemical equilibrium problems, the prospective teachers were asked to solve similar equilibrium problems on their own on the Activity Sheet III (Appendix B). One example problem was given below:

$CS_{2(g)}$ + $4H_{2(g)}$ $\rightleftharpoons$ $CH_{4(g)}$ + $2H_2S_{(g)}$ reaction is at equilibrium in a container with a movable piston at constant pressure and temperature. How does the number of CH_4 molecules change if some amount of CS_2 gas is added to the container? Explain your reasoning.

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

FLOW of the 4th SESSION

In the short presentation related to misconceptions part of the fourth session before starting the activities, three methods to identify misconceptions of students were described. Firstly, interviewing with students was described as one of the methods to discover their understanding and a short section of one interview transcript was shared with the prospective teachers. Secondly, concept cartoons were introduced as an alternative way to identify student misconceptions and some example concept cartoons were presented and discussed. Finally, conceptual questions were described as the most common method to identify student misconceptions. Examples of several different types of conceptual questions such as true-false, multiple-choice, modeling or two-tier questions were discussed with the participating prospective teachers.

Flow of the 8th Activity : Factors Affecting Acid Strength

Target Misconceptions
1. The strength of an acid is determined by the pH of the acid solution
2. The strength of an acid is determined by the concentration of the acid solution
3. Changing concentration of an acid solution does not affect its pH value

1. In the eighth activity, the chosen student responses which were given to the fifth question of the CCT were shown to the prospective teachers. One example response (Student#221) from student responses was given below:

(5th Question)

The name of acid	Molarity (M)	pH value	Acidity Constant (Ka) (at 25°C)
HNO_3	0,10	1,00	$3,0 \times 10^{1}$
HCN	0,01	5,40	$6,2 \times 10^{-10}$
CH_3COOH	1,00	2,38	$1,8 \times 10^{-5}$
HF	0,50	1,75	$6,6 \times 10^{-4}$
HCl	0,01	2,00	$1,3 \times 10^{6}$

5a) According to the table given above, order the given acids from the strongest acid to the weakest one. Explain your reasoning.

The strongest **...** ***The weakest***

HNO_3 > HF > HCl > CH_3COOH > HCN

Because ; the acid that has the lower pH value has a higher acid strength.

2. Prospective chemistry teachers were asked to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were requested to suggest instructional strategies to change the misconceptions about the chemical equilibrium which they identified.

4. The target misconceptions of 12th grade students showed that the strength of an acid was considered as dependent on the pH and concentration of acid solutions. Students need to understand the meaning of acidity constant deeper and use this value to comment on the strength of given acids.

5. The first part of the eighth activity was an inquiry laboratory activity, prospective teachers were given an inquiry question: “Is the strength of an acid dependent on the concentration and pH values of acid solution?”. Prospective teachers were expected to design an experiment to answer the research question with given laboratory materials. Then, the characteristics of strong and weak acids were discussed. In the second part of the activity, prospective teachers checked the pH values of two different acids with the same concentration. Then, the acidity constant concept was explained.

6. Prospective teachers discussed what factors affect dissociation of acids in water and whether increasing the concentration of an acid solution would increase the strength of the acid.

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

FLOW of the 5th SESSION

In the short presentation related to misconceptions part of the fifth session before starting the activities, methods to change misconceptions of students were introduced to prospective teachers. First of all, the four condition of conceptual change proposed by Posner *et al.* (1982) were explained and discussed. Then, the findings of some research studies conducted to change misconceptions of students in different chemistry topics were shared with the prospective teachers.

Flow of the 9th Activity : The particles of Acid Solutions

Target Misconceptions
1. Acids do not dissociate in water
2. Acids dissociate in different percentages in their concentrated and diluted solutions
3. There is no water molecule in strong acid solutions
4. In weak acid solutions, the concentration of acid molecules and ions are equal

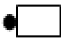
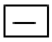
1. In the ninth activity, the chosen student responses which were given to the sixth question of the CCT were shown to the prospective teachers. One example response (Student#246) from student responses is given below:

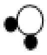
(6th Question)

$HA + H_2O \rightarrow A^- + H_3O^+$ The dissociation reaction of a strong acid in water

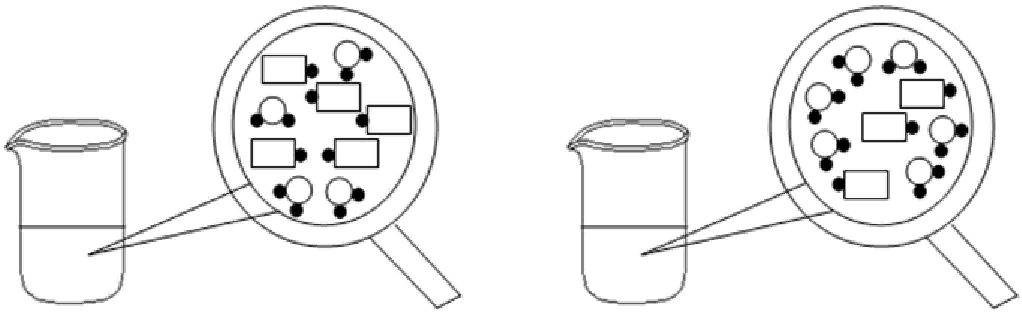
$HA + H_2O \rightleftharpoons A^- + H_3O^+$ The dissociation reaction of a weak acid in water

if you suppose that you look the particles of acid solutions with the magic magnifying glass, what do oyu expect to see? Draw the the particles of concentrated and diluted solutions of strong and weak acids. Show the particles as

for HA :  for A^- : 

for H_2O :  for H_3O^+ : 

6a)



Concentrated strong acid solution Diluted strong acid solution

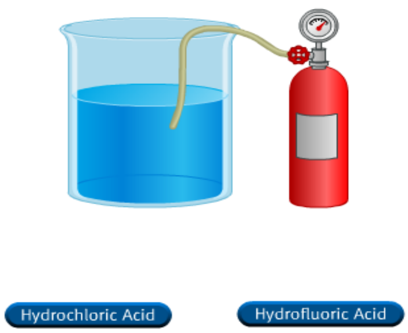
Explanation: In the concentrated solution, the percentage of acid is higher

2. Prospective chemistry teachers were asked to discusse student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were expected to suggest instructional strategies to change the misconceptions about the acid solutions which they identified.

4. The target misconceptions of 12th grade students showed that students had difficulty to visualize the acid solutions. Students might think that dissociation of an acid was similar to dissolution of an ionic salt in water. Thus, representations of concentrated and diluted solutions of strong and weak acids at the molecular level would help students to overcome these misconceptions.

5. In the ninth activity, first of all prospective teachers were expected to differentiate the strength and the concentration concepts of acids. Then, participants watched an animation about the dissociation of strong and weak acids in water and the researcher emphasized the limitations of the demonstration in the animation. It was emphasized that, this kind of representation, as the one in the animation, might cause students to think that dissociation of an acid was a physical change.



The researcher introduced a method to represent the particles of acid solutions, in this method, the reaction of an acid with water and the formation of acid ions were emphasized. Then, the researcher showed example representations of concentrated and diluted solutions of strong and weak acids according to this method.

6. Prospective teachers were expected to draw concentrated and diluted solutions of HCl and HF solutions on the Activity Sheet V (Appendix B).

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

Flow of the 10th Activity : Comparing Electrolysis and Evaporation of Water

Target Misconceptions
1. It is hydrogen bonding that holds hydrogen and oxygen atoms together within the water molecule

1. In the tenth activity, the chosen student responses which were given to the first question of the CCT were presented to the prospective teachers. One example response (Student#263) from student responses was given below:

	True	False	Explanation
It is hydrogen bonding that holds hydrogen and oxygen atom together within the water molecule	X		Hydrogen forms hydrogen bonding with F, O and N elements

2. Prospective chemistry teachers were requested to discuss student responses as a group and evaluate them as scientifically correct or incorrect.

3. Participating prospective chemistry teachers were expected to suggest instructional strategies to change the misconceptions about the hydrogen bonding which they identified.

4. The target misconceptions of 12th grade students showed that students had a insufficient understanding about intermolecular and intramolecular forces.

5. In the activity, the electrolysis and the evaporation of water and the change of intramolecular and inter-molecular forces in these two chemical phenomena were explored.

6. Prospective teachers were expected to draw a concept map with given concepts and molecular representation of hydrogen bonding (Appendix B).

7. The participants evaluated the activity in terms of its effectiveness to change the target misconceptions and its contribution to participants' conceptual and pedagogical knowledge.

APPENDIX B : ACTIVITY SHEETS

ACTIVITY SHEET I

1. OTURUM : MADDENİN TANECİKLİ YAPISI

1. DERS

Hedeflenen Kavram Yanılgıları

Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 2a, Öğrenci: 010;

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Soru No: 2b, Öğrenci: 025;

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Soru No: 2c, Öğrenci: 013;

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Soru No: 2e, Öğrenci: 086;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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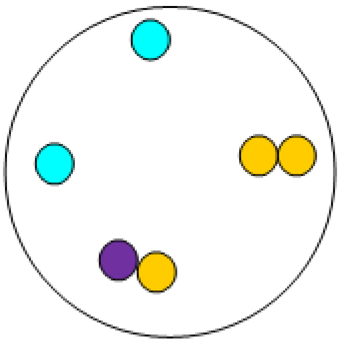
Etkinlik Soruları :

1) Aşağıda moleküler düzeyde gösterimleri verilen maddeler için verilen ifadelerden hangisi/hangilerinin doğru olduğunu belirtiniz ve neden böyle düşündüğünüzü açıklayınız. Ayrıca verilen maddenin hangi maddelerden oluştuğunu belirtiniz.



a. Elementtir
b. Bileşiktir
c. Karışımdır

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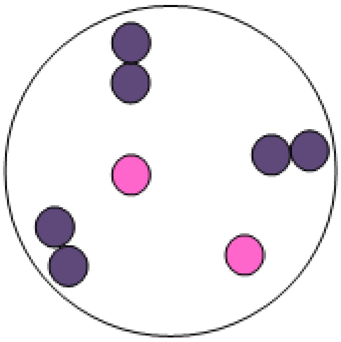

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b. Bileşiktir
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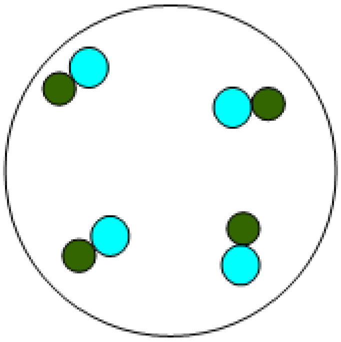

a. Elementtir
b. Bileşiktir
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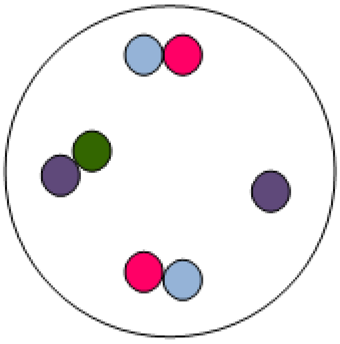

a. Elementtir
b. Bileşiktir
c. Karışımdır

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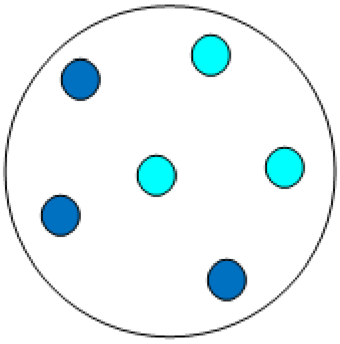

a. Elementtir
b. Bileşiktir
c. Karışımdır

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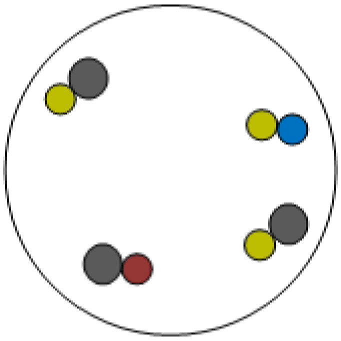

a. Elementtir
b. Bileşiktir
c. Karışımdır

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Madde .... ten oluşmaktadır.

2) Aşağıdaki gösterimde verilen maddeler için verilen ifadelerden hangisi söylenebilir?

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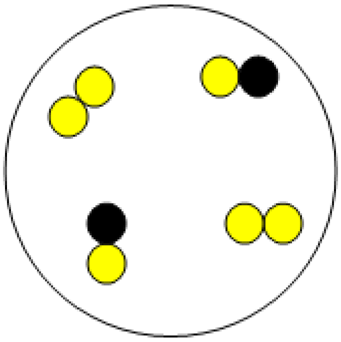

- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır. ( )
- 2 farklı bileşikten oluşmaktadır ( )

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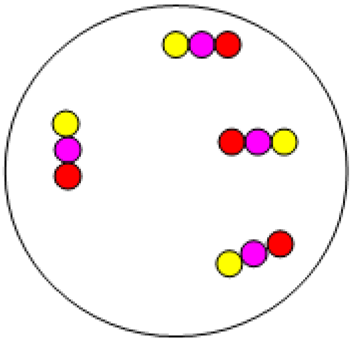

- 3 farklı elementten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır. ( )
- 2 farklı bileşikten oluşmaktadır ( )

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3) Size verilen farklı renklerdeki oyun hamurları ile,

Fe katısını moleküler düzeyde gösteriniz ve çiziniz.

O_2 gazını moleküler düzeyde gösteriniz ve çiziniz.

HCN bileşiği ile He elementinin karışımını moleküler düzeyde gösteriniz ve çiziniz.

H_2O ve NH_3 bileşiklerinin karışımını moleküler düzeyde gösteriniz ve çiziniz.

Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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2. DERS

Hedeflenen Kavram Yanılgıları

Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 1a, Öğrenci: 006;

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Soru No: 1a, Öğrenci: 244;

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Soru No: 1a, Öğrenci: 094;

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Soru No: 1b, Öğrenci: 112;

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Soru No: 1b, Öğrenci: 018;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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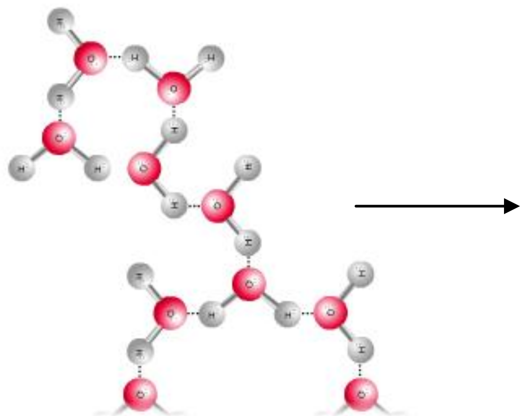
Etkinlik Soruları :

1) Aşağıda suyun farklı fiziksel hallerindeki moleküler gösterimleri verilmiştir. Her bir resmin yanına suyun farklı fiziksel hallerindeki moleküllerin yapısı, moleküller arası mesafe, moleküller arası çekim kuvveti gibi özelliklerini düşünerek ilgili özelliklerini yazınız.



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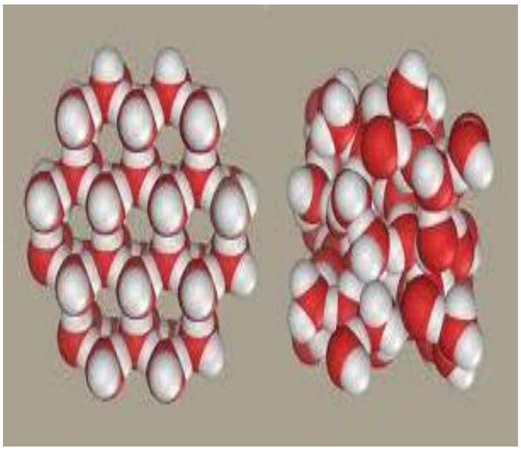

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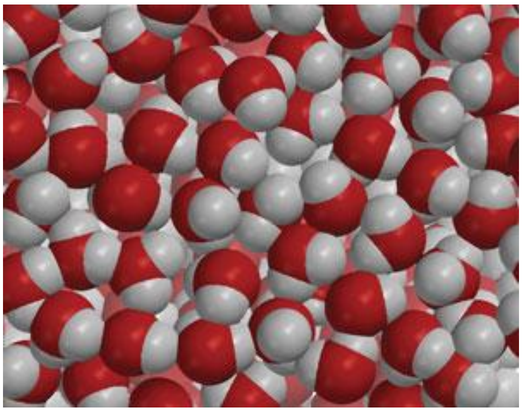

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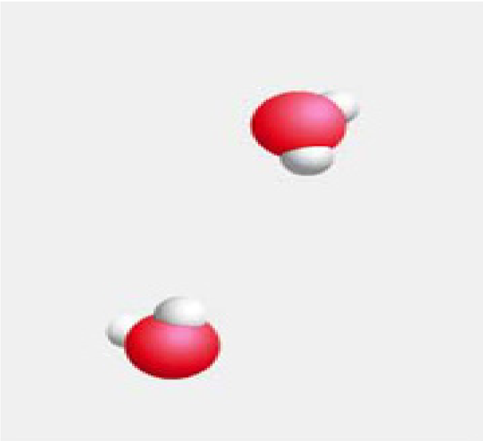

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2) Su katı halden, sıvı hale ve sıvı halde gaz hale geçtiğinde hangi özellikleri değişmiş ve hangi özellikleri korunmuştur? Açıklayınız.
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3) Maddeyi oluşturan taneciklerin arasında ne bulunur? Açıklayınız.
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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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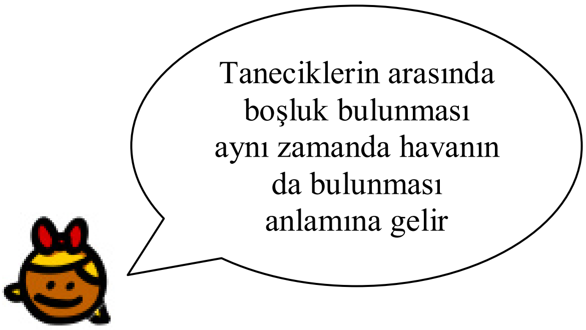
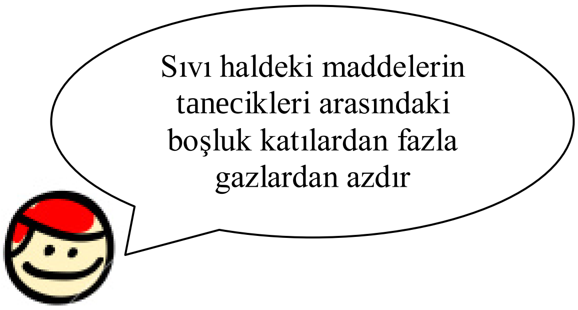
ACTIVITY SHEET II

2. OTURUM : MADDENİN TANECİKLİ YAPISI

1. DERS

Hedeflenen Kavram Yanılgıları





Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 1a, Öğrenci: 428;

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Soru No: 1a, Öğrenci: 100;

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Soru No: 1a, Öğrenci: 282;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Öncesi Soru :

Hacmi bilinen iki sıvı karıştırıldığında, karışımın hacmi hakkında ne söylenebilir? Lütfen tahmininizi açıklayınız.

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Etkinlik Soruları :

1. Sıvı	**Hacim**	**2. Sıvı**	**Hacim**	**Karışım**	**Toplam Hacim**
Su		**Etil alkol**		**Su - Etil alkol**	
Su		**Zeytinyağı**		**Su - Zeytinyağı**	

1) Su ve etil alkol sıvılarını karıştırdığınızda nasıl (homojen/heterojen) bir karışım elde ettiniz. Nedenlerini, moleküller arası çekim kuvvetlerini düşünerek açıklayınız.

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2) Su ve zeytinyağı sıvılarını karıştırdığınızda nasıl (homojen/heterojen) bir karışım elde ettiniz. Nedenlerini, moleküller arası çekim kuvvetlerini düşünerek açıklayınız.

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3) Hangi karışım(lar)da karışımı oluşturan maddelerin hacimlerinin toplamı karışımın hacmine eşittir? Açıklayınız.

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4) Hangi karışım(lar)da karışımı oluşturan maddelerin hacimlerinin toplamı karışımın hacmine eşit değildir? Açıklayınız.

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5) Sıvıların karıştırılmadan önceki ve karıştırıldıktan sonraki moleküllerinin nasıl görüneceğini çizerek gösteriniz.

Karıştırılmadan Önce **Karıştırıldıktan Sonra**

Etil alkol Su Etil alkol – Su karışımı

Karıştırılmadan Önce **Karıştırıldıktan Sonra**

Zeytinyağı Su Zeytinyağı – Su karışımı

Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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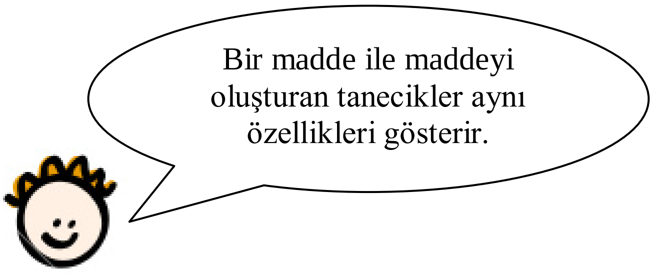
2. DERS

Hedeflenen Kavram Yanılgısı



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 1a, Öğrenci: 392;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Soruları :

1) Karbonun allotropları olan elmas ve grafitin, resimlerini dikkate alarak, taneciklerini çiziniz.

Elmas **Grafit**

2) Çizdiğiniz molekül modellerine göre aşağıdaki ifadenin doğruluğunu tartışınız.

"Elması oluşturan atomlar renksiz ve parlakken, grafiti oluşturan atomlar siyah ve mattır."

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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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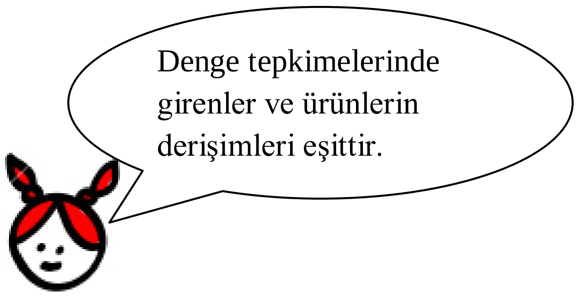
ACTIVITY SHEET III

3. OTURUM : KİMYASAL DENGE

1. DERS

Hedeflenen Kavram Yanılgıları



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 3a, Öğrenci: 002;

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Soru No: 3a, Öğrenci: 431;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Soruları :

1) Yaptığınız deneyin sonuçlarına göre farklı miktarlarda su-buz kullanmanız neleri değiştirdi/değiştirmedi belirtiniz.

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2) Denge tepkimelerinde girenlerin ve ürünlerin derişiminin denge üzerindeki etkilerini tartışınız.
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3) $\mathbf{N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}}$ tepkimesinin dengede olduğu biliniyor. Buna göre; N_2, H_2 ve NH_3 gazlarının derişimleri arasındaki ilişkiyi tartışınız.

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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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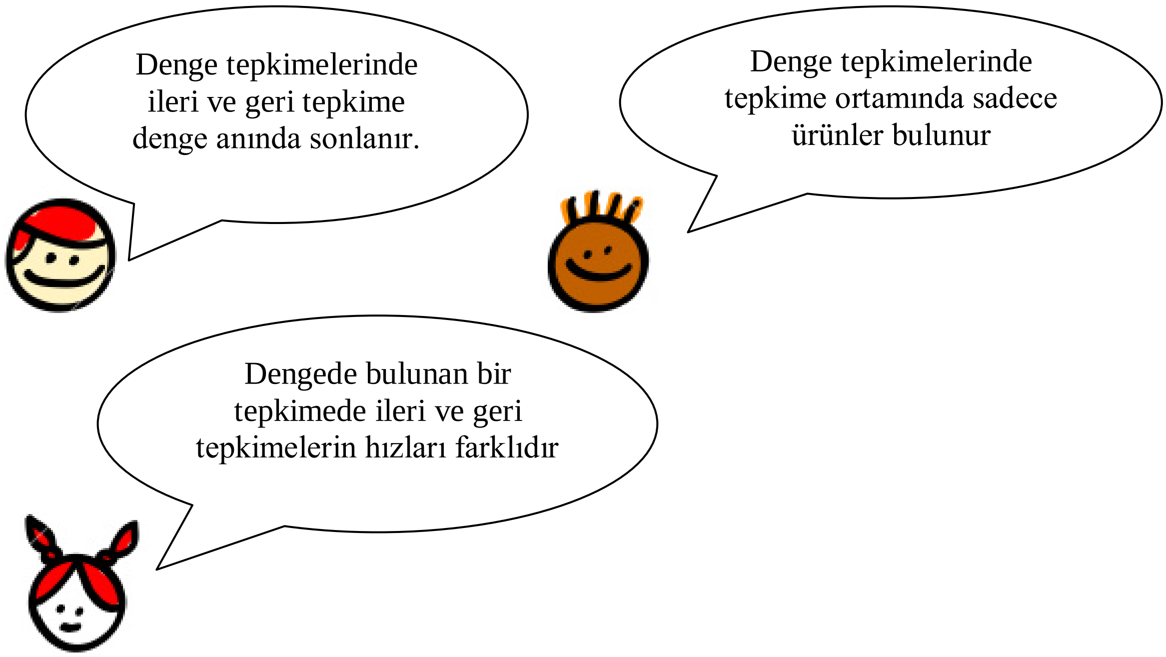
2. DERS

Hedeflenen Kavram Yanılgıları



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 3b, Öğrenci: 042;

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Soru No: 3b, Öğrenci: 003;

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Soru No: 3c, Öğrenci: 164;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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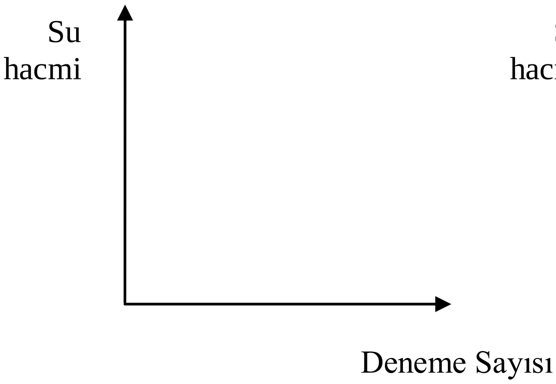
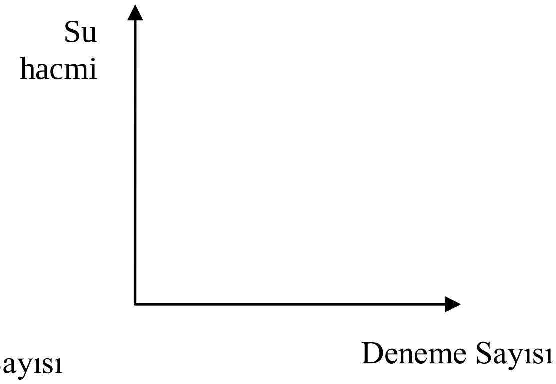
Etkinlik Soruları :

1) İzlediğiniz videoya göre, her iki kap için su hacminin deneme sayısıyla değişimini grafik üzerinde gösteriniz



A Kabı



B Kabı

3) Yukarıdaki grafiklerden yararlanarak denge tepkimelerinde ileri ve geri tepkimelerin hızının zamanla değişimini grafik çizerek gösteriniz.

4) Kimyasal tepkimelerde dengeye ulaşmadan önce ve dengeye ulaştıktan sonra ileri ve geri tepkimenin hızları ve tepkime ortamında bulunan maddeler hakkında ne söylenebilir? Açıklayınız.

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5) $\mathbf{N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}}$ tepkimesinin dengede olduğu biliniyor. Buna göre; ileri ve geri tepkimenin hızlarını karşılaştırınız ve tepkime ortamında bulunan maddeleri belirleyiniz.

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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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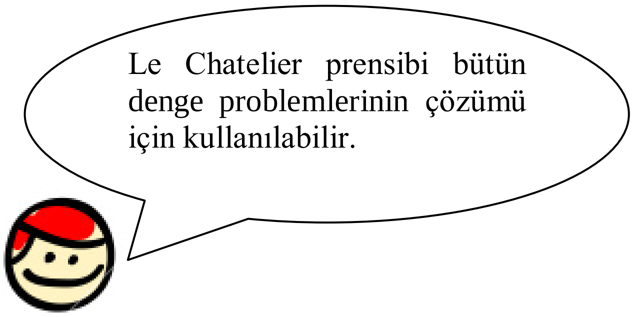
3. DERS

Hedeflenen Kavram Yanılgıları



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 4a, Öğrenci: 240 ;

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Soru No: 4a, Öğrenci: 020 ;

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Soru No: 4b, Öğrenci: 010 ;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Soruları :

1) $\mathbf{CS_{2(g)} + 4H_{2(g)} \rightleftharpoons CH_{4(g)} + 2H_2S_{(g)}}$ tepkimesi, **pistonlu kapta, sabit basınç ve sıcaklıkta** dengededir. Buna göre; tepkime kabına bir miktar daha CS_2 gazı ilave edilirse, kaptaki CH_4 moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.

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2) $\mathbf{CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}}$ tepkimesi, **pistonlu kapta, sabit basınç ve sıcaklıkta** dengededir. Buna göre; tepkime kabına bir miktar daha Ar gazı ilave edilirse, kaptaki H_2 moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.

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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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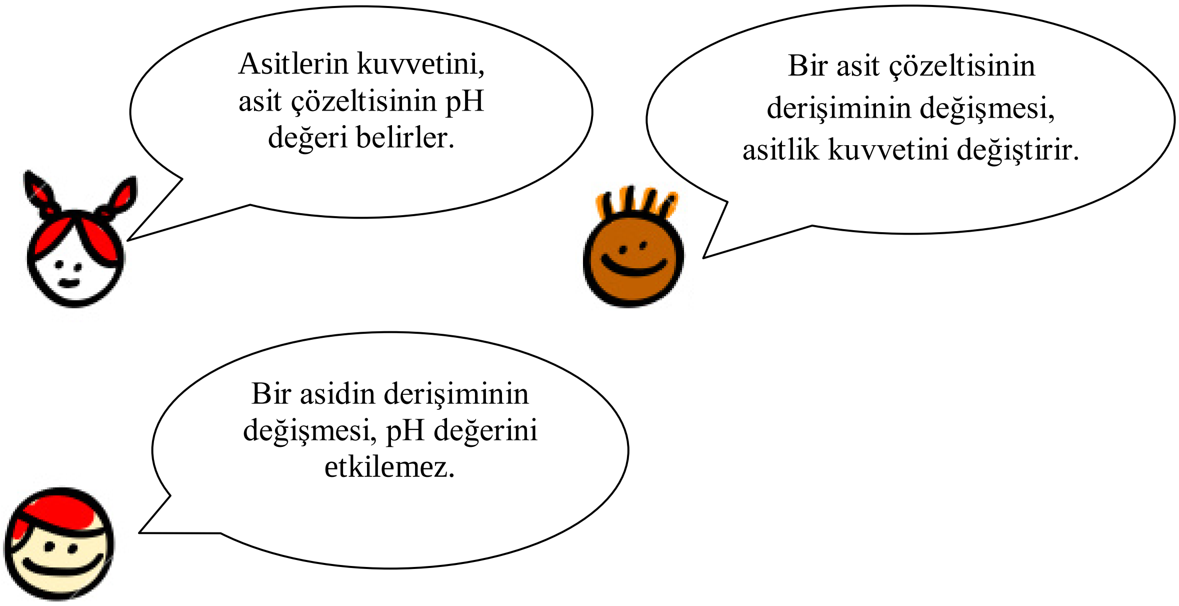
ACTIVITY SHEET IV

4. OTURUM : ASİTLER

Hedeflenen Kavram Yanılgıları



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 5a, Öğrenci: 221;

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Soru No: 5a, Öğrenci: 252;

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Soru No: 5b, Öğrenci: 136;

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Soru No: 5b, Öğrenci: 105;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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1. Bölüm : Araştırma Laboratuvarı

"Bir asidin kuvveti, asit çözeltisinin derişim ve pH değerlerine bağlı mıdır?"

Size verilen laboratuar malzemeleri ile bir deney tasarlayarak yukarıdaki araştırma sorusuna cevap vermeye çalışınız. Tasarladığınız deneyi kısaca açıklayınız.

Malzemeler : 1,1 M HNO_3 çözeltisi, su, pH kağıdı, farklı büyüklükte dereceli silindirler, beherler

Deney :
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Sonuç : "Bir asidin kuvveti, asit çözeltisinin derişim ve pH değerlerine bağlı mıdır?"
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2. Bölüm : Aynı derişime sahip farklı asitlerin pH değerlerinin belirlenmesi

Asit	**pH (yaklaşık)**
5 M HCl	
5 M CH_3COOH	

Tartışma Sorusu : "Bütün asitler suda aynı oranda mı iyonlaşır, asitlerin suda iyonlaşmasını etkileyen faktör(ler) nedir tartışınız."

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Sorular :

1) Aynı derişime sahip asit çözeltilerinin farklı pH değerlerine sahip olmasının nedenlerini açıklayınız.
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2) Bir asit çözeltisinin derişimi arttığında asitlik kuvveti artar mı tartışınız.
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Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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ACTIVITY SHEET V

5. OTURUM : ASİTLER ve MADDENİN TANECİKLİ YAPISI

1. DERS

Hedeflenen Kavram Yanılgıları

Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 6a, Öğrenci: 246;

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Soru No: 6b, Öğrenci: 008;

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Soru No: 6a, Öğrenci: 233;

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Soru No: 6a, Öğrenci: 162;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Soruları :

1) Kuvvetli bir asitle, zayıf bir asit arasındaki farkları açıklayarak yazın.
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2) Derişik bir asitle, seyreltik bir asit arasındaki farkları açıklayarak yazın.
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3) HCl ve HF çözeltilerinin derişik ve seyreltik çözeltilerini moleküler seviyede gösteriniz.

Derişik HCl çözeltisi **Seyreltik HCl çözeltisi**

Derişik HF çözeltisi **Seyreltik HF çözeltisi**

Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?

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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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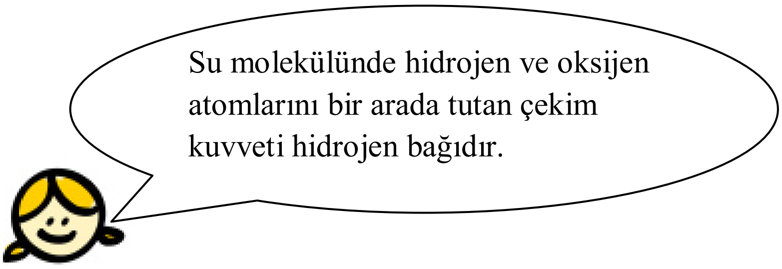
2. DERS

Hedeflenen Kavram Yanılgıları



Kimya Kavram Testinde Öğrenci Cevapları

Kimya kavram testinde öğrencilerin verdiği cevapları, grup arkadaşlarınızla tartışarak hangi yönlerden doğru veya hatalı bulduğunuzu kısaca açıklayınız.

Soru No: 1a, Öğrenci: 263;

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Soru No: 1a, Öğrenci: 132;

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Sizce bu kavram yanılgılarının düzeltilmesi için nasıl bir etkinlik hazırlanmalıdır?

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Etkinlik Soruları :

1) Su molekülünün içindeki ve su moleküllerin arasındaki etkileşimleri belirleyerek özelliklerini açıklayınız.

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2) Aşağıda verilen kavramlarla hidrojen bağı konusunda bir kavram haritası tasarlayınız. Kavram haritasını tasarlarken size verilen kavramlar haricinde başka kavramlar da ekleyebilirsiniz.

Elektronegatiflik

Kaynama noktası

Gaz

Hidrojen

Oksijen

Kısmi pozitif yük

Hidrojen bağı

Polar molekül

Elektron

Flor

Sıvı

Katı

Kovalent bağ

Su molekülü

Molekül

Kısmi negatif yük

Moleküller arası çekim kuvvetleri

Kavram Haritası :

Etkinliğin Değerlendirilmesi

Hedeflenen kavram yanılgılarının düzeltilmesi için tavsiye edilen etkinliğin uygun ve yeterli olduğunu düşünüyor musunuz?
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Bu etkinliğin, size, kavramsal anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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Bu etkinliğin, size, pedagojik anlamda ne gibi katkıları olduğunu düşünüyorsunuz yazınız.

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APPENDIX C : CHEMISTRY CONCEPT TEST

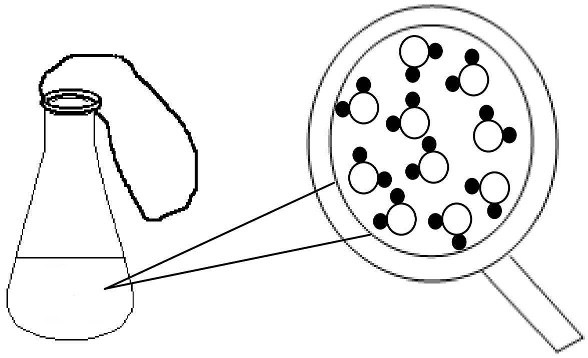
KİMYA KAVRAM TESTİ

(1. Soru)

1a) Aşağıda suyun farklı fiziksel hallerindeki özellikleri ile ilgili bazı ifadeler verilmiştir. Bu ifadeleri doğrulukları açısından değerlendiriniz ve neden böyle düşündüğünüzü açıklayınız ***(Dikkat!!! Doğru olduğunu düşündüğünüz ifadeler <u>için de</u>, neden böyle düşündüğünüzü açıklamayı unutmayınız).***

	Doğru	Yanlış	Açıklama
Su buharını oluşturan moleküllerin arasında hava bulunur.			....
Buzu oluşturan moleküllerin arasında biraz aralık (mesafe) bulunur.			....
Su molekülünde hidrojen ve oksijen atomlarını bir arada tutan çekim kuvveti hidrojen bağıdır.			....
Suyu oluşturan moleküller, madde katı halde iken sert; sıvı ve gaz halde iken yumuşaktır.			....
Suyu (sıvı halde iken) oluşturan moleküllerin arasında biraz aralık (mesafe) bulunur.			....
Su buharlaştığında, su molekülleri genişler.			....
Suyun (sıvı halde iken) yoğunluğu, su buharından fazladır, çünkü su buharlaştığında kütlesi azalır.			....

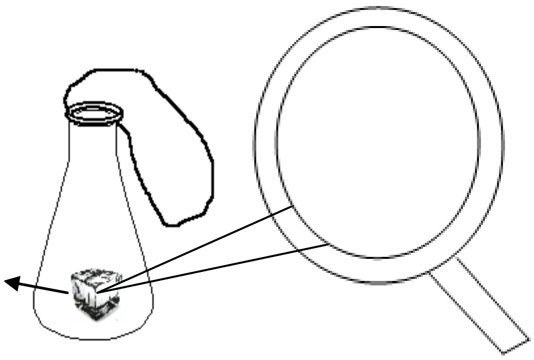
1b) Elinizde maddelerin taneciklerini (atom ve moleküllerini) göstermeye yarayan bir büyüteciniz olduğunu ve kabın içindeki maddelere bu büyüteçle baktığınızı varsayınız. Aşağıdaki gösterimde, cam kabın içindeki madde sıvı halde (su) iken, H_2O moleküllerinin dizilimi sembolize edilmiştir.



Referans gösterim

Buna göre, cam kabın içinde madde katı halde (buz) iken ve balonun içinde madde gaz halde (su buharı) iken, H_2O moleküllerinin diziliminin nasıl olacağını, büyüteçlerin içine çizerek gösteriniz. H_2O moleküllerini ●○● ile, hidrojen atomunu ● ile, oksijen atomunu ise ○ ile gösteriniz ve çizimlerinizi neden bu şekilde yaptığınızı açıklayınız (***Dikkat!!! Çizimlerinizi yaparken; moleküller arası mesafeler, moleküllerin birim alanda dağılımı ve molekül içi/moleküller arası bağlar gibi noktaları göz önünde bulundurmaya çalışınız ve açıklamalarınızı yaparken; yukarıdaki referans gösterim ile sizin çizdiğiniz gösterimler arasındaki farklılıkları belirtiniz***)

Buz



Açıklama:

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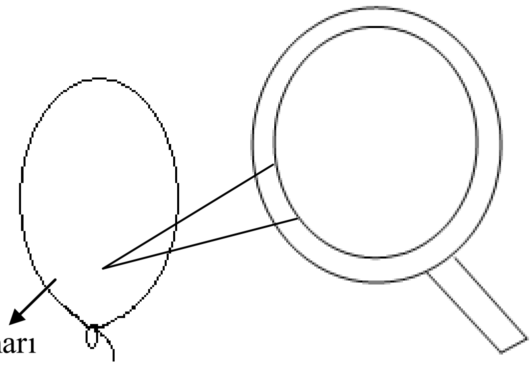

Su buharı

Açıklama:

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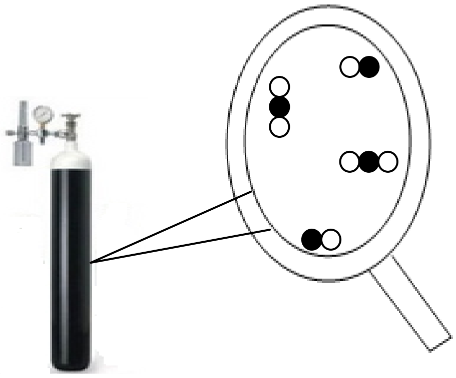
(2. Soru)

Aşağıdaki tüplere, içlerinde bulunan gazların taneciklerini (atom ve moleküllerini) gösterebilen bir büyüteç ile bakıldığını ve aşağıdaki görüntülerin izlendiğini varsayınız. Bu görüntülere göre, her bir madde için verilen ifadelerden **hangisi/hangileri** nin doğru olduğunu işaretleyiniz ve neden böyle düşündüğünüzü açıklayınız (***Dikkat!!!: Aynı madde için birden fazla doğru ifade olabilir***).

2a) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;

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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;

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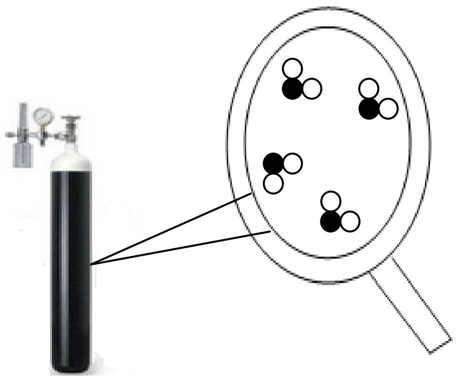
2b) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;

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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;

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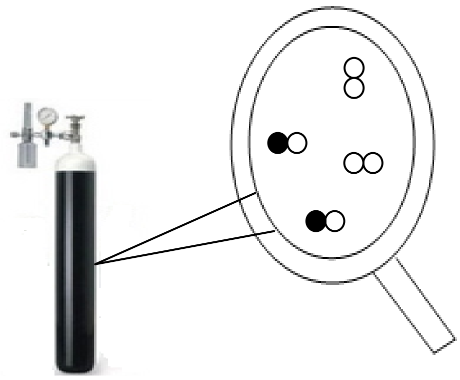
2c) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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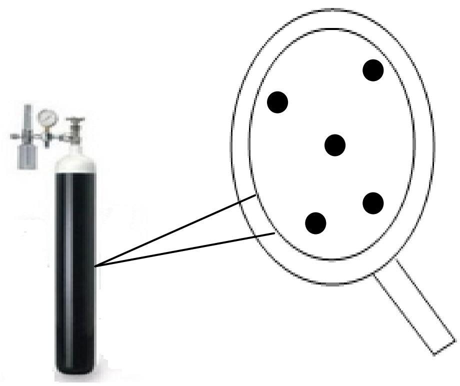
2d) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü; ....
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü; ....
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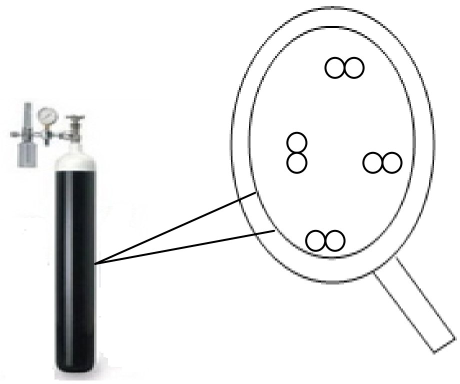
2e) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

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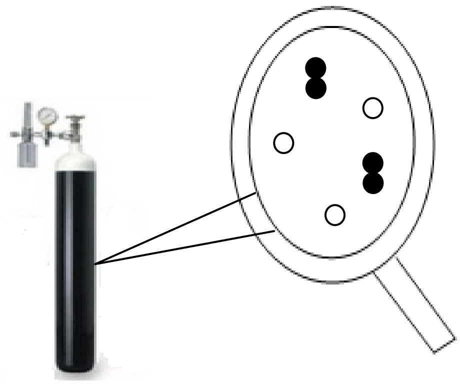
2f) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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(3. Soru)

$H_{2(g)}$ + $I_{2(g)}$ $\rightleftharpoons$ $2HI_{(g)}$ tepkimesi kapalı bir kapta dengeye ulaşmaktadır. Bu tepkime dengede iken;

3a) Girenlerin ve ürünlerin molariteleri ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) Girenlerin molaritesi ürünlerin molaritesinden daha yüksektir.
b) Ürünlerin molaritesi girenlerin molaritesinden daha yüksektir.
c) Girenler ve ürünlerin molariteleri eşittir.
d) Girenlerin ve ürünlerin molaritelerini karşılaştırmaya yetecek kadar bilgi yoktur.

Çünkü; ……………………………………………………………………………………………
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3b) İleri ve geri tepkimelerin hızları ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) İleri tepkimenin hızı geri tepkimenin hızından daha fazladır.
b) Geri tepkimenin hızı ileri tepkimenin hızından daha fazladır.
c) İleri ve geri tepkimelerin hızları eşittir.
d) İleri ve geri tepkime denge anında sonlandığından tepkime hızından söz edilemez.

Çünkü; ……………………………………………………………………………………………
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3c) Tepkime ortamında bulunan maddeler ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) Tepkime ortamında sadece HI bulunur.
b) Tepkime ortamında H_2 ve I_2 bulunur.
c) Tepkime ortamında H_2 , I_2 ve HI bulunur.
d) Soruyu cevaplamaya yetecek kadar bilgi verilmemiştir.

Çünkü; ……………………………………………………………………………………………
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(4. Soru)

$4HCl_{(g)}$ + $O_{2(g)}$ $\rightleftharpoons$ $2H_2O_{(g)}$ + $2Cl_{2(g)}$ tepkimesi, **pistonlu kapta, sabit basınç ve sıcaklıkta** dengededir. Buna göre;

4a) Tepkime kabına bir miktar daha HCl (hidrojen klorür) gazı ilave edilirse, kaptaki Cl_2 moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.

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Çünkü; ……………………………………………………………………………………………
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4b) Tepkime kabına bir miktar He (Helyum) gazı ilave edilirse, kaptaki O_2 moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız. ………………………………………………………………………………………………

Çünkü; ……………………………………………………………………………………………
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(5. Soru)

Asit türü	Derişimi (M)	pH değeri	Asitlik sabiti (Ka) (25^{o}C’de)
HNO_3	0,10	1,00	$3{,}0 \times 10^{1}$
HCN	0,01	5,40	$6{,}2 \times 10^{-10}$
CH_3COOH	1,00	2,38	$1{,}8 \times 10^{-5}$
HF	0,50	1,75	$6{,}6 \times 10^{-4}$
HCl	0,01	2,00	$1{,}3 \times 10^{6}$

5a) Yukarıdaki tabloda verilen asit çözeltilerinin asitlik kuvvetini, en kuvvetli olandan en zayıf olana doğru sıralayınız ve sıralamayı neye göre yaptığınızı açıklayınız.

En Kuvvetli .... En Zayıf

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Çünkü; ……………………………………………………………………………………………
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5b) Tabloya göre, 0,10 M HNO_3 ve 0,01 M HCN farklı molaritelerde iki farklı asit çözeltisidir. 0,1 M HNO_3 çözeltisinin asitlik kuvvetinin, 0,01 M HCN çözeltisinin asitlik kuvvetinden daha büyük olduğu bilinmektedir. Buna göre;

HCN çözeltisinin molaritesi 0,01 M’dan, 1,00 M’ a çıkarılırsa asitlik kuvveti nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.
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Çünkü; ……………………………………………………………………………………………
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0,10 M HNO_3 çözeltisi ile 1,00 M HCN çözeltisini asitlik kuvvetleri açısından karşılaştırınız ve cevabınızı nedenleriyle açıklayınız.
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Çünkü; ………………………………………………………………………………………
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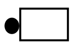
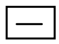
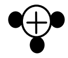
(6. Soru)

$HA + H_2O \rightarrow A^- + H_3O^+$ Kuvvetli bir asidin suda iyonlaşma denklemi

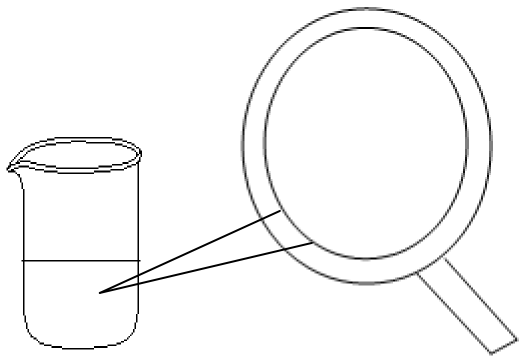
$HA + H_2O \rightleftharpoons A^- + H_3O^+$ Zayıf bir asidin suda iyonlaşma denklemi ise;

bu asitlerin sudaki çözeltilerine molekülleri gösterebilen bir büyüteç ile baktığınızı varsayarsanız, bu çözeltileri moleküler düzeyde nasıl gösterirsiniz ve çiziminizi nasıl açıklarsınız? Çiziminizi yaparken;

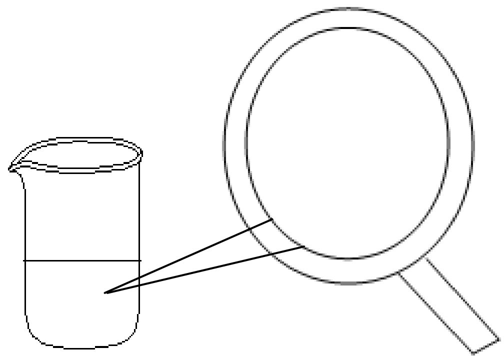
HA'yı  ile , A^-'yi  ile ,

H_2O'yu  ile , H_3O^+'yu  ile gösteriniz.

6a)



Derişik kuvvetli asit çözeltisi



Seyreltik kuvvetli asit çözeltisi

Açıklama:
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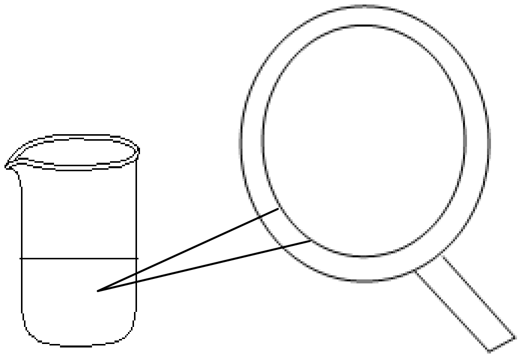
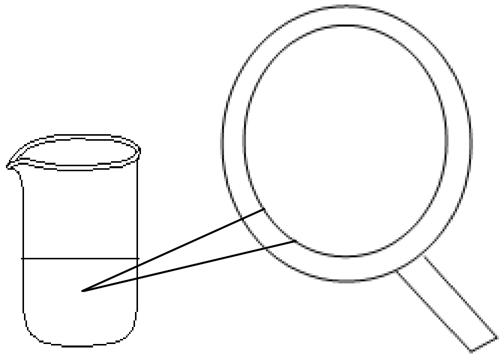
6b)



Derişik zayıf asit çözeltisi



Seyreltik zayıf asit çözeltisi

Açıklama:

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APPENDIX D : CHEMISTRY CONCEPT TEST FORM B

KİMYA KAVRAM TESTİ B FORMU

(1. Soru)

$N_{2(g)}$ + $O_{2(g)}$ $\rightleftharpoons$ $2NO_{(g)}$ tepkimesi kapalı bir kapta dengeye ulaşmaktadır. Bu tepkime dengede iken;

1a) Girenlerin ve ürünlerin molariteleri ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) Girenlerin molaritesi ürünlerin molaritesinden daha yüksektir.
b) Ürünlerin molaritesi girenlerin molaritesinden daha yüksektir.
c) Girenler ve ürünlerin molariteleri eşittir.
d) Girenlerin ve ürünlerin molaritelerini karşılaştırmaya yetecek kadar bilgi yoktur.

Çünkü; ……………………………………………………………………………………..
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1b) İleri ve geri tepkimelerin hızları ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) İleri tepkimenin hızı geri tepkimenin hızından daha fazladır.
b) Geri tepkimenin hızı ileri tepkimenin hızından daha fazladır.
c) İleri ve geri tepkimelerin hızları eşittir.
d) İleri ve geri tepkime denge anında sonlandığından tepkime hızından söz edilemez.

Çünkü; ……………………………………………………………………………………..
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1c) Tepkime ortamında bulunan maddeler ile ilgili aşağıda verilen ifadelerden hangisi sizce daha doğrudur? Neden böyle düşündüğünüzü açıklayınız.

a) Tepkime ortamında sadece NO bulunur.
b) Tepkime ortamında N_2 ve O_2 bulunur.
c) Tepkime ortamında N_2 , O_2 ve NO bulunur.
d) Soruyu cevaplamaya yetecek kadar bilgi verilmemiştir.

Çünkü; ……………………………………………………………………………………..
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(2. Soru)

$2H_2S_{(g)} + CH_{4(g)} \rightleftharpoons 4H_{2(g)} + CS_{2(g)}$ tepkimesi, **pistonlu kapta, sabit basınç ve sıcaklıkta** dengededir. Buna göre;

2a) Tepkime kabına bir miktar daha CS_2 gazı ilave edilirse, kaptaki H_2S moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.
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Çünkü; ……………………………………………………………………………………......
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2b) Tepkime kabına bir miktar Ar (Argon) gazı ilave edilirse, kaptaki CH_4 moleküllerinin sayısı nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.
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Çünkü; ……………………………………………………………………………………......
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(3. Soru)

Asit türü	**Derişimi (M)**	**pH değeri**	**Asitlik sabiti (Ka) (25°C'de)**
HOCN	0,010	2,72	$3,5 \times 10^{-4}$
HCl	0,001	3,00	$1,3 \times 10^{6}$
HNO_2	1,000	1,57	$7,2 \times 10^{-4}$
HOBr	1,000	4,30	$2,5 \times 10^{-9}$
HNO_3	0,100	1,00	$3,0 \times 10^{1}$

3a) Yukarıdaki tabloda verilen asit çözeltilerinin asitlik kuvvetini, en kuvvetli olandan en zayıf olana doğru sıralayınız ve sıralamayı neye göre yaptığınızı açıklayınız.

En Kuvvetli* .... *En Zayıf

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Çünkü; …………………………………………………………………………………………
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3b) Tabloya göre, 0,1 M HNO_3 ve 0,01 M HOCN farklı molaritelerde iki farklı asit çözeltisidir. 0,1 M HNO_3 çözeltisinin asitlik kuvvetinin, 0,01 M HOCN çözeltisinin asitlik kuvvetinden daha büyük olduğu bilinmektedir. Buna göre;

HOCN çözeltisinin molaritesi 0,01 M'dan, 1 M' a çıkarılırsa asitlik kuvveti nasıl değişir? Neden böyle düşündüğünüzü açıklayınız.

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Çünkü; ………………………………………………………………………………………………
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0,1 M HNO_3 çözeltisi ile 1 M HOCN çözeltisini asitlik kuvvetleri açısından karşılaştırınız ve cevabınızı nedenleriyle açıklayınız.

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Çünkü; ………………………………………………………………………………………………
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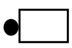
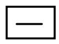
(4. Soru)

$HA + H_2O \rightarrow A^- + H_3O^+$ Kuvvetli bir asidin suda iyonlaşma denklemi

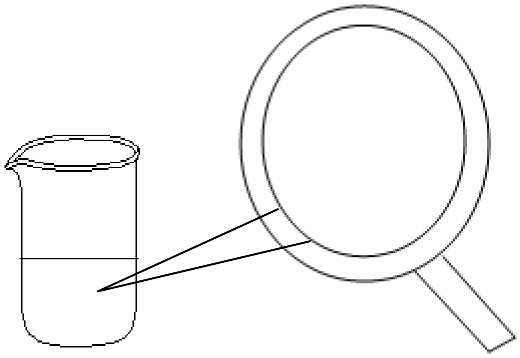
$HA + H_2O \rightleftharpoons A^- + H_3O^+$ Zayıf bir asidin suda iyonlaşma denklemi ise;

bu asitlerin sudaki çözeltilerine molekülleri gösterebilen bir büyüteç ile baktığınızı varsayarsanız, bu çözeltileri moleküler düzeyde nasıl gösterirsiniz ve çiziminizi nasıl açıklarsınız? Çiziminizi yaparken;

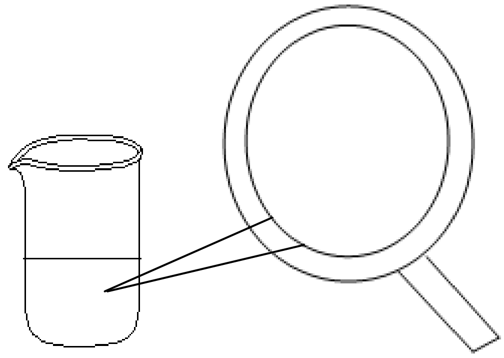
HA'yı  ile , A^-'yi  ile ,

H_2O'yu  ile , H_3O^+'yu  ile gösteriniz.

4a)



Derişik kuvvetli asit çözeltisi



Seyreltik kuvvetli asit çözeltisi

Açıklama:

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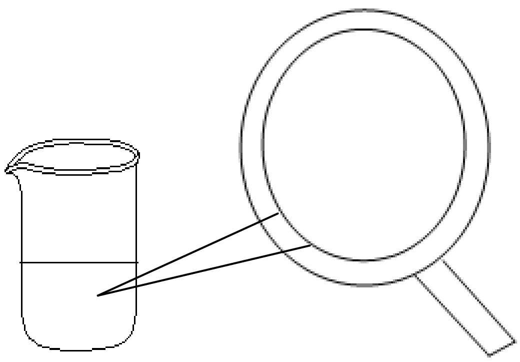
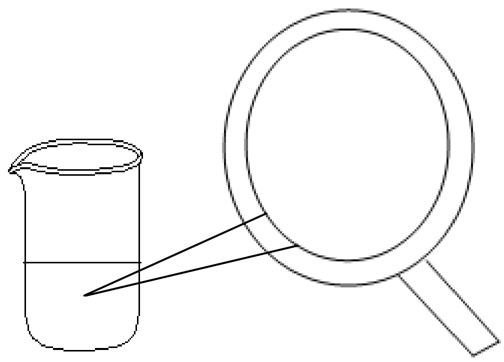
4b)



Derişik zayıf asit çözeltisi



Seyreltik zayıf asit çözeltisi

Açıklama:

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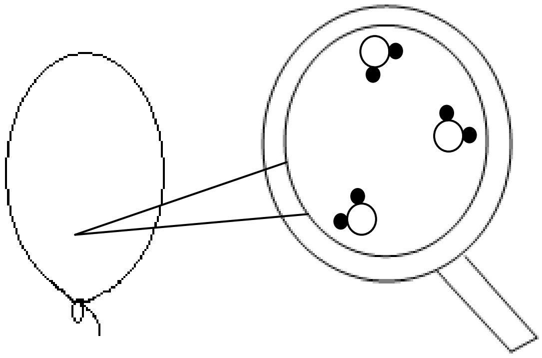
(5. Soru)

5a) Aşağıda suyun farklı fiziksel hallerindeki özellikleri ile ilgili bazı ifadeler verilmiştir. Bu ifadeleri doğrulukları açısından değerlendiriniz ve neden böyle düşündüğünüzü açıklayınız ***(Dikkat!!! Doğru olduğunu düşündüğünüz ifadeler <u>için de</u>, neden böyle düşündüğünüzü açıklamayı unutmayınız).***

	Doğru	Yanlış	Açıklama
Buz eridiğinde, su molekülleri küçülür.			....
Buzu oluşturan moleküllerin arasında biraz aralık (mesafe) bulunur.			....
Su molekülünde hidrojen ve oksijen atomlarını bir arada tutan çekim kuvveti hidrojen bağıdır.			....
Suyun (sıvı halde iken) yoğunluğu, su buharından fazladır, çünkü su buharlaştığında kütlesi azalır.			....
Suyu (sıvı halde iken) oluşturan moleküllerin arasında biraz aralık (mesafe) bulunur.			....
Buzu oluşturan moleküllerin arasında hava bulunur.			....
Suyu oluşturan moleküller, madde katı halde iken sert; sıvı ve gaz halde iken yumuşaktır.			....

5b) Elinizde maddelerin taneciklerini (atom ve moleküllerini) göstermeye yarayan bir büyüteciniz olduğunu ve kabın içindeki maddelere bu büyüteçle baktığınızı varsayınız. Aşağıdaki gösterimde, balonun içindeki madde gaz halde (su buharı) iken, H_2O moleküllerinin dizilimi sembolize edilmiştir.

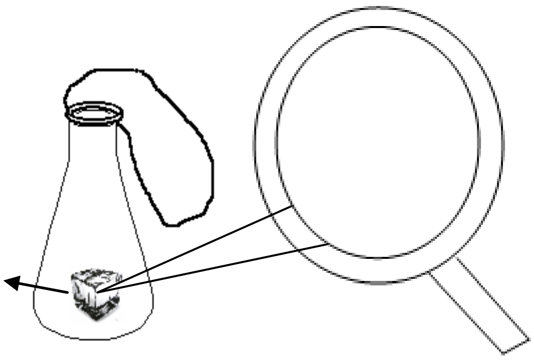


Referans gösterim

Buna göre, cam kabın içinde madde katı halde (buz) iken ve kabın içinde madde sıvı halde (su) iken, H_2O moleküllerinin diziliminin nasıl olacağını, büyüteçlerin içine çizerek gösteriniz. H_2O moleküllerini ile, hidrojen atomunu ● ile, oksijen atomunu ise ○ ile gösteriniz ve çizimlerinizi neden bu şekilde yaptığınızı açıklayınız.

(***Dikkat!!! Çizimlerinizi yaparken; moleküller arası mesafeler, moleküllerin birim alanda dağılımı ve molekül içi/moleküller arası bağlar gibi noktaları göz önünde bulundurmaya çalışınız ve açıklamalarınızı yaparken; yukarıdaki referans gösterim ile sizin çizdiğiniz gösterimler arasındaki farklılıkları belirtiniz***)

Buz



Açıklama:

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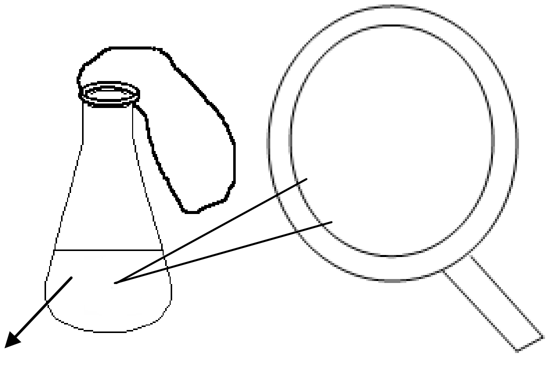

Su

Açıklama:

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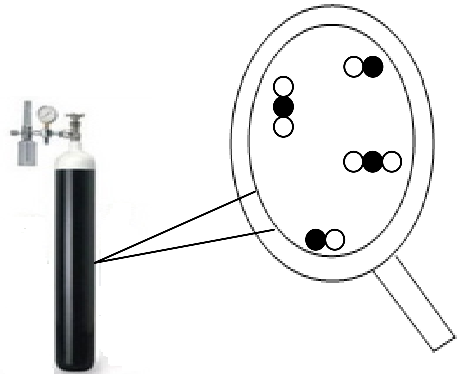
(6. Soru)

Aşağıdaki tüplere, içlerinde bulunan gazların taneciklerini (atom ve moleküllerini) gösterebilen bir büyüteç ile bakıldığını ve aşağıdaki görüntülerin izlendiğini varsayınız. Bu görüntülere göre, her bir madde için verilen ifadelerden **hangisi/hangileri** nin doğru olduğunu işaretleyiniz ve neden böyle düşündüğünüzü açıklayınız (***Dikkat!!!: Aynı madde için birden fazla doğru ifade olabilir***).

6a) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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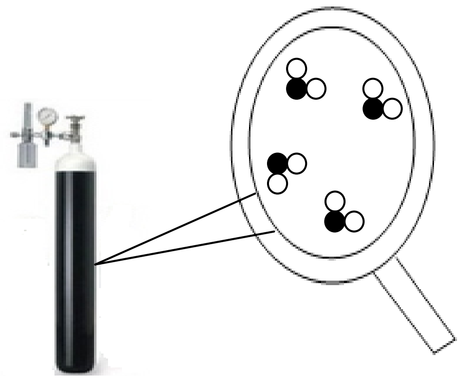
6b) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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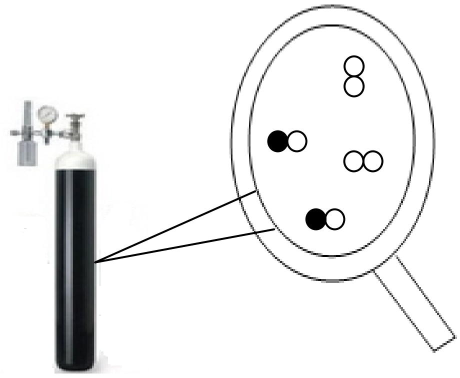
6c) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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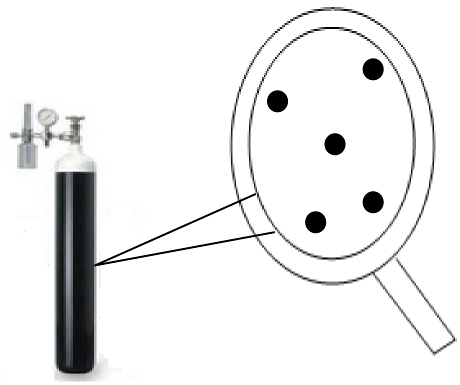
6d) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü; ....
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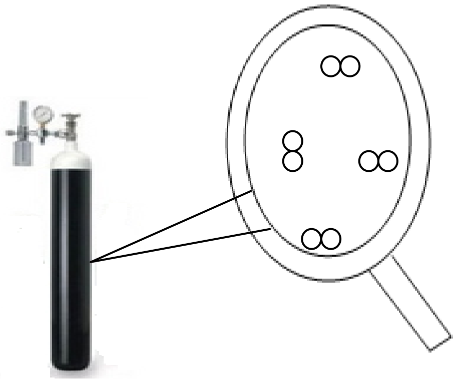
6e) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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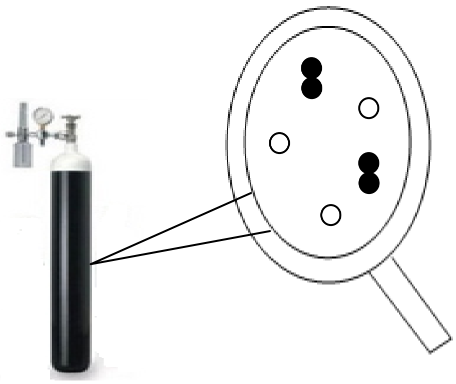
6f) Tüpteki madde:



- Karışımdır ( )
- Saf maddedir ( )
- Bileşiktir ( )

Çünkü;
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- Sadece 1 elementten oluşmaktadır ( )
- 2 farklı elementten oluşmaktadır ( )
- 1 element ve 1 bileşikten oluşmaktadır ( )
- Sadece 1 bileşikten oluşmaktadır ( )
- 2 farklı bileşikten oluşmaktadır ( )

Çünkü;
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APPENDIX E : EVALUATION RUBRIC FOR CCT

Evaluation Rubric for the First Item of CCT

Item #	SU	PU	PUSM	SM
1a1	There is nothing between the particles of water vapor in vacuum. Yet, there may be air between the particles of water vapour in an open container	There is not air but nothing between the particles of water vapor	-	There is air between the particles of water vapor
1a2	When liquid water freezes, its volume increases. It indicates us there is some space between the particles of ice and the space is more than that of liquid water.	There is some space between the particles of ice	-	There is not any space between the particles of ice The space between the particles of ice is less than that of liquid water
1a3	The covalent bond that is formed by sharing electrons of oxygen and hydrogen atoms holds these atoms together within the water molecule. Hydrogen bonding occurs between molecules of water	Hydrogen bonding is not the force that holds oxygen and hydrogen atoms in water molecule	Hydrogen bonding can occur between hydrogen atom and one of fluor, oxygen and nitrogen atoms. Thus, it is the force the force that holds oxygen and hydrogen atoms in water molecule	Hydrogen bonding is the force that holds oxygen and hydrogen atoms in water molecule
1a4	The properties of matters result from the arrangement of their particles and the attraction between them. An individual particle does not have the properties of the bulk matter	The structure of molecules do not change in phase changes	-	The particles of a substance have the same properties with the bulk matter
1a5	When alcohol and water is mixed, total volume of the mixture will be less than the sum of the volumes of mixing water and alcohol. It indicates that there is some space between the particles of liquids. Also, when ice melts, its volume decreases. It indicates that the space between the particles of liquid water is less than that of ice	There is some space between the particles of liquid water	-	There is not any space between the particles of liquid water The space between the particles of liquid water is more than that of ice
1a6	When water changes phase, only the space between water molecules increases or decreases. The size of molecules does not change, molecules do not expand or shrink	When water changes phase, water molecules do not change	-	When liquid water evaporates, water molecules expand When ice melts, water molecules shrink
1a7	When water evaporates, the space between water molecules increase. The volume of water increases so the density of water vapor is less than the density of liquid water. Mass is always conserved since the matter cannot be destroyed	The mass of water does not change when it is evaporated	-	The mass of water decreases when it is evaporated

1b1	If all of the characteristics of ice are indicated in the answer • Ice is shown by particles • Ice molecules are the same as in liquid water • The space between molecules of ice is more than that of liquid water • There is strong attraction between ice molecules. It is the hydrogen bonding attraction between hydrogen of one water molecule and oxygen of another. • The particles of ice are in ordered fashion	If at least one of the characteristics of ice is indicated in the answer	If both of one characteristic of water and one specific misconception are indicated in the answer	The space between molecules of ice is less than that of liquid water The particles of ice are disordered The molecules of ice is smaller than that of liquid water and water vapor
1b2	If all of the characteristics of water vapor are indicated in the answer • Water vapor is shown by particles • The molecules of water vapor are the same as in liquid water and ice • The molecules of water vapor are completely separated • The attraction between the moelcules of water vapor are too weak • The particles of water vapor are disordered	If at least one of the characteristics of water vapor is indicated in the answer	If both of one characteristic of water vapor and one specific misconception are indicated in the answer	Water molecules decompose to hydrogen and oxygen atoms when evaporated The molecules of water vapor is larger than that of ice and liquid water
Post	If all of the characteristics of liquid water are indicated in the answer • Liquid water is shown by particles • The molecules of liquid water are the same as ice and water vapour • The space between molecules of liquid water is less than that of ice • The particles of liquid water are disordered	If at least one of the characteristics of liquid water is indicated in the answer	If both of one characteristic of water and one specific misconception are indicated in the answer	The space between molecules of liquid water is more than that of ice The molecules of liquid water is larger than that of ice and smaller than that of water vapor

Evaluation Rubric for the Second Item of CCT

Item #	SU	PU	PUSM	SM
2a1	Mixture Different particles indicate that there are more than one substance	-	If the matter is classified as both a mixture and a compound and explained as a mixture of two compounds	The matter is a compound A matter can be both a mixture and a compound The matter is a pure substance
2a2	The matter consists of two different compounds There is two different molecules that is composed of two different atoms		If the responder says both of the matter consists of two different elements and the matter consists of two different compounds	An element and an atom are the same things
2b1	Pure Substance & Compound The same particles indicate that there is only one substance and different atoms indicate that it is a compound	If the responder says and explain only one of that the matter is a pure substance and the matter is a compound	If the responder says and explain that the matter is a compound but not a pure substance	Compounds are not pure substances
2b2	The matter consists of only one compound There is one kind of molecule that is composed of two different atoms	-	If the responder says both of the matter consists of two different elements and the matter consists of only one compound	An element and an atom are the same things
2c1	Mixture Different particles indicate that there are more than one substance	-	If the matter is classified as both a mixture and a compound and explained as a mixture that is including a compound If the matter is classified as a mixture but explained as a mixture of two compounds	A matter can be both a mixture and a compound All of the polyatomic chemical species are compounds
2c2	The matter consists of an element and a compound There are two different molecules: one of them is composed of the same kind of atoms and the other one is composed of two different atoms	-	If the responder says both of the matter consists of two different elements and the matter consists of an element and a compound	An element and an atom are the same things All of the polyatomic chemical species are compounds
2d1	Pure Substance The same particles indicate that there is only one substance and the same kind of atoms indicate that it is an element	-	If the matter is classified as both a pure substance and a compound	The matter is a compound The matter is a mixture
2d2	The matter consists of only one kind of element There are the same kinds of atoms	-	-	The matter may be a compound
2e1	Pure Substance The same particles indicate that there is only one substance and the same kind of atoms indicate that it is an	-	If the matter is classified as both a pure substance and a compound	All of the polyatomic chemical species are compounds

	element			
2e2	The matter consists of only one kind of element There are the same kinds of atoms	-	-	If the responder says both of the matter consists of two different elements and the matter consists of only one compound ("An element and an atom are the same things" and "All of the polyatomic chemical species are compounds") If the responder says the matter consists of only one compound ("All of the polyatomic chemical species are compounds")
2f1	Mixture Different particles indicate that there are more than one substance	-	If the matter is classified as a mixture of an element and a compound	All of the polyatomic chemical species are compounds The matter is a pure substance since it consists of two pure substances
2f2	The matter consists of two different elements There are two different particles: one of them is an atom and the other one is a molecule that is composed of the same kind of atoms	-	-	If the responder says both of the matter consists of two different elements and the matter consists of an element and a compound ("An element and an atom are the same things") If the responder says the matter consists of an element and a compound ("All of the polyatomic chemical species are compounds")

Evaluation Rubric for the Third Item of CCT

Item #	SU	PU	PUSM	SM
3a	To calculate the concentration of reactants and products in a chemical equilibrium condition, it is necessary to know the initial concentration of reactants and products and also equilirium constant	If the responder says it is not possible to comment on the concentrations of reactants and products and explain it as one of the followings • It is necessary to know mole number of reactants and products • It is necessary to know equilirium constant	-	The concentrations of reactants and products are equal at the chemical equilibrium condition The concentrations of reactants and products are proportional to the stoichiometric coefficients in the reaction equation at the chemical equilibrium condition
3b	A reversible reaction reachs equilibrium when the rates of forward and reverse reactions become equal	The rates of forward and reverse reactions are equal at the moment of chemical equilibrium	-	The forward and reverse reactions are completed at the moment of chemical equilibrium The rates of forward and reverse reactions are equal because the mole number of reactants and products are equal
3c	The forward and reverse reactions always go on at the moment of chemical equilibrium. Thus all of the reactants and products are found in the medium, none of them are used up	All of the reactants and products are found in the medium at chemical equilibrium condition	-	Only reactants are found in reaction medium at chemical equilibrium condition Only products are found in reaction medium at chemical equilibrium condition

Evaluation Rubric for the Fourth Item of CCT

Item #	SU	PU	PUSM	SM
4a	For the given reaction; $Qd = \frac{[H_2O]^2 [Cl_2]^2}{[HCl]^4 [O_2]}$ $Qd = \frac{(n_{H2O})^2 (n_{Cl2})^2 V}{(n_{HCl})^4 (n_{O2})}$ It is not known the number of moles of HCl added and how much the volume of the container changed. Thus, it not possible to comment on which reaction's rate will increase and how the number of the molecules of Cl_2 change	There is not enough information to solve the question	-	According to Le Chatelier principle, since one of the reactants is added to the medium, the rate of the forward reaction will increase. Thus, the number of the molecules of Cl_2 will increase
Post	For the given reaction; $Qd = \frac{[H_2]^4 [CS_2]}{[H_2S]^2 [CH_4]}$ $Qd = \frac{(n_{H2})^4 (n_{CS2})}{(n_{H2S})^2 (n_{CH4}) V^2}$ It is not known the number of moles of CS_2 added and how much the volume of the container changed. Thus, it not possible to comment on which reaction's rate will increase and how the number of the molecules of H_2S change	There is not enough information to solve the question	-	According to Le Chatelier principle, since one of the products is added to the medium, the rate of the reverse reaction will increase. Thus, the number of the molecules of H_2S will decrease
4b	For the given reaction; $Qd = \frac{[H_2O]^2 [Cl_2]^2}{[HCl]^4 [O_2]}$ $Qd = \frac{(n_{H2O})^2 (n_{Cl2})^2 V}{(n_{HCl})^4 (n_{O2})}$ When some amounts of He is added to the container, the mathematical value of reaction quotient increases. For the reation to reach equilibrium, the reaction quotient has to be equal to the equilibrium constant. Thus, the rate of reverse reaction increases, the number of O_2 molecules increase	When a noble gas is added to the system, the volume of the container increases so the gas contentration in the container decreases. According to Le Chatelier principle, the rate of the reaction which inreases gas contentration will increase. Thus, the rate of reverse reaction will increase and the number of O_2 molecules will increase	-	The equilibrium is not destroyed since He is a noble gas and do not react with the matters found in the medium
Post	For the given reaction; $Qd = \frac{[H_2]^4 [CS_2]}{[H_2S]^2 [CH_4]}$ $Qd = \frac{(n_{H2})^4 (n_{CS2})}{(n_{H2S})^2 (n_{CH4}) V^2}$ When some amounts of Ar was added to the container, the mathematical value of reaction quotient decreases. For the reaction to reach equilibrium, the reaction quotient has to be equal to the equilibrium constant. Thus, the rate of forward reaction increases, the number of CH_4 molecules decrease	When a noble gas is added to the system, the volume of the container increases so the gas contentration in the container decreases. According to Le Chatelier principle, the rate of the reaction which increases gas concentration will increase. Thus, the rate of forward reaction will increase and the number of CH_4 molecules will decrease	-	The equilibrium is not destroyed since Ar is a noble gas and do not react with the matters found in the medium

Evaluation Rubric for the Fifth Item of CCT

Item #	SU	PU	PUSM	SM
5a	$HCl > HNO_3 > HF > CH_3COOH > HCN$ Acidity constant determines how much an acid will dissociate in water. Thus, the larger the acidity constant, the stronger the acid	The larger the acidity constant, the stronger the acid.	-	The pH of the acid solution determines the strength of an acid The concentration of the acid solution determines the strength of an acid
Post	$HCl > HNO_3 > HNO_2 > HOCN > HOBr$ Acidity constant determines how much an acid will dissociate in water. Thus, the larger the acidity constant, the stronger the acid	The larger the acidity constant, the stronger the acid.	-	The pH of the acid solution determines the strength of an acid The concentration of the acid solution determines the strength of an acid
5b1	The strength of an acid does not change when the concentration of acid solution. The amount of acid and water determines the concentration of acid solution but does not affect the structure of the acid	The strength of an acid does not depend on the concentration of acid solution.	-	When the concentration of acid solution increases, the strength of the acid also increases
5b2	The acid, HNO_3, is a stronger acid since it has a higher acidity constant. It dissociates in water in higher ratio. The strength of an acid does not change when the concentration of acid solution.	The strength of an acid does not depend on the concentration of acid solution.	-	When the concentration of acid solution increases, the strength of the acid also increases

Evaluation Rubric for the Second Item of CCT

Item #	SU	PU	PUSM	SM
6a	Strong acids completely dissociate in water so the acid molecules are not observed in the acid solution. The number of H_3O^+ and A^- ions should be equal because of the reaction equation. The number of H_3O^+ and A^- ions should be higher in concentrated acid than the weak acid solutions if the number of water molecules are the same	If the responder draws equal number of he number of H_3O^+ and A^- ions but does not draw water molecules	-	There is no water molecules in concentrated acid solutions Strong acids weakly dissociate in water The number of H_3O^+ ions is higher than A^- ions in concentrated acid solutions
6b	Weak acids do not completely dissociate in water. The acid molecules are observed in the acid solution and higher number of acid molecules is found in concentrated solution The number of H_3O^+ and A^- ions should be equal because of the reaction equation. The number of H_3O^+ and A^- ions should be higher in concentrated acid than the weak acid solutions if the number of water molecules are the same	If the responder does not draw higher number of acid molecules in concentrated solution	-	Weak acids completely dissociate in water The number of H_3O^+ ions is higher than A^- ions in concentrated acid solutions

APPENDIX F : KNOWLEDGE AND BELIEFS ABOUT CHEMISTRY MISCONCEPTIONS AND TEACHING EFFICACY QUESTIONNAIRE

KİMYA KAVRAM YANILGILARI HAKKINDA BİLGİ VE DÜŞÜNCELER

1) “Kavram yanılgısı” terimini birine açıklamanız gerekse nasıl tanımlardınız?

2) Kendi deneyimlerinizi, okuduklarınızı ve öğrendiklerinizi düşündüğünüzde, öğrencilerin sıklıkla sahip olabildikleri kimya kavram yanılgılarına örnek olarak neleri verirdiniz?

3) Öğrencilerin kimya kavram yanılgılarının sebepleri/kaynakları neler olabilir? Açıklayınız.

4) Bir ders planı hazırlanırken, öğrencilerin o konu hakkındaki olası kavram yanılgıları dikkate alınmalı mıdır? Soruya cevabınız evet ise, bunu yapmak mümkün müdür ve nasıl yapılabilir?

5) Öğrencilerin kavram yanılgılarını tespit etmek için ne gibi yöntemler kullanılabilir?

6) Öğrencilerin kavram yanılgılarını değiştirmek için ne gibi yöntemler kullanılabilir?

7) Dersinizi işlerken, öğrencilerinizden bazılarında bir kavram yanılgısı olduğunu fark ettiğinizi varsayalım.

a) Dersinizin akışında değişiklik yapar mısınız? Cevabınız evet ise, bu nasıl bir değişiklik olur?

b) Bu konuyu daha sonra öğretmek için hazırladığınız ders planında değişiklik yapar mısınız? Cevabınız evet ise, bu nasıl bir değişiklik olur?

8) Sizce, öğrencilerin kavram yanılgılarını değiştirmek zor mudur?

9) Şu anki kimya alan bilginiz ve pedagojik donanımınızla hangi öğretim yöntemlerini daha iyi kullanabileceğinizi düşünüyorsunuz? (Kendinizi değerlendirirken en yetkin olduğunuzu düşündüğünüz öğretim yönteminden başlayarak bir sıralama yapınız)

10) Şu anki kimya alan bilginiz ve pedagojik donanımınızla hangi kimya konularını öğretmede yeterli olduğunuzu düşünüyorsunuz? (Kendinizi değerlendirirken aşağıda verilen derecelendirme ölçeğini kullanınız)

(1): Yetersiz olduğumu düşünüyorum

(2): Ne tam yeterli ne de tam yetersiz olduğumu düşünüyorum

(3): Yeterli olduğumu düşünüyorum

Konular	**Değerlendirme**		
Maddenin Tanecikli Yapısı	(1)	(2)	(3)
Bileşikler	(1)	(2)	(3)
Karışımların Özellikleri ve Sınıflandırılması	(1)	(2)	(3)
Kimyasal Tepkimeler	(1)	(2)	(3)
Mol Kavramı	(1)	(2)	(3)
Çözünürlük ve Çözeltiler	(1)	(2)	(3)
Atomun Yapısı	(1)	(2)	(3)
Periyodik Tablo	(1)	(2)	(3)
Kimyasal Türler Arası Etkileşimler	(1)	(2)	(3)
Asitler ve Bazlar	(1)	(2)	(3)
Gazlar	(1)	(2)	(3)
Kimyasal Denge	(1)	(2)	(3)
Kimyasal Tepkimelerde Enerji	(1)	(2)	(3)
Elektrokimya	(1)	(2)	(3)
Radyoaktivite	(1)	(2)	(3)
Organik Kimya	(1)	(2)	(3)

11) Kimya eğitimi literatüne göre: “Kovalent bağ yapan bileşiklerde, erime ve kaynama olayları sırasında molekül içi bağlar kırılır” kavram yanılgısına öğrencilerde sıklıkla rastlanmaktadır. Bu kavram yanılgısını değiştirmek için iki saat sürecek bir ders planı hazırlamanız istense, nasıl bir akış önerirdiniz? (Kullanacağınız öğretim yöntem ve materyallerini de belirtecek şekilde açıklayınız)

APPENDIX G : PROGRAM EVALUATION FORM

PROGRAM DEĞERLENDİRMESİ

6 hafta süren bu programa katılmanın, sana kattıkları hakkında bir yazı yazman ve bu yazıyı yazarken aşağıdaki sorulara cevaplarını da yazında içermen istense neler yazardın?

1) Bu programa katıldıktan sonra, farklı kimya konularına hitap eden benzer bir programın başlayacağı duyurulsa, gene katılır mısın?

2) Bu programın öğretmenlik bilgi ve becerilerine neler kattığını düşünüyorsun? Örnekler vererek açıklar mısın?

3) Sence bu programa katılman sonucunda öğrenmiş olduğun en önemli şey ne oldu?

4a) Programın en beğendiğin özelliği ne oldu?

4b) Programın en beğenmediğin özelliği ne oldu?

5) Sence bu program başka gruplar için tekrar yapılsa neler eklenebilir / neler çıkarılabilir? Programla ilgili nelerin değişmesini önerirsin?

6) Bu programa katılımın sayesinde, sende de var olduğunu farkettiğin ve bu süreç içerisinde düzelttiğini düşündüğün kavram yanılgın/yanılgıların oldu mu? Olduysa bunlar neler?

7) Öğretmenliğe başladığında, bu programda öğrendiğin içerik ve yöntemlerden ilham alarak benzer uygulamalar yapacağını düşünüyor musun? Eğer düşünüyorsan kullanacağını düşündüğün şeyler neler olacaktır?

8a) Yapılan etkinliklerden en çok aklında kalan hangisi oldu? Böyle düşünmenin nedeni sence nedir?

8b) Yapılan etkinliklerden en sıkıcı bulduğun hangisi oldu? Böyle düşünmenin nedeni sence nedir?

9a) Bu programa katılmadan önce, maddenin tanecikli yapısı, kimyasal denge ve asitler konularını öğretmek için ne gibi yöntemler kullanmayı düşünürdün?

9b) Bu programa katıldıktan sonra, bu konuları öğretmek için kullanmayı düşündüğün yöntemlerde ne gibi değişiklikler oldu?

10) Etkinlikler sırasında sormak isteyip de soramadığınız, hala kafanızı karıştıran bir nokta kaldı mı? Varsa nedir?

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