# IMPROVING 11TH GRADE STUDENTS' UNDERSTANDING OF ACID-BASE CONCEPTS BY USING 5E LEARNING CYCLE MODEL

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# ABSTRACT

IMPROVING 11TH GRADE STUDENTS' UNDERSTANDING OF ACID-BASE CONCEPTS BY USING 5E LEARNING CYCLE MODEL

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The purpose of this study was to compare the effectiveness of instruction based on 5E learning cycle model over traditionally instruction on students' understanding of acid-base concepts. Also, the effect of instruction on students' attitude toward chemistry as a school subject and the effect of gender difference on understanding of acid-base concepts and attitudes toward chemistry were investigated.

During the second semester of 2007-2008, 130 eleventh grade students from six classes of two different high schools attended this study. The classes were randomly assigned as control and experiment groups. Students in the control groups were instructed by traditional instruction whereas students in the experimental groups were taught by 5E model. Attitude Scale Toward Chemistry as a School Subject and Acid-Base Concept Test were administered as a pre and post-tests. In addition, Science Process Skill Test and Views on Science-Technology-Society instrument was utilized.

The hypotheses were tested by using two-way analysis of covariance (ANCOVA) and two-way analysis of variance (ANOVA). The results revealed that 5E Model caused a significantly better understanding of acids and bases than the traditional instruction. In addition, these models of instruction developed the similar attitude toward science as a school subject. Science process skill was a strong predictor in understanding the concepts. On the other hand, no significant effect of gender difference on understanding the acids and bases and on students' attitudes toward chemistry as a school subject was found. The results of Views on Science-Technology-Society gave a picture of the students' views on nature of science.

Keywords: 5E Learning Cycle, Acid-Base Concepts, Attitude Towards Chemistry as a School Subject, Science Process Skill, Views on Nature of Science.

# ÖZ

## 11. SINIF ÖĞRENCİLERİNDE ASİT-BAZ KAVRAMLARININ ANLAŞILMASININ 5E ÖĞRENME DÖNGÜSÜ MODELİ KULLANILARAK GELİŞTİRİLMESİ


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Bu çalışmanın amacı 5E öğrenme döngüsü modelinin, 11. sınıf öğrencilerinin asit-baz kavramlarını anlamalarına olan etkisini geleneksel yöntem ile karşılaştırarak incelemektir. Ayrıca, öğretim yönteminin ve cinsiyet farkının öğrencilerin kimya dersine yönelik tutumlarına etkisi ile cinsiyet farkının asit-baz kavramlarının anlaşılmasına olan etkisi de araştırılmıştır.

Bu çalışma, iki ayrı lisenin toplam altı sınıfında bulunan 130 on birinci sınıf öğrencisi ile 2007-2008 eğitim yılının güz döneminde yapılmıştır. Sınıflar kontrol grubu ve deney grubu olarak rastgele seçilmiştir. Kontrol grubunda geleneksel yöntem kullanılırken deney grubunda 5E Modeli kullanılmıştır. Kimya Dersi Tutum Ölçeği ve Asit-Baz Kavram Testi her iki gruba ön-test ve son-test olarak uygulanmıştır. Ayrıca çalışmada, Bilimsel İşlem Beceri Testi ve Bilimin Doğası Hakkındaki Görüşler anketi de kullanılmıştır.

Araştırmanın hipotezleri iki yönlü ortak değişkenli varyans analizi (ANCOVA) ve iki yönlü varyans analizi (ANOVA) kullanılarak test edilmiştir. Sonuçlar, her iki okul tipinde de, 5E Modeli kullanılarak uygulanan öğretim yönteminin, asit-baz kavramlarının anlaşılmasında geleneksel yönteme göre daha etkili olduğunu göstermiştir. Her iki öğretim yönteminin öğrencilerin kimya dersine yönelik tutumlarını istatistiksel açıdan benzer derecede geliştirdiği gözlenmiştir. Bilimsel işlem becerisinin de öğrencilerin asit-baz kavramlarını anlamalarına istatistiksel olarak anlamlı katkısı olduğu saptanmıştır. Cinsiyet farkının asitler ve bazlar konusunu anlama ve kimya dersine yönelik tutuma bir etkisinin olmadığı ortaya çıkmıştır. Bilimin Doğası Hakkındaki Görüşler anketinin sonuçları ise öğrencilerin bilimin doğasını hakkındaki fikirlerine ulaşmamızı sağlamıştır.

Anahtar Sözcükler: 5E Öğrenme Döngüsü Modeli, Asit-Baz Kavramları, Kimya Dersi Tutum Ölçeği, Bilimsel İşlem Becerisi, Bilimin Doğası Hakkında Görüşler.

To My Parents

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| | |
|---|---|
| 5E | : Instruction based on 5E Learning Cycle Model |
| TDCI | : Traditionally Designed Chemistry Instruction |
| ABCT | : Acid Base Concept Test |
| ASTC | : Attitude Scale Towards Chemistry as a School Subject |
| SPST | : Science Process SkillTest |
| VOSTS | : Views on Science-Technology-Society |
| T-VOSTS | : Turkish Version of Views on Science-Technology-Society |
| df | : Degrees of freedom |
| SS | : Sum of squares |
| MS | : Mean square |
| $\overline{X}$ | : Mean of the sample |
| P | : Significance level |
| F | : F statistic |

# CHAPTER 1

# INTRODUCTION

Throughout the last two centuries science has become an increasingly noteworthy factor in improving the quality of life and understanding of the world (Marek, and Cavallo, 1997). Most scientists would argue that science is an important tool for understanding the way the world works, for comprehending some of the critical issues of the day, and even for improving citizenship. Also, for many parents, the most compelling rationale might be to develop the skills their children will need to prosper in a 21st century workforce (BSCS, 2008). However, many students view science as an endless barrage of terms, facts and formulas; all which seem to have little relevance to or connection with their understanding of scientific phenomena and with their the world they inhabit (MacGowan, 1997). Further, most research studies have found that science courses have been characterized as boring and irrelevant to the world of the students (Allard and Barman, 1994) and many students have difficulty in learning science (Weiss, 1987; LaPointe, Meade, and Philips, 1989; Sheppard, 1997).

Students show wide range of difficulties to learn the basic concepts of science. Discovering the reason of it has been target of many studies (i.e., Fisher, 1985; Nakhleh, 1992; Chambers and Andre, 1997; Boujaoud, 2004). Several studies revealed that learning science is often difficult for students because their theories about how the world works conflict with scientific understandings they are to learn (Fellows, 1994). Students come into a classroom with their own experiences. They construct ideas about the natural world based, in part, on observations of objects, phenomena, and their interactions. With time, these ideas also become linked and tested through their experiences and interactions with the ideas of others (Lunetta, Hofstein and Clough, 2007). If a student uses existing concepts to deal with new phenomena, this is called assimilation. (Posner et al., 1982). However, if there is a discrepencay between the conceptual framework and the new information, student must actively reconstruct the conceptual framework through accomodation (Bodner, 1986). From this point of view, learning in science entails more than just adding new concepts to knowledge.

Generally, when students' preconceptions are different from the views of scientists, these differing frameworks are referred to in the literature as "misconceptions" (Helm, 1980; Griffiths and Grant, 1985; Ross and Munby, 1991; Nakhleh and Krajcik, 1994; Huddle and Pillay, 1996). In this study, the term "misconception" was used to refer to the students' conception that is inconsistent with scientific conception. As the literature indicates, misconceptions are pervasive, stable, resistant, and affect the further learning negatively (Andersson, 1986; Griffiths and Preston, 1992). In other words, misconceptions are really big obstacles to promote science learning. Therefore, it becomes very important to find out students' preconceptions and misconceptions before instruction and take them into consideration during the instruction.

Most science educators have focused their attention upon students' misconceptions at science concepts (Osborne and Wittrock, 1983). Some studies in science education have indicated that students have considerable degree of misconceptions about chemistry concepts (i.e., Camacho and Good, 1989; Garnett, 1992; Abraham et al., 1994; Pardo and Solaz-Patolez, 1995; Ebenezer and Ericson, 1996). Indeed, students struggle to learn chemistry, but are often unsuccessful. The difficulties that students have in learning chemsitry have been attributed to the abstractness of the subject (Herron, 1975; Carter and Brickhouse, 1989), the mathematical nature (Schmidt, 1984; Johnstone, 1984) and the remoteness of the language used (Glassman, 1967). Also, reseracher s stated that chemists use three different levels to describe or represent phenomena; the macrscopic, the microscopic, and the symbolic (Gabel, Samuel, and Hunn, 1987), and thus the link between these levels should be explicitly taught (Harrison and Treagust, 2000; Ebenezer, 2001; Ravialo, 2001). The interactions and distinctions between these are necessary for achievement in comprehending chemical concepts (Ghassan, 2007). Acid-base concept is one of the challenging chemistry topics for students to understand (Zoller, 1990; Nakhleh and Krajcik, 1994; Demircioğlu, Özmen and Ayas, 2004), and promoting meaningful learning is too difficult for this concept.

It is obvious that instructors should consider supplementing the lecture format with a variety of active learning teaching strategies that would encourage the students to become aware of their prior knowledge and misconceptions. Ausubel (1968) also stated the most important single factor influencing learning is what the learner already knows. However, research studies, which examine the teaching procedure used in teaching science, revealed that most science courses are taught with the belief that students are empty vessels that need to be filled with large amounts of information (Billings, 2001) and teaching science in most schools is done with the inform-verify-practice procedure (Marek, and Cavallo, 1997). In inform-verify-practice procedure, students are informed about what they are to know so they have no experiences to coordinate. That is, the experiences someone else has had are coordinated into a logical system and presented to them. However, Albert Einstein stated that “the object of all science is to coordinate our experiences and bring them into a logical system.” (Holton, and Roller, 1958, cited in Marek, and Cavallo, 1997). Therefore, if Einstein is correct, it is obvious that science cannot be taught with the inform-verify-practice teaching procedure (Marek, and Cavallo, 1997).

Today, research studies have indicated that inform-verify-practice procedure do not allow higher level thinking to occur in classrooms but rather relegate science to the memorization of facts. In rote learning, students do not develop hierarchical framework of successively more inclusive concepts, instead they accumulate isolated propositions in their cognitive structure. This causes poor retention and retrieval of new knowledge to solve problems (Uzuntiryaki, 2003). In other worlds, many students taugt with traditional learning tend not to learn meaningfully and thus may have difficulty relating what is taught to them in science with other science ideas, and with real world experiences (Novak, 1988). Instead, for meaningful learning to occur, new knowledge must be related by the student to relevant existing concepts in that student's cognitive structure. These observations lead to a new approach to education called constructivist approach. A constructivist approach sees learners as mentally active agents struggling to make sense of their world (Pines and West, 1986). Also, it allows students to construct knowledge, to think and to learn.

Constructivist ideas have had a major influence on science educators over the last decade (Appleton, 1997). The learning cycle approach also promotes the constructivist philosophy whereby students construct knowledge by identifying and testing their existing understandings, by interpreting the meaning of their ongoing experiences, and by adjusting their knowledge frameworks accordingly (Ewers, 2001). Karplus (1960) also argued that the teaching of science requires more than content. Teaching requires a plan derived from both the discipline of science and the manner in which students learn. He called the teaching procedure that was invented to satisfy those requirements the learning cycle. The learning cycle moves children through a scientific investigation by allowing them first to explore materials, then to construct a concept, and finally to apply this concept to new ideas (Marek and Cavallo, 1997). Further, all phases of the learning cycle incorporates the Piagetian approach into a succinct methodology of learning: experiencing the phenomena or concept (Exploration Phase), applying terminology to the concept (Concept/Term Introduction), and application of the concepts into additional conceptual frameworks (Concept Application) (Odom, and Kelly, 2001).

The learning cycle, the antithesis of inform-verify-practice approach in science, promotes meaningful learning because students must construct, formulate, and explain their ideas from their own experiences. The students are not given answers, which tend to close their minds and stop their process of making links and meaning of their experiences. Textbook definitions and readings are used by students only after having direct experience with the phenomena. Thus, students first form a knowledge base of understanding of the concept that was central to their concrete experiences in the exploration. This knowledge base is the relevant prior knowledge upon which to link new ideas they learn in the concept application phase of the learning cycle. Furthermore, the concept application phase typically includes many activities that help students to link ideas and relate them to their everyday lives. Also, Piaget labeled this process of linking ideas within the mental structure as "organization" (Marek and Cavallo, 1997).

In addition, the learning cycle was intended to attain many national goals and standards of science education for the twenty-first century (National Research Council, 1996). The learning cycle was designed to be consistent with the nature of science and to promote critical thinking through inquiry, collaborative grouping, and the construction of new ideas.

The development of the ability to think has long been accepted as a central purpose of education (Educatinal Policies Commission 1961; American Association for the Advancement of Science, 1990) because the ability to think independently allows indviduals in our society to make choices and enjoy true freedom. Thus, educators need to help children- who represent the future leaders and decision makers of our society- develop the ability to think logically (Marek and Cavallo, 1997). The ability to think is based on the use of the rational powers of the mind (Educational Policies Commission, 1961). Also, Marek and Cavallo (1997) equate ability to think with students' development and use of the rational powers: classifying, comparing, evaluating, analyzing, synthesizing, imagining, inferring, deducing, recalling, and generalizing. All phases of the learning cycle lead students to develop their rational powers. The exploration phase of the learning cycle is the time during which the major assimilation that leads to conceptual understanding takes place. In making this assimilation students classify the results they receive, which means that they compare them and comparing results requires at least a minor evaluation. Students use several of the rational powers, therefore, in just the act of exploring. Before, term introduction, students must make a thorough analysis of the data resulting from their exploration. Term introduction is obviously a synthesis incorporating the use of imagination. Classifying, comparing, evaluating, and inferring are necessary in formulating the concept. All these activities lead to transference of the data received through the context of exploration to the context of knowledge construction. Such activities also make evident why accommodation takes place during the term introduction phase. In the concept-application phase, the newly acquired knowledge is immediately put to use in a new context and with new materials. This causes students to recognize their fresh understanding of the concept and generalize about it. Most certainly, students are using deduction throughout this entire learning cycle phase. In light of the foregoing, it can be concluded that the combination of curriculum organization and classroom teaching procedures using the learning cycle leads students to achieve the central purpose of education, that is, they are developing the ability to think (Marek and Cavallo, 1997).

In addition to help students acquire scientific knowledge; another goal of science education is to understand its development. In other words, science education should not only teach what science is, but also how scientific knowledge is constructed through a series of complex interactions among different views, such as cultural and social (Huang, Tsai, and Chang, 2005). Traditional science education focuses mainly on the acquisition of scientific facts, but very little on the process as well as the nature of developing scientific knowledge (Duschl, 1990). That is, science curricula, teachers, and students may not have appropriate understandings of the nature of science, and most of them express empiricist-aligned (in contrast to constructivist) views about the nature of science (Lederman, 1992). However, understanding the nature of science is important because it not only should help students function in our society, but also should enrich their lives by making them insiders who can share in the science adventure story as it unfolds (American Association for the Advancement of Science, 1993).

Findings indicate that the learning cycle influenced learner's conceptions of the nature of science and science instruction (i.e., Senneca, 1997). In this study, we used another version of learning cycle, which is called 5E Learning Cycle Model (Engage, Explore, Explain, Elaborate and Evaluate), because 5E sequence automatically structures constructivist, inquiry–based learning while addressing content required by high school students (Wilder and Shuttleworth, 2005). This model is designed to incorporate all aspects of constructivist learning environments by engaging students and allowing students to explore the concepts being introduced, discover explanations for the concepts they are learning, and elaborate on what they have learned by applying their knowledge to new situations. Throughout the process the model offers multiple opportunities for evaluation of students' understanding. (Bybee, 1993; MaryKay and Megan, 2007).

In this study, we primarily concerned with students' misconceptions and instructional strategies that affect the understanding of scientific concept. In this respect, we aimed to improve eleventh grade students' understanding acid and base concepts by 5E Learning Cycle Model. The contribution of students' science process skills to their understanding of acid and base concepts was also examined in our study. Lazarowitz (2002) indicated that learning science requires high cognitive skills. Science process skills involve identifying variables and hypotheses, designing investigations, graphing and exploring data, explaining results and drawing conclusions.

In present study, we also dealt with the effect of treatment on students' attitudes toward science as a school subject. Much research in science education indicated that the type of instruction affected students' attitudes toward science as a school subject (Parker, 2000; Chang, 2002). Students' attitudes, feelings and perceptions of science are important for science achievement. Moreover, we examined the students' understanding of the nature of science. Many contemporary science educators agree that encouraging students' understanding of the nature of science, its presuppositions, values, aims, and limitations should be central goal of science teaching (McComas, Clough and Almazroa, 1998). The nature of science has been defined in numerous ways. By the nature of science we mean the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge, as consisted with the definition of Abd-el-Khalick, Bell and Lederman (1998). Researchers have argued that richer understandings of the nature of science promote deeper interest and engagement in the subject (King, 1991; Matthews 1994; Lederman, 1998). In our opinion, the most important reason students should understand the nature of science is that this understanding is crucial to responsible personal decision making and effective local and global citizenship.

# CHAPTER 2

# REVIEW OF LITERATURE

The need for students to receive a good science education has been more important in the highly globalized and competitive 21st century. Thus, schools today are under enormous pressures that were not present few years ago (BSCS, 2008). Although the greater consistency between goals, theories, and practices in the learning and teaching of science has been highly recommended for ages (i.e., Lunetta and Tamir, 1979; Marek and Cavallo, 1997), one of the acute problems in teaching science today has been the mismatch which often exists between the stated goals for science education and the learning outcomes visible in school graduates (Lunetta and Tamir, 1979; Mettes, Pilot, Roossink, and Kramers-Pals, 1980; Osborne, and Gilbert, 1980; Nurrenbern and Pickering, 1987; Marek and Cavallo, 1997). Today, although it is mostly agreed that teaching what is called science without involving the students in a quest or search is not a teaching science (Marek and Cavallo, 1997), most of current traditional teaching is focused on the content of the curriculum and on knowledge and information transmission. Whereas this is an essential aspect of the schools, it is no longer enough for an effective and stimulating learning process. Further, even helping students to acquire scientific knowledge is not enough for the 21st century; students should understand the nature of science is that this understanding is crucial to responsible personal decision making and effective local and global citizenship (Smith and Scharmann, 1999). On this ground that we began the discussion with the misconceptions which are very big obstacles to promote science learning. Next, learning cycle models, which lead students on the quest for knowledge, were explained. Finally, nature of science was discussed.

## 2.1 Misconceptions

Substantial research has indicated that students hold and use a variety of ideas or conceptions about natural phenomena they begin to study science formally (Driver and Erickson, 1983; Osborne and Freyberg, 1985; Wandersee, et.al., 1994; Sheppard, 1997). These conceptions, known as a student's prior knowledge, are frequently contrary to scientifically accepted ideas (Osborne and Freyberg, 1985) and they have been referred to in the literature as "misconceptions" (Helm, 1980; Fisher, 1985; Cho, Kahle, and Nordland, 1985; Griffiths and Grant, 1985); "alternative conceptions" (Driver and Easley 1978; Gilbert and Swift, 1985; Nakhleh, 1992; Palmer, 2001); "preconceptions" (Novak 1977); or "children' science" (Gilbert, Osborne, and Fensham, 1982). In this study, the term "misconception" will be used to refer to the students' conception that is inconsistent with scientific conception.

During learning, students try to connect new knowledge into their cognitive structure. If they hold misconceptions, these misconceptions interfere with subsequent learning (Ben-Zvi et al., 1986; de Vos and Verdonk, 1987; Haidar and Abraham, 1991; de Posada, 1997). Therefore, new knowledge cannot be connected to their existing structure and misunderstanding of the concept occurs (Nakhleh, 1992). Thus, teacher must identify students' misconceptions and find out to prevent them from occurring. In order to dispel students' misconceptions, it is necessary to identify the sources of them. However, the origins of students' misconceptions are difficult to pinpoint (Sheppard, 1997). Generally speaking, the possible sources of students' misconceptions are: direct observations and perceptions of the natural world (Head, 1982), social environment (Strauss, 1981; Stepans, 1991; Herron, 1996), everyday language (Gilbert et al., 1982; Prieto et al., 1989; Renstrom et.al., 1990), ordinary language in the classroom (Osborne, 1983; Ross, 1989; Veiga, et.al., 1989; Bergquist and Heikkinen 1990), the inadequate prerequisite knowledge (Bodner, 1986; Garnett et al., 1990; Garnett and Treagust, 1992a,b; Taber, 1995), teacher (Gilbert and Zylberstajn, 1985; Lawrenz, 1986; Ross, 1989; Banerjee, 1991; Heller and Finley, 1992; Hodge, 1993), and textbooks (Cho et al. 1985; Andersson, 1990; Dall'Alba et.al., 1993).

Misconceptions are embedded in students' alternative belief system; therefore, many of the misconceptions are pervasive, stable, and resistant to change and some students persist in giving answers consistent with their misconceptions despite years of formal schooling in science (Driver and Easley, 1978; Fredette and Lockhead, 1980; Gunstone and White, 1981; Hewson and Hewson, 1983; Osborne, 1983; Halloun and Hestenes, 1985; Wandersee et al. 1994). Over the last three decades, various teaching models have been developed to change students' misconceptions into scientific conceptions (Demircioglu et. al., 2005) because misconceptions have been found to be resistant to change by traditional instruction (Fisher, 1985). Most researchers supported that create disequilibrium necessary for students to rearrange their conception in the direction of the expert's conception (Pinarbasi, 2007). Also, researchers insisted that, before teaching a concept, teachers should check the literature to find out misconceptions that students may bring to class and which methods are the best in correcting these misconceptions (Pinarbasi, 2007).

Students' misconceptions in school sciences at all levels constitute a major problem of concern to science educators, scientist researchers, teachers, and, students (Johnstone and Kellett, 1980; Nussbaum, 1981; Osborne and Wittrock, 1983; White and Tisher, 1985). Within this framework, chemistry has a particular status (Campbell, 1978). Although much recent science education research has focused on students' understanding of various science topics, comparatively little research has been conducted in chemistry (Skelly, 1993; Sheppard, 1997). Studies in science education aimed to determine the students' understandings of chemistry concepts indicated that students hold a variety of incorrect ideas about many chemistry concepts (Fensham, 1994; Gabel and Bunce, 1994): the mole (Duncan and Johnstone, 1973; Novik and Mannis, 1976; Gabel and Sherwood, 1984; Staver and Lumpe, 1995); chemical equilibrium (Camacho and Good, 1989; Gussarsky and Gorodetsky, 1990; Banerjee, 1991; Pardo and Solaz- Patolez, 1995); chemical reaction (Barker and Millar, 1999), gases (Benson, et al., 1993), stoichiometry (BouJaoude and Barakat, 2000), atoms and molecules (Griffiths and Preston, 1992), electrochemistry (Garnett, 1992; Garnett and Treagust, 1992a,b); solutions (Abraham et al., 1994; Ebenezer and Ericson,1996); the particulate nature of matter (Ben-Zvi, Eylon, and Silberstein, 1986; Gabel et.al., 1987; Lythcott, 1990); bonding (Peterson and Treagust, 1989; Boo, 1998; Tan, and Treagust, 1999; Nicoll, 2001; Coll and Treagust, 2003); solubility (Longden, et.al., 1991); and acid-base chemistry (Ross, 1989; Nakhleh, 1990; Vidyapati and Seetharamappa, 1995; Sheppard, 1997; Sisovic and Bojovic, 2000).

### 2.2. Misconceptions in Acids and Bases

Acids and bases is one of the basic topics that has applications in many areas of chemistry. Further, improved instruction on acids and bases may lead to improved instruction in other areas of science (Ross, 1989). For instance, biochemistry students need to have an understanding of the nature of acids and bases, because enzymes function occurs in specific acid-base environments. By the same token, agricultural scientists draw from a prior knowledge of acids and bases to enhance their expertise in crop cultivation (Whitman, Zinck, and Nalepa, 1982). Moreover, commercial investments about acid-base industry and its effects on environment make people concerned about acids and bases.

There have been a number of studies about student understanding of acid-base chemistry (Cros et al., 1986, 1988; Ross, 1989; Nakhleh, 1990; Ross and Munby, 1991; Nakhleh and Krajcik, 1993, 1994; Botton, 1995; Vidyapati and Seetharamappa, 1995; Sheppard, 1997; Sisovic and Bojovic, 2000; Demircioğlu et al, 2004). Results have showed that acid-base chemistry is not simple (Ross, 1989) because mastery of its concepts, requires an integrated understanding and knowledge of many conceptual areas of chemistry, such as the particulate nature of matter, concentrations, solutions, chemical equilibrium, stoichiometry and chemical reactions (Sheppard, 1997). Previous research studies reveal that students do not have an adequate level of understanding of the acid and base concepts (Hand, 1989; Ross, 1989; Nakhleh, 1990; Vidyapati and Seetharamappa, 1995). Actually, students usually learn the concepts of acids and bases with memory strategies (Lin et.al., 2004). Thus, they simply memorize definitions regarding acids and bases without being able to truly comprehend the concepts (Smith and Metz, 1996); therefore, students hold many misconceptions related to acids and bases (Ross, 1989; Zoller, 1990). As the literature indicates, misconceptions are pervasive, stable, resistant, and affect students' further learning (Andersson, 1986; Griffiths and Preston, 1992). Therefore, it becomes very important to find out and prevent students' misconceptions during the instruction (Demircioğlu et.al., 2004). In this regard, students' misunderstanding in acids and bases constitutes a major problem of concern to science education researchers. Some of the studies on students' concepts of acids and bases at different stages in students' school or university training are reviewed below.

Many researchers have designed their research studies to identify the misconceptions about acid-base concepts. Among misconceptions research, the most common approaches for obtaining information is using interviews. For example, Cros et. al. (1986, 1988), Ross (1989), Ross and Munby (1991), Vidyapati and Seetharamappa (1995), Sheppard (1997) and Pınarbası (2007) used interviews to identify students' understanding level of acids and bases.

Cros et. al. (1986) investigated 400 first-year university students' conceptions of the constituents of matter and conceptions of acids and bases. For this purpose, they used free interviews, semi-structured interviews and questionnaires. They found that students have a good knowledge of formal descriptions, but inadequate conceptions of concrete phenomena, such as heat being released during an acid base reaction. Students did not appear to connect their knowledge with everyday phenomena. Further, the authors stated that students found it easy to give examples of acids; the most frequently mentioned being hydrochloric (93%), sulphuric (61%), and ethanoic acids (56%), but when asked to list three bases, 43% couldn't name more than two. In addition, 17% answered that pH was a measurement of the degree of acidity. The results of this study also indicated that education is not sufficiently linked to experimental work and the practical aspects of chemistry in everyday life and in the modern world.

In a follow-up study, Cros et. al. (1988) investigated to what extent, after one year of study at university level, the conceptions of students have evolved and how their knowledge of scientific theory has progressed. They found that some of the students had modified their concepts; for example, the former descriptive definition for acids (pH less than 7) replaced a scientific definition *(*an acid releases or can release $H^+$). However other concepts, such as the descriptive definition used for pH, hardly changed. The result of the study also revealed that the students do not perceive the relationship between the scientific notions they master and their applications, not only in the daily practices of chemists, but also in everyday life**,** supports the findings of Cros et.al. (1986).

The results of the Cros et. al. studies give a point to the purpose of the study, conducted by Ross and Munby (1991). They design a study to investigate senior high-school students' understanding of acids and bases and to explore the methodological approach offered by concept mapping. During the study, two audio taped interviews were conducted with each participant. The study was started with a multiple-choice test. This test was used to gain additional information for the interviews and to select the participants. The first interviews conducted three days after the administration of the multiple-choice test included tasks written on a card that contained a stimulus in the form of a drawing, diagram, or picture. In the second interviews, each student was asked to write five words or phrase he or she associated with acids and bases. The second interviews were conducted four weeks after the first interviews. The interviews were grounded on a model concept constructed from the curriculum. The results were depicted in concept maps and compared to the model concept map. The misconceptions regarding acids noted by Ross and Munby (1991) are that acids taste bitter and peppery; all substances with sharp or strong smells are acids; all acids are strong and poisonous; strong acids have a higher pH than do weak acids; soil cannot be acidic because things grow in it. Moreover, the discrepancy found in performance between the acid subscale and the base subscale supports the findings of Cros et.al. (1986), and difficulties found in the ion subscale confirmed the results of Burns' study (as cited in Carr 1984).

Sheppard (1997) investigated high school students' understanding of acid-base chemistry, prior to and after formal chemistry instruction. Sixteen students enrolled in a regular chemistry course were interviewed three times during the school year; before and after studying the topic of acids and bases and then while conducting a titration using a microcomputer-based laboratory (MBL). The findings showed that students had considerable difficulty with several areas of acid-base chemistry and did not develop an integrated conceptual understanding of the topic. Students were unable to describe acid-base concepts accurately and revealed a number of alternative conceptions, which remained unchanged by instruction. Specific areas of difficulty included the concepts of pH, neutralization, strength and the theoretical descriptions of acids and bases. Further, most students could not relate the concepts to actual solutions and were unable to describe acid-base phenomena at a sub-microscopic level.

Vidyapati and Seetharamappa (1995)'s study was undertaken to explore higher secondary school students' understanding of acids and bases. The study's participants were 75 high school students coming from five schools in different regions of India. The authors used free interviews and a questionnaire-based enquiry followed by structured interview. The questions in the questionnaire involved defining and giving examples of acids and bases in terms of Arrhenius, Bronsted-Lowry and Lewis theories, giving examples of acids and bases in everyday life and concept of neutralization. The results of the study showed that few students could correctly define and give examples of acids and bases using the different acid-base models. Suprisingly, a greater number of students could give correct examples of acids and bases for each of the theoretical descriptions, than could define the theories. Moreover, they found that overall the students were as knowledgeable about bases as they were about acids, which contrasts with the results of the Cros et.al.'

(1986) study. Also, many students were found to have little knowledge of acids and bases in everyday life and that many of examples they cited were taken from the texts themselves. Moreover, about 85% of the students have a misconception as regard to ‘neutralization’ term. These students believed that a neutral solution always results in a neutralization reaction, a finding similar to that of the Schmidt (1991) study. Also, about 70% of the participants were not aware that neutralization is accompanied by evolution of heat. And, only 15% of students considered that the pH of a solution would drop if an acid were added directly to a base. Clearly, students think of only strong acids reacting with strong bases in a neutralization reaction. It appears from this study that the students’ knowledge of acids and bases is qualitative and formal and is not sufficiently connected with daily life encounters.

Smith and Metz (1996) built their research study on prior research using microscopic representations to examine undergraduate students’ conceptual knowledge of acid strength and solution chemistry. Also, the researchers tested graduate students and faculty to see if conceptual weaknesses persist past the undergraduate level. They reported that alternative conceptions about acid strength persist at graduate level chemistry, with many students misrepresenting ions, bonding and dissociation on a sub-microscopic level. For example, many students believe a strong acid has a strong bond. Furthermore, students usually stated that a weak acid is easily pulled apart due to weak bonds or weak attractions between the charged species. While many students could define strength verbally, they could not accurately describe or explain the phenomena. Notwithstanding this, Sheppard (1997) claimed that this study has two deficiencies. First, the authors omit the solvent molecules from all the sub-microscopic representations of acids and bases and the solvent is an important factor in acid-base chemistry. Secondly, the sub-microscopic representation of weak acids, incorrectly shows them as being made of associated ions, as opposed to molecules.

Ross (1989) also conducted a study to investigate high school students’ understanding of acids and bases with quantitative and qualitative methods. Analyses of data showed that the students held idiosyncratic conceptions of acids and bases which did not coincide with the concepts found in the curriculum guidelines or prescribed texts. Also, the author found that the students retained their everyday concepts of acids and bases and grasped few of the scientific concepts. As a result of this study, the misconceptions that students hold were stated as follows:

- Acids contain hydroxide ions.
- All acids are strong acids.
- Concentrated is the same as strong.
- Acids are poisonous.
- Acid rain is formed from water and chlorine or hydrogen gas.
- Acids contain hydrogen in the gaseous state.
- Acids and bases react to form a solution.
- A strong acid has a higher pH than a weak acid.
- A gas is released when an acid and a metal reacts because heat changes the liquid to a vapor.
- When hydrochloric acid and magnesium react more gas is released than acetic acid reacts with magnesium because the reaction is more violent.
- When hydrochloric acid and magnesium react more gas is released than acetic acid reacts with magnesium more hydrogen bonds need to be broken.
- A strong acid reacts more slowly than a weak acid.

Demerouti et al. (2004) constructed and utilized a questionnaire consisting of ten multiple-choice and eight open-type questions in order to investigate students' misconceptions and difficulties associated with acids and bases. The test was given to 119 Greek students in the twelfth grade. They found that the students had misconceptions and difficulties on some topics. These were: dissociation and ionization, definition of Brønsted-Lowry acids and bases, ionic equilibria, neutralization, pH, buffer solutions, and degree of ionization.

Demircioğlu et.al. (2004) examined the sophomores' understandings and misunderstandings of acid and base concepts in a high school. 150 sophomores enrolled in this study. The authors developed A 25 item, 3 section test to measure the concept of acids and bases. Results of the study implied that students did not have an adequate level of understanding of the acid-base concepts. Some misconceptions students showed were: acids can harm everything; strong acids melt metals and destroy them; all acids and bases are harmful and poison; the pH of a salt solution resulted from neutralization is always 7 and there are neither $H^+$ nor $OH^-$ ions in a neutralization reaction between a strong acid and a strong base.

Pınarbaşı (2007) studied to explore the conceptions of Turkish undergraduate students regarding concepts of acids and bases and to determine the difficulties that students may have in understanding these concepts. He developed open-ended diagnostic questions and semi-structured interviews. The findings revealed a number of misconceptions. These can be summarized as: pure water (or a neutral solution) has always a pH of 7; the pH of an acid solution that is excessively diluted can be over 7; all salts are neutral in terms of acidity-basicity; the neutralization of a strong base by a weak acid (and vice versa) does not proceed to completion (even if the reactants are in stoichiometric amounts), hence the resulting solution is basic (or acidic); hydrolysis is considered as being the separation of a substance into ions by water. Furthermore, he stated that the domain of acids, bases and neutralization offers a unique area for studying because this domain produces a rich and complex conceptual framework which includes various key aspects of chemistry. For example, neutralization involves chemical change, a central concern in chemistry that needs to be emphasized. Moreover, an explanation of neutralization makes reference to the atomic theory which is vital for understanding of all topics in chemistry. At advanced levels, neutralization is considered in relation to other important chemistry concepts such as reaction rate and chemical equilibrium (Pınarbası, 2007).

In addition to the research focused on investigating students' misconceptions related to acid-base concepts, several researches focused on exploring what kinds of reasons result in the students' misconceptions. For example, Lin et.al. (2004) studied to identify students' mental models, to understand ninth graders' changes before and after formal instruction, and to search for their causes. Moreover, they also examined the differences of mental models between students with high achievement and students with low achievement. The sample consisted of 38 ninth grade students from a local high school in Taipei city. After taking a set of two-tier diagnostic test, the authors chose six target students; three were with high achievement and the others were with low achievement. Before formal instruction, the authors interviewed target students for understanding their mental models about acids and bases and their causes of concepts. After formal instruction in acids and bases, all students took a post-test and the authors interviewed theses 6 target students again for understanding changes of students' mental models and causes of misconceptions after instruction. When they compared high achievement students and low achievement students, they found that students with high achievement held more identical mental models, and their sources came from teaching in school more. However, students with low achievement were influenced by the context of questions and their sources were various. This study also was a part of an integrated project designed to build up a databank for misconceptions held by students in Taiwan in order to improve teachers, researchers, and curriculum designers' understandings of students' science concepts for better quality of learning. As a result of this study, the author suggested that there are two main sources of students' misconceptions: one was teaching in school and the other was intuition which was influenced by the representations or superficial meanings of characters and symbols.

As a result of the many advances that have been made in this area of chemistry over the last century, there is disagreement about what should be taught about acids and bases in introductory courses (Hawkes, 1994). Textbooks describe the chemical properties of acids and bases and also three different theories of acidity, each with its own specialized terminology, which the beginning chemistry student is expected to master. Thus this leads to confusion for students (Osborne and Cosgrove, 1983; Sheppard, 1997).

In other words, the use of models may be another contributing factor to students' misconceptions (Drechsler and Schmidt, 2005**)**. Carr's (1984) textbook survey revealed conflicting viewpoints and varied sequences of the models used to explain the concepts acids and bases. He suggested students might be confused when the three models (Arrhenius, Lewis, and Bronsted-Lowry), are introduced in the same chemistry course. Besides, Hawkes (1992) observed that the Arrhenius acid-base model confused students. When asked to use the Brønsted model, which applies to a variety of bases, students' thinking was still dominated by the Arrhenius model, in which only $OH^-$ ion-producing substances are considered as bases. Moreover, Demerouti et al. (2004) indicated that students from upper secondary school were more familiar with the Arrhenius model; they did not use the Brønsted model to explain the properties of acids and bases.

Several research studies also identified that many chemistry textbooks did not clearly distinguish acid-base models, and not discuss why scientists use different models (i.e., Oversby, 2000; Drechsler and Schmidt, 2005). No explanation was provided why a new model was introduced and how a new model differs from the previous one. For instance, Oversby (2000) identified in a survey chemistry textbooks that explained different acid-base models but did not discuss the strengths and limitations of each model. Rayner-Canham (1994) also stated that when teacher teach theories, they rarely take the time to show why one theory supersedes another, yet there is always a reason. Many students enter college chemistry courses with the simple Arrhenius Theory of acids and bases firmly established among their chemical beliefs. This naive view fits well with the students' knowledge base and nothing in their experiences contradicts the paradigm. Then, when the Bronsted-Lowry Theory is introduced, students may see it as having to learn a more complex concept for no real reason. Therefore, teachers need to show students the reasons for the increasing complexity of theories (Rayner-Canham, 1994). In the study conducted by Rayner-

Canham, two simple sets of demonstrations were described that show definitely why the Arrhenius Theory of acids and bases had to be replaced. The author's study support that demonstrations are far more useful and effective if they serve a specific educational purpose.

Research has shown that teachers were aware that different models exist but did not use them in their classes (Justi and Gilbert, 2002). Drechsler and Schmidt's (2005) study also supported this idea. Their study concentrates on different models used to explain acids and bases and how teachers and textbooks handle these models. In this study the analysis of the textbooks and the interviews revealed that the acid-base concepts presented by the books and by the teachers were the same. And, the teachers were well aware of the importance of models but had difficulties to make use of them to explain the properties of acids and bases. Moreover, textbooks and teachers neither described the differences between the models nor clarified why the Brønsted model was introduced. Some teachers had not even commented on the differences between them.

In addition, researchers mentioned some problematic representations shown in textbooks. For example, curriculum designers usually use concrete scientific models for explaining abstract concepts. The way they use may make students only learn the models we presented but not the concepts themselves (Renner and Marek, 1988; Stepans, 1991; Lin et.al., 2004). Erduran (1996) analyzed eight physical science textbooks for coverage on acids, bases, and neutralization. She investigated that although textbooks are readable, they fail in making explicit connections to important, underlying themes such as chemical change and physical properties. Moreover, she stated that conceptual frameworks which the students are exposed to in textbooks might be deficient not only in terms of content but also in terms of how content is weaved into a broader framework.

Lin et.al. (2004) also stated that the concepts of acids and bases are easily influenced by everyday languages and experiences. They suggested that if teachers or languages in textbooks just state the scientific languages but not point out the difference between scientific and everyday languages, students will misunderstand easily. Herron (1996) also argued that languages in chemistry make students confused. The main reason is that the meanings of the same words in chemistry and everyday life are different. In other words, students are able to understand the chemistry languages only in chemistry contexts. However, teaching should helps students realize not only the superficial level of chemistry symbols but also the link between the representations of chemistry symbols and the process of chemical reactions in real world (Lin et.al., 2004).

In addition, researchers suggested that the term “neutralization” does indeed act as a hidden persuader that leads students to a misconception of the process involved (i.e., Schmidt, 1991; Lin et.al., 2004). In other words, many students understand the concept in its literal sense viz neutralization always results in a neutral solution (Sheppard, 1997). Schmidt (1991) also showed that students had difficulties understanding the concept of neutralization, and he attributed part of this difficulty to the ambiguous use of the term neutral in ordinary language and in the chemical context. Neutralization is the core concept of acids and bases. If students have misconceptions, it will have much effect on students’ learning of acids and bases. Therefore, teachers and curriculum designers should explain the word neutralization clearly (Lin et.al., 2004)

Many students were found to have little knowledge of acids and bases in everyday life (Vidyapati and Seetharamappa, 1995). For instance, Toplis (1998) stated that pupils’ often hold erroneous ideas about acids and alkalis obtained from everyday experience, some of which are confused and resistant to change. Driver et al. (1994) also suggested that pupils’ ideas about acids are derived from sensory experiences such as tasting sour foods, and from advertisements for antacid remedies and crime stories about acid baths and news about the effects of acid rain. Vidyapati and Seetharamappa (1995) reported similar ideas in a questionnaire survey with higher secondary school students. When asked to identify acidic substances in everyday life the most frequent answers were: fruits (64%), soda/soft drinks (69.3%) and vinegar (26.6%). Moreover, research by Ross (1986) found that common household products were incorrectly classified and although students knew of acid rain and antacids, few related this knowledge to chemistry. These appear to be reasonable notions about acids. Moreover, concerning misconceptions of bases, students think that fruits are basic, bases are blue, and bases do not contain hydrogen (Ross and Munby, 1991; Nakhleh and Krajcik, 1994).

Students' misconceptions also may be arising formal school instruction and the interaction between teachers and students (Griffiths and Preston, 1989). For instance, Schmidt (1997) indicated that the idea that in any reaction between an acid and a base a neutral solution is formed has been found to be quite common among students, however, the main source of the concept neutralization was school instruction. In school, besides inappropriate teaching strategies, teachers' own misconceptions also may result in students' misconceptions (Blosser, 1986; Westbrook and Marek, 1992). For instance, Bradley and Mosimege (1998) indicated whether student teachers at a university and a college of education hold any misconceptions about acids and bases. The misconceptions were explored through the study focused on: theory of acids and bases; properties of acids and bases; acid and base strength; pH function; equations for acid-base reactions; molecular representations of acids and bases. The results of their study showed that achievement was disappointing generally and student teachers at the university performed better.

In addition to aforecited factors that may have prevented the students from acquiring the acid-base concepts, the students' deficient prior knowledge is also a crucial one (Ross, 1989). Research studies have indicated that students lacked knowledge of the concepts that they are generally expected to learn before instruction on acids and bases. For example, some students did not interpret information provided in equations and seemed not to know about the activity series of metals. Moreover, among the acid-base concepts, the pH and ion concepts appear to be most significant if students are to understand acids and bases. Ross‘s (1989) study showed that most students did not understand ions, so misconceptions have arise in the concept of pH (Ross, 1989).

The findings of researches focused on investigating students’ misconceptions and the kinds of reasons result in students’ misconceptions related to acid-base concepts are crucial because by taking misconceptions and their sources into account, removing of misconceptions could be achieved.

Many studies have been conducted about ways of teaching acids and bases. For instance, Hand and Treagust (1991) studied about students’ achievement and science curriculum development using a constructive framework. They conducted individual semi-structured student interviews through three months and from these interviews, they found five misconceptions about acids and bases among sixty 16-year-old students. These were: an acid is something which eats material away and can burn you; testing of an acid can only be done by trying to eat something away; to neutralize is to break down an acid or to change from an acid; a base is something which makes up an acid; and a strong acid can eat material away faster than a weak acid. Hand and Treagust’s (1991) study different that the studies above, because it aimed to remedy the student misconceptions. They developed and implemented a curriculum about acids and bases based on the conceptual change approach, which designed to change students’ misconceptions about acid and bases to scientific conceptions. The results of their study revealed also that students taught by using the new curriculum about acid and bases topic have had a higher achievement than those taught by using traditional methods.

Nakhleh and Krajcik (1993) studied the influence of different levels of information, presented by three technologies (chemical indicators, pH meters, and microcomputer-based laboratories) on students’ actions and thought processes. Their study was a first attempt to investigate how students learn in laboratory using various technologies. They investigated students’ initial and final understanding of acid-base concepts and their concurrent thought processes and actions during the process of acid-base titrations. Each student used one technology to titrate a strong acid, weak acid, and polyprotic acid with a strong base, and they verbalized their thoughts while titrating. At the end of the study, they revealed that the technology's level of information had influence on students' ability to construct understanding from the laboratory experience, and also affected the focus of students' observations. They also investigated microcomputers enhance laboratory learning. In addition to this, their study also revealed that students held three main ideas about how acids and bases behave when mixed. One idea is that the acid and base do not react; they simply form a physical mixture. Another idea is that they do react, but they react by sticking together to form one particle. A third, more appropriate idea is that acid and bases react by double displacement. Moreover, the results of this study have four implications for science teaching practice. These were: prelaboratory and postlaboratory discussions become critical to meaningful learning from the laboratory activity; laboratory activities should be clustered in terms of the procedural skills taught in them; laboratory activities should be simplified in order to focus the students attention on what is to be learned from the laboratory; students should be allowed the time to explore the boundaries of the topic, either by laboratory projects or by demonstrations.

Then, Nakhleh and Krajcik (1994) also studied to investigate changes in secondary students' understanding of acid, base, and pH concepts before, after and during a series of acid-base titrations using same technologies: chemical indicators, pH meters, and microcomputer-based laboratories (MBL). Changes in the understanding of students were explored by using the verbal data obtained in initial and final interviews to construct concept maps and estimate the depth of their molecular understanding. After the initial interview, students were grouped by the level of technology employed. Within each group, students individually performed the same set of titrations using different technologies. No teacher mediated instruction was provided. The results indicated that the order of the influence of technology on understanding is: MBL > chemical indicator > pH meter. Moreover, they stated that students using MBL activities constructed more detailed and more integrated chemical concepts, which may have resulted in more meaningful learning. Moreover, they also established that some of students who participated in the study had the following misconceptions: pH is inversely related to harm and bases are not harmful; bubbles or bubbling is a sign of chemical reaction or strength; acids and bases have their own particular color or color intensity (bases are colored blue, acids are colored pink, and even different pH solutions have different colors); molecules fight and combine, and phenolphthalein helps with neutralization; acids melt metals, acids are strong and bases are not strong; pH is a compound called phenolphthalein, a chemical reaction and a number related to intensity. Finally, researchers also proposed that research need to be done on effective methods of using MBLs in teaching.

Demircioğlu et.al. (2005) designed a study to identify the effects on students' achievement and misconceptions of new teaching material (NTM) developed for acids and bases. Also, they explored students' attitudes towards chemistry. The sample of the study was eighty-eight tenth grade students from a secondary school on the north coast of Black Sea Region in Turkey. The research was carried out with an experiment and control group design. Both experiment and control groups were observed during the implementation of the unit. In a typical instructional sequence, while the experimental teacher tried to help their students recognize and resolve the conflict between personal knowledge and scientific knowledge with the NTM, the control group teacher used a traditional approach mainly involving talk and chalk sessions without practical sessions. The two groups spent equal time studying the unit. However, the lessons in the experimental group generally focused on the prepared worksheets, analogies and demonstrations from the NTM, designed to encourage conceptual conflict for those students holding misconceptions about acids and bases. They concluded that the students' misunderstandings of the concepts of the acids and bases generally originated from their experiences in everyday life. And, the students in both groups had more difficulty in understanding the neutralization (titration process) and related concepts than the others in the unit, because of the complex structure of the neutralization concept. The results indicated the implementation of the new material produced better results both in terms of achievement and attitudes. Moreover, it is observed that training with the NTM based on the conceptual change strategy was more successful in remedying students' misconceptions on acids and bases than conventional instruction. This result supported the notion that it is not easy to eliminate misconceptions just by employing traditional instructional methods.

In addition, several researchers developed analogies to teach concepts relating to acids and bases (i.e., Kramer, 1986; De Lorenzo, 1995; Silverstein, 2000; Last, 2003). For instance, Silverstein (2000) developed a football analogy to explain weak and strong acid-base. He believed that problem often arise, when chemistry teachers attempt to explain the differences between weak and strong acids, and between weak and strong bases. Because, for acids in aqueous solution, teachers often speak of complete vs partial ionization, or ≈100% dissociation. This type of terminology work for one with a strong grasp of the equilibrium concept, but for many students it does not seem to do the trick. Partial ionization is a difficult concept for some to comprehend; the phrase may not evoke much in the mind of a visual learner. He stated that visual analogies are often helpful when difficulties like these arise. Hence in his analogy he likens an acid, which is a proton donor, to a quarterback. The quarterback is a football donor, whose job is to deliver the ball by either passing it to a receiver or handing it off to a running back. With all the details of analogy he added that a similar analogy may be drawn between a base and a wide receiver. The results indicated that the analogy can help even students unfamiliar with the mores of the gridiron to comprehend the mores of aqueous protons.

### 2.3 Learning Cycle

Learning cycle was designed to promote scientific understanding and thinking abilities among students (Lawson and Snitgen, 1982; Saunders and Shepardson, 1987; Schneider and Renner, 1990; Marek and Methven, 1991; Guzetti, Snyder, Glass, and Gamas, 1993; Marek and Cavallo, 1995; Lavoie, 1999). To this end, it is the one predominant teaching method that has long histories of use remain widespread in the science education community (i.e., Renner, 1986; Bergquist, 1991; Marek and Methven, 1991; Trifone, 1991; Gang, 1995; Abraham, 1998; Lawson, 2000; Odom and Kelly, 2001).

The learning cycle is developed by Karplus (1977), but it is not right to say who first invented the learning cycle because the learning cycle is one method of teaching which purports to be consistent with the way people spontaneously construct knowledge. In other words, anyone who has reflected upon how to teach effectively has no doubt discovered aspects of the learning cycle (Lawson et.al., 1989). At first hand, the learning cycle was formally introduced for elementary-age students as a part of Science Curriculum Improvement Study (1974). However, it was later adapted for a wide variety of grade levels and topics (Purser and Renner 1983; Saunders and Shepardson 1987; Stepans et al. 1988; Zollman, 1990; Barman 1992; Barman et al. 1993; Allard, and Barman, 1994).

The learning cycle bring a unique epistemology to learning and have proven to provide a better understanding of the learner and the learning process (Odom and Kelly, 2001). Learning cycle is deeply rooted in Piaget's developmental theory, but it is also embodies other constructivist paradigms of learning and development. These paradigms include Vygotsky's (1978) social constructivist theory and Ausubel's (1963) meaningful learning theory (Marek, Gerber and Cavallo, 1999). Scaffolding, for example, is used throughout the learning cycle. Also, in the learning cycle classroom, teachers work within each student's zone of proximal development toward attaining new levels of development. Moreover, because of the students' active role in the learning process, the learning cycle promotes the use of students' meaningful learning strategies as opposed to rote strategies (Marek, Gerber and Cavallo, 1999). Especially, learning cycles promote a meaningful learning by providing application activities that help students link their understanding of the concept to other experiences in science and in everyday life (Ausubel, 1963).

Originally, Karplus and Thier (1967) determined three distinct phases for the learning cycle, named as exploration-invention-discovery (Abell and Lederman, 2007). More recently, these phases have been referred to as explore, explain, and expand (Trowbridge and Bybee, 1990) and to exploration, term/concept introduction or invention, and concept application (e.g., Renner, Abraham, and Birnie, 1988; Lawson, 1995; Marek and Cavallo 1997; Sunal and Sunal, 2000) with slightly different terms being used by the different authors (Dwyer and Lopez, 2001). Basically, a three-phase learning cycle approach is based on the Piagetian notions of learning new concepts through assimilation and disequilibration in the first phase, accommodation in the second phase, and conceptual expansion in the third phase (Lawson, 1995; Renner and Marek, 1990; Abell and Lederman, 2007).

Learning cycles begin with an exploration where students learn through their own actions and reactions as they explore new materials and ideas (Maier and Marek, 2006). During this phase, students are involved in scientific processes such as, measuring, observing, experimenting, gathering data and interpreting data related to a particular science concept. The concept and related terminology are not provided to students; instead, the teacher provides appropriate experiences and acts as facilitator (Cavallo, McNeely and Marek, 2003). Also, this phase provide an opportunity for students to begin to develop the declarative and procedural knowledge with the development of their hypothesis creation and testing skills (Odom and Kelly, 2001). Ideally, exploration should confront students with new information that will cause them to think about how the data or experience they encountered fit with what they already know (Rule, 1995; Maier and Marek, 2006). If a student can account for the data based on prior knowledge assimilation has occurred. During assimilation, observations or experiences are accounted for by students' existing knowledge (Maier and Marek, 2006). However, if new concepts do not fit in with old ideas, this leads to a questioning of old thinking patterns and disequilibrium occurs (Rule, 1995).

Following the exploration is the concept/term introduction, when students analyze and interpret the newly collected data. This second phase of the learning cycle is designed to allow students to re-equilibrate and accommodate the new concept (Maier and Marek, 2006). In this phase, students are in the accommodation, because they make their own meaning out of the observations. Here, students either achieved to make adjustments in each mental structure to make it fit their experience, or they do not construct the new mental structure and then fall in the disequilibrium phase again (Türkmen and Usta, 2007). During this phase, the teacher uses textbooks, audiovisual aids, other written materials, or mini-lectures (Allard and Barman, 1994). Although the teacher takes an active role in presenting the concept, this phase should not take on the form of a lecture. Instead, students are guided by the teacher in a discussion designed to let them interpret the newly collected data. Students arrange and report their group data so that they can formulate hypotheses for the phenomenon under examination (Maier and Marek, 2006). Moreover, appropriate scientific language and terminology should be provided during this phase (Heard and Marek, 1985).

According to Maier and Marek (2006) learning is not be completed by collecting data and developing the concept. Therefore, there is more required on the part of the learner for a full understanding of the concept (Piaget, 1975). Lawson (1995) also pointed out that without a variety of applications, the concept's meaning may remain restricted to the examples used at the time it was initially defined and discussed. Without the application phase, many students may fail either to abstract the concepts from its concrete examples or to generalize it to other situations. Moreover, applications aid students whose conceptual reorganization takes place more slowly than average, or who did not adequately relate the teacher's original explanation to their experiences (Lawson, 2001). To this end, the last phase, concept application, offers additional opportunities for students to apply the newly accommodated concept to what they already know. This effectively tests and reinforces students' understandings of the concept (Maier and Marek, 2006). In this phase students may involve additional laboratory experiences, demonstrations, readings, questions, and/or problem sets (Marek, Eubanks and Gallaher, 1990). Concept application matches to the organization phase in the Piaget's mental functioning (Marek, Gerber and Cavallo, 1999), and aimed to aid the organization and generalization of knowledge by adjustment of related mental structures and transfer from one context to another (Türkmen and Usta, 2007).

Since its introduction, a large amount of research studies concerning the learning cycle approach have been conducted. These studies provide the evidence that learning cycle approach has widespread applicability to a variety of grade levels and disciplines (e.g., Abraham and Renner, 1986; Saunders and Shepardson, 1987; Jackman, 1990; BSCS, 1992; Libby, 1995; Barman, Barman, and Miller, 1996; Colburn and Clough, 1997; Marek and Cavallo, 1997; Lavoie, 1999; Musheno and Lawson, 1999; Marek, 2000; Lawson, 2001; Odom and Kelly, 2001; Cavallo and Laubach, 2001; Lindgren and Bleicher, 2005). In studies involving the learning cycle and science education, researchers have reported the positive gains in encouraging students to think creatively and critically, as well as in facilitating a better understanding of scientific concepts, developing positive attitudes toward science, improving science process skills, and cultivating advanced reasoning skills over the more traditional approaches (e.g., Ivins, 1986; Abraham, and Renner, 1986; Lawson, Abraham, and Renner, 1989; McComas III, 1992; Lawson, 1995; Abell and Lederman, 2007). For example, Ates (2005) conducted a study to investigate the effectiveness of learning cycle method on teaching direct current (DC) circuits to freshmen female and male students. Participants of the study were one hundred and twenty freshmen from four intact classes. The intact classes were randomly assigned into one of the two treatment groups. The experimental group (female =30, male = 31) completed a DC circuit unit with the learning cycle method, while the control group (female = 24, male = 35) completed a DC circuit unit with the traditional method. After the groups were formed, the Turkish version of the Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT), which is originally developed by Engelhardt and Beichner (2004), were administered to students in both groups to measure their pre-understanding of DC circuit concepts. After students in both groups completed instruction designed for the groups, all students received the DIRECT again as a post-test. Finally, experimental group students completed a questionnaire about their perceptions of learning-cycle method. Analyses of questionnaire responses in the present study suggested that the majority of female and male students in the learning-cycle group were actively involved in the unit, enjoyed working with hands-on activities, and were very interested in participating in the learning-cycle activities. The finding of this study also revealed that the learning-cycle method is likely to be effective for both females and males, and led to the better understanding of the DC circuit concepts than did traditional method.

In 1993, Champion explored the differences in content achievement and understanding of experimental design of a sophomore at university human biochemistry course using a learning cycle approach versus an expository method. Researcher found that neither method produced student mastery of concepts; however, the learning cycle promotes significantly greater understanding of experimental design. Then, Champion indicated that since the expository students did not have to design their own experiments, they had more time to spend on analysis. Learning cycle students wrote more introductory sections to reports, whereas the expository students merely recopied student materials. According to the result of the study, the author stated that learning cycle promotes student understanding of experimental design, whereas expository methods foster the development of data analysis techniques.

Kurey (1991) also compared a learning cycle approach to a traditional one in performance of private suburban high school students in chemistry. Prior to the start of the experiment, the cognitive level of students were determined. Then, students were classified as concrete, transitional, or formal and alternatively assigned to each treatment. Four topics in chemistry were taught in the study were: expansion of gases, density, molecular models, and gas laws. The author found no significant differences in performance based on developmental level for the expansion of gases and density, however, students at all cognitive levels benefited from the learning cycle for the molecular models and gas law units. These findings revealed that the performance of students in chemistry can be enhanced by the learning cycle approach when cognitive development is considered; therefore the author suggested that the learning cycle be used to teach students concrete and formal chemistry topics.

Zollman (1990) mentioned several criticisms of typical science courses. For example, most students view physics courses as a collection of facts and also view science as knowledge to be recalled. He also stated that some physicists have improved courses for future teachers that emphasize the nature of physics and the reasoning involved in science to address the criticism of typical science courses. The design of these courses is usually based on the Piagetian model of intellectual development, and the most common way of teaching these courses is with small class sizes of 20 to 30 and a large quantity of hands-on materials. Therefore, the adoption of this method at many universities limited (Zollman, 1990). To overcome this difficulty, Zollman adapted a general learning/teaching model for a class of about 100 students with one faculty member assigned to it. His course is constructed of 15 activity based units, each of which is one-week long. Each unit involves hands-on activities and is based on the learning cycle format developed by Robert Karplus (1977). To adapt the learning cycle for a large-enrollment course taught by a single faculty member, Zolmann used a combination of activities completed in an open laboratory environment and large class meeting. At the end of the study, students' attitudes toward this course were assessed through a student feedback on instruction form, and no differences in attitudes were detected. The major topics of the course were space and time, forces, energy, and electricity and magnetism. The result showed that the learning cycle group, for all topic categories, scored higher than the lecture group, but the differences in the score for forces and energy were statistically significant. Thus, the evaluation of the course led Zollman to conclude that the learning-cycle course contributed positively to student understanding of forces and energy

Cavallo, McNeely and Marek (2003) conducted a study to investigated ninth-grade students' explanations of chemical reactions using two forms of an open-ended essay question during a learning cycle. One form provided students with key terms to be used as anchors upon which to base their essay, whereas the second form did not. Sixty ninth-grade physical science students (26 males, 34 females) in four separate science classes were enrolled in the study, and the instructor of all four classes was one experienced teacher, who used the same inquiry-based, learning cycle curriculum for all classes. The essays were administered at three points: pre-learning cycle, post-concept application, and after additional concept application activities. Students' explanations were qualitatively examined and grouped according to common patterns representing their understandings or misunderstandings. Results showed that more misunderstandings were elicited by the use of key terms as compared to the non-use of key terms in the pre-test. Misunderstandings in the key term essay responses generally involved the misuse of these terms and their association with the concept. Also, a significant positive shift in students' understanding over the learning cycle was observed. No significant increase in understanding occurred after additional application activities. Further, gender differences were found in favor of females in understanding.

In 1993, Klindienst studied with urban middle school students and probed the effects of the learning cycle on three dependent variables; cognitive structures regarding electricity as evidenced by changes in concept maps, content achievement, and attitudes toward learning cycle. Klindienst determined that: the cognitive structures of students in the learning cycle group were significantly more complex than the cognitive structures of students in the traditional group; students taught by the learning cycle achieved higher scores on a teacher-made test than students taught by traditional methods, and the attitudes toward learning science were significantly higher for those students in the learning cycle group. Klindienst suggested that the more complex cognitive structures of students taught by the learning cycle could be attributed to the fact that the learning cycle requires students to process information in a variety of ways. As a consequence, students incorporate new information into existing schema or create new schema to accommodate the information, thus following the learning process as outlined by Piaget. Klindienst also stated that the reason the learning cycle students exhibited better attitudes toward learning science is the sense of control over learning that this method gives to the learner.

Ward and Herron (1980) indicated that inadequate cognitive development is the important reason that students have trouble with chemistry. Therefore, they suggested that procedures should be sought which enhance intellectual development, and which assist students in applying formal operational logic to science problems. Linn and Thier (1975) suggested that the use of the learning cycle as a basis for an entire semester of laboratory instruction would be expected to increase the level of performance of both the concrete and formal operational students. In light of the foregoing, Ward and Herron developed three experiments (chromatography of a felt tip pen, activity series, and chemical interactions) in a college chemistry course in order to compare the effectiveness of a learning cycle laboratory format with a traditional lab format. Each of these experiments emphasizes the use of a particular formal scheme. The subjects for this study were 256 college chemistry students. In general, the researchers determined that students who are operating at the concrete level of intellectual development suffer a disadvantage when compared to their formal operational classmates, not only on material requiring formal reasoning, but on concrete material as well. Concrete and formal students appear capable of competing at an equal level only on material that requires nothing more than the memorization of facts and formulas. However, the performance differences between the groups can be reduced by using the learning cycle because it helps make formal concepts more amenable to students. Ward and Herron believe that long-term use of learning cycle method would undoubtedly increase its effectiveness. The result also indicated that the learning cycle approach was clearly superior to the traditional approach in one of the three experiments. In the other two they found no differences. They noted flawed tests, limited time spent on the study and infidelity to teaching method by teaching assistants as possible reasons for the ambiguous results.

Odom and Kelly (2001) probed the effects of concept mapping, the learning cycle, expository instruction, and a combination of concept mapping/learning cycle at enhancing achievement in diffusion and osmosis content. 108 secondary students (grades 10–11) enrolled in four different sections of college preparatory biology classes were taught with the aforementioned treatments. Each of the four sections was randomly assigned to a treatment group (concept mapping; learning cycle, expository, and concept mapping/learning cycle). The same teacher taught each of the four classes. The Diffusion and Osmosis Diagnostic Test (DODT) was used to measure the conceptual understanding immediately and seven weeks after instruction. The authors suggested that the learning cycle and the concept mapping provide a unique approach to learning that can help students construct knowledge. The topics they selected to study, diffusion and osmosis, involve many complex process that require multiple learning cycles. From this point of view, one of the negative viewpoints of the learning cycle approach was mentioned in this study: with the learning cycle there is no formal mechanism to make connections between numerous concepts and activities. The results of the study indicated the concept mapping/learning cycle and concept mapping treatment groups significantly outperformed the expository treatment group in conceptual understanding of diffusion and osmosis. There was no significant difference among the learning cycle group and other treatments. The effect of the learning cycle was not clearly identified in this study.

More recently, Dogru-Atay and Tekkaya (2008) probed the comparative effect of the learning cycle and expository instruction on 8th-grade students' achievement in genetics. The sample of this study consisted of 213 eighth-grade students who were 13-14 years of age, attending eight whole classes in two public elementary schools in Turkey. The authors randomly chose four whole classes from each school. In each school, they randomly assigned two classes as experimental groups and two as control groups. Experimental group (n= 104) received learning cycle instruction, and the control group (n= 109) received expository instruction. The data indicated a statistically significant post treatment difference between the experimental and control groups in favor of the experiment group after instruction. Also, they found that students' logical thinking ability and meaningful learning orientation accounted for a significant portion of variation in genetics achievement

Additional comparative studies have also reported similar findings. For instance, Eaton (as cited in McWhirter, 1998) compared the achievement of 65 upper elementary students taught by learning cycle methodology and 55 students taught by conventional methods in their abilities to utilize science processes (observation, classification, measuring, experimentation, interpretation and prediction), and findings of the study cut in favor of students taught by learning cycle. Schneider and Renner (as cited in McWhirter, 1998) indicated that ninth grade concrete students taught with learning cycle methodology showed significantly greater gains in concept knowledge than those students taught by formal or lecture-based instruction when measured by a written test. In addition, Stepans and colleagues (as cited in Allard and Barman, 1994) found that the learning cycle was more effective in bringing about conceptual change and understanding than was a more traditional lecture approach. Campbell (as cited in Lawson,1995) compared the effectiveness of the learning cycle approach to conducting physics laboratory activities plus the personalized system of instruction (PSI) to the more traditional lecture-lab-recitation method of college freshman physics teaching. Campell found the learning cycle and PSI approach to be significantly better than the traditional approach in provoking students to utilize formal reasoning patterns. Students had a more positive attitude and significantly fewer of them dropped out of the learning cycle/PSI course as well. Content achievement was not significant different between the two approaches. Similarly, Davis (as cited in Lawson, 1995) found more positive attitudes and better understanding of the nature of science among fifth and sixth graders in learning cycle classes than in classes using a traditional approach, but there were no differences in content achievement between students who experienced the two approaches. Further, Saunders and Shepardson (as cited in McWhirter, 1998) conducted a study with 115 sixth grade students to compare what they called formal versus concrete instructional strategies. The formal approach was characterized by oral and written language activities whereas the concrete approach was defined according to learning cycle parameters. The study found definite superiority of the learning cycle approach over the formal approach in science achievement.

Further, the summary conducted by Abraham and Renner (1986) supports the contention that the learning cycle approach has many advantages when compared with other approaches to instruction. Some studies in Abraham and Renner (1986)' study is in the following statements.

- Pavelich, and Abraham (as cited in Abraham and Renner, 1986) stated that the learning cycle approach more accurately reflects scientific inquiry processes than traditional approaches
- Abraham (as cited in Abraham and Renner, 1986) indicated that students distinguish the learning cycle approach from traditional approaches in the following ways:
    - The learning cycle approach emphasizes the explanation and investigation of phenomena, the use of evidence to back up conclusions, and the designing of experiments.
    - Traditional approaches emphasize the development of skills and techniques, and receiving of information, and the knowing of the outcome of an experiment before doing it
- Lawson and Renner (as cited in Abraham and Renner, 1986) stated that using the learning cycle approach, formal operational students learn both concrete and formal concepts better than concrete operational students
- Schneider, and Renner (as cited in Abraham and Renner, 1986) indicated that for concrete operational students, the learning cycle approach is superior to traditional approaches in content achievement, and in intellectual development gains.

In examining why the learning cycle approach might be more effective than traditional instructional approaches, one hypothesis is that the learning cycle sequence is more compatible with how students actually learn (Lawson 1988; Odom and Kelly 1998). Actually, one of the important differences between the learning cycle approach and traditional approaches is the sequence of the phases of instruction (Abraham and Renner, 1986). In traditional models of instruction, for instance, the students are first informed of what they are expected to know. Then, some type of proof is offered to the students in order for them to verify that what they have been told or shown is true. Thus, the science laboratory is often used to allow the students to verify that newly acquired information is true. Lastly, the student answers questions, work problems, or engages in some form of practice with the new idea. This inform-verify-practice sequence of phases corresponds roughly to the three instructional phases of the learning cycle with the sequence of the first two phases reversed (Renner, 1982). In light of the foregoing, Abraham and Renner (1986) indicated that the sequence of the phases is the important aspect which contrasts the learning cycle approach with the traditional approach. Then, they hypothesized that altering the sequence should have certain effects on the learning and attitude of students. They altered the sequence of the three phases of the learning cycles in order to give insights into the factors which account for the success of the learning cycle, to serve as an indirect test of the association between Piaget’s theory and the learning cycle, and to compare the learning cycle with traditional instruction. Six sequences of the three phases of the learning cycle are stated and each of the six sequences (one normal and five altered) was studied with content and attitude measures. Six classes of high school chemistry were utilized in the study. The treatments (sequences) were assigned to the six classes at random by drawing lots. In this study, four types of data, collected in order to monitor the effect of the treatments, were class observations and post-activity discussion; case studies; achievement analysis, and attitude analysis. This study provides evidence that the normal learning cycle sequence is the optimum sequence for achievement of content knowledge, confirmed by Renner, Abraham, and Birnie’s (1988) investigations. Moreover, results indicated that the most important phase of the learning cycle when considering the sequence variable is the invention phase. Indeed, the authors determine the key factor to be discussed by the sequence of the phases of the learning cycle as the position of the invention phase. Going from the gathering data to the invention phase is basically inductive in nature, whereas going from the invention to the expansion phase is basically deductive in nature. In 1983, Lott conducted a meta-analysis of 39 studies from 1957 through 1980 to evaluate the effectiveness of inductive versus deductive teaching methods. He found that inductive approaches (i.e., learning cycle approaches) are more effective for intermediate level students, and when greater intellectual demands are placed on students. Similarly, Ivins (1986) found the inductive approach created greater achievement and retention of content. A study by Ivins compared the effect two instructional sequences involving science laboratory activities. One of these used an inductive approach (learning cycle) to instruction and the other used a deductive approach.

Several researchers investigated the necessity for each phase of the learning cycle. The effects of students' missing portions of learning cycles are illustrated in a series of studies investigating high school physics and chemistry learning cycles (Renner et al. 1988, Abraham 1989; Tobin et.al., 1994). By eliminating one or more phases of the learning cycle and then testing the students for science concept understanding, these studies emulate the effects of student absences on learning. Data from these studies showed that all phases of the learning cycle were important for gaining complete understandings of science concepts.

Many of the above cited studies have centered on the effectiveness of the use of learning cycle methodology when compared to traditional methodologies. In addition to these aforementioned studies, some different studies concerning the learning cycle have been conducted. For example, Marek, Askey and Abraham (2000) studied to investigate an alternative procedure for making up missed class work: viewing a video presentation of the missed portions of a learning cycle about density taught in high school chemistry classes. Two treatment groups were selected for the study. Students in the first treatment group completed data sheets while watching a point-of-view videotape of an exploration phase that was a laboratory activity about density, and then they wrote answers to questions posed by the videotaped instructor. This procedure simulated make-up work. Second treatment group of students experienced activities organized within three phases of learning cycle, so they participated in a conventional exploration, class discussions and application activities. In this study, a primary goal of the videotape design was to cause disequilibration in the students followed by the students' eventual reequilibrations and subsequent concept understandings. In this regard, students were required to record predictions and data interpretations by using the printed materials with embedded questions and by using the VCR's pause feature. If they didn't follow these procedures then they couldn't disequilibrate and reequilibrate. Several researchers also supported that if a videotape is to be used as a make-up procedure, it should simulate interaction with the viewer (i.e., Salomon, 1984; Salomon and Leigh, 1984; Cennamo et al., 1990). For instance, Cennamo et al. (1990) stated that the type of questions that needed to be asked during a quasi-interactive video must be at a higher level than simple recall. Otherwise, the viewer comes away from the video experience with very little retainable knowledge. The result of Marek et.al.'s (2000) study indicated that teachers can videotape investigations to conveniently and effectively use as make-up assignments for a chemistry learning cycle. Moreover, the results demonstrated that the sequence of learning cycle activities influenced learning, which supports the findings of other studies previously conducted (i.e., Abraham and Renner, 1986; Renner, Abraham, and Birnie, 1988; Abraham, 1989).

A case study done by Dwyer and Lopez (2001) provides an example of the effective use of simulations in learning cycle lessons for upper and middle school students engaged in environmental studies. The purpose of this case study was to develop, administer, and collect student data on learning cycle lessons that use simulations in all phases of the learning cycle. 14 upper elementary and 17 middle school science students were observed, along with their teacher, using simulations as they engaged in learning cycle lessons revolving around river ecosystem. Data collected included videotaped sessions of students using simulations, teacher journal, student field logs, student concept maps, student and teacher interviews, and products of student activities. The students were assessed for their understanding of concepts during and after completing the learning cycle lessons. It was found that with the specific guidance in simulations such as “Exploring the Nardo,” students perform better.

In addition, some research studies supported that the textbook lessons can be developed into more meaningful learning experiences for students by organizing them to follow the learning cycle or by modifying them to fit this approach (Barman, 1992). In 1992, Barman illustrated the evaluation of a technique that introduces elementary science methods students to the learning cycle and provided them with a mechanism for using this strategy with current elementary science textbooks. This study provides evidence that the technique described in Barman’s study can be one way to help preservice teachers improve their science teaching, and simultaneously, help them in becoming more comfortable with using their textbook as a guide rather than the main component of their science lessons. Moreover, Musheno and Lawson (1999) applied the learning cycle to science text. They wrote two textbook reading passages - one learning cycle and the other traditional- in order to teach the concepts of symbiosis, mutualism, commensalism, and parasitism. They designed the passages as similar as possible except for the structure of the information. Most of the wording in examples used to introduce concepts is identical in each passage; but, the learning cycle passage presents the examples before the terminology and asks questions to help in linking and organizing the information presented. In this study, the learning cycle passage is written with a bottom-up structure; in other words, the lower-order concepts of mutualism, commensalism, and parasitism are presented prior to introducing the higher-order and more abstract concept of symbiosis. Also, questioning, idea linking, and extensions presented after terms are introduced represent the concept application phase in the learning cycle passage. The traditional passage is written with a top-down structure, introducing the higher- order concept of symbiosis before mutualism, commensalism, and parasitism, and presenting terminology before examples and definitions. The authors worked with 123 ninth and tenth grade students attending science classes in two suburban high schools. Students were tested for reasoning ability, and classified as empirical-inductive, transitional, or hypothetical-deductive reasoners. Then, they randomly assigned to read either a learning cycle or traditional text passage. Immediate and delayed posttests provided concept comprehension scores that were analyzed by type of text passage and by reasoning level. The results indicated that students who read the learning cycle passage got higher scores on concept comprehension questions than those who read the traditional passage, at all reasoning levels. This result provides the evidence that reading comprehension and scientific inquiry involve similar information-processing strategies and confirms the prediction that science text presented in the learning cycle format is more comprehensible for readers at all reasoning levels.

Further, Scharman (as cited in Reap 2000) designed a descriptive study to investigate the role of the learning cycle as a tool for identifying and addressing misconceptions. In the study, the necessity of using minds-on as well as hands-on activities in the exploration phase was stressed. Activities described as minds-on included the use of analogies, the formation of opinion statements, and the formation of independent decisions. Moreover, Lawrenz and Munch (as cited in Mcwhiter 1998) studied the impact the small groups on the individual learner within the learning cycle framework. They found homogeneous ability grouping to be the best in terms of student gains in content achievement when compared to heterogeneous ability groups or students chosen groups. This study indicated that students using learning cycle methodology learn best when they interact with others at or near their level of thinking.

In addition, some studies have been done related to understanding of the learning cycle. For instance, Settlage (2000) studied to deepen science teacher educators' knowledge about the process of instilling the learning cycle within the teaching repertoire of elementary education majors.  He worked with students enrolled in typical preservice elementary science methods at an urban university. The results showed that attitudes toward science and teaching efficacy were posited to explain the rate at which students grasped this instructional approach. Moreover, understanding of the learning cycle was found to be predictable by science teaching outcome expectancy but not by personal science teaching efficacy nor attitudes toward science. Also, at the end of the methods, significant increases in both measures of efficacy were discovered and individual efficacy scores course were correlated significantly with scores on the learning cycle instrument. These data revealed that preservice teachers' belief in their ability to shape students' science learning can accurately predict their potential for embracing the learning cycle as a viable teaching approach. In addition, instruction about the learning cycle appears to contribute to the teaching efficacy of preservice teachers.

Hampton, Odom and Settlage (1995) developed The Learning Cycle Test to assess teachers' understanding of the learning cycle and highlights common misconceptions identified through the administration of the diagnostic instrument. This test was administered to 28 undergraduate students enrolled in elementary science methods who had received following instruction on the learning cycle prior to test administration. Students participated in learning cycle lessons modeled by the instructor, developed learning cycle lessons, participated in small group and whole class discussions about the learning cycle, and read and critiqued recent research on the learning cycle. And, as a culminating activity students taught a learning cycle lesson to the class. Results revealed that elementary science methods students continue to have alternative conceptions about the learning cycle after instruction on the learning cycle, and the most common alternative conceptions were centered around the teacher explaining and/or defining the concept prior to or during exploration. This study also revealed that The Learning Cycle Test appears to provide a feasible approach for evaluating students' understanding and for identifying alternative conceptions about the learning cycle.

Marek and Methven (1991) performed a study to investigate the relationship among (1) teacher's attitudes and implementation of in-service workshop developed science materials (learning cycles) (2) elementary school student's conservation reasoning and language used to describe properties of objects. The science in-service workshop of this research was sponsored by the National Science Foundation. The purposes of workshop were for the participants to understand: that science is a search for knowledge and not only the knowledge; that teaching science as a search for knowledge will lead students to construct their own knowledge about the world around them, and how to develop a curriculum (learning cycles) which represents science, allow their students to experience science as a search for knowledge, and is compatible with their student's learning abilities. For the study, data were gathered from over 100 students from grades K-5 and 16 teachers who had participated in an in-service program. Researchers used qualitative and quantitative techniques to examine both the teachers involved in the in-service program and the students of these teachers. A representative comparison group of students and teachers was selected which generally matched the teachers participating in the in-service workshop. The experimental group used learning cycles and the comparison group taught science by exposition. The result showed that the teachers involved in the learning cycle classrooms implemented the workshop-developed learning cycles into their science classes, and they provided their students with many opportunities for coordinating experiences. Furthermore, the conceptual invention allowed the students to develop the logical system by given them the opportunity to invent concepts from data which they had gathered. Also, it is found that the experimental students increased 44% in their conservation reasoning abilities during the school year, while the comparison students had an increase of only 17%. The authors attributed this significant difference in gains of the experimental group to the numerous direct experiences or learning cycles provided for them. They stated that these experiences allowed the students to manipulate objects, observe and record data, interact with their peers and teacher, provide data during discussions from which the concept invented, and use the concept in additional situations with other materials. Moreover, the students of this study in the learning cycle classroom were better able to use property words than their counterparts in non-learning cycle classrooms. Elementary school students in lab-centered science classes were more willing to talk during the structured interviews of this study and therefore achieved higher levels of social transmission, and finally, they experienced science as the discipline is structured and described by scientists.

Marek, Eubanks and Gallaher (1990) investigated the relationships that exist between high school science teachers’ understanding of Piagetian developmental model of intelligence, the learning cycle and classroom teaching practices. All of the teachers in this study employed the learning cycle teaching procedure; however, the extent to which each teacher implemented and practiced the learning cycle differed. They noted that the teachers who exhibited a sound understanding of the Piagetian model of intelligence and the learning cycle were more likely to effectively implement learning cycle curricula. Further, they were able to successfully integrate their students’ laboratory experiences with class discussions to construct science concepts. Although the teachers who exhibited misunderstandings of the Piagetian developmental model of intelligence and learning cycle also engaged their students in laboratory activities, these activities were weakly related to learning cycles. Consequently, the result indicated that the greater the degree of understanding, the greater the skill and facility with the learning cycle teaching procedure.

Some applications of learning cycles to a wide variety of disciplines, including chemistry, have been identified by several researchers (i.e., Herron, J.D. 1975). For example, Libby (1995) defined the application of the Piaget-based learning cycle technique for teaching introductory organic chemistry course and the step-by-step process used to convert his lecture course into a discussion-based active course. Moreover, Guymon, James and Seager (1986) developed an exercise termed “R and R” (rectangles and rulers) as a learning cycle to help students to establish the rules for using significant figures for themselves. This exercise included students in making measurements which helps them relate the use of significant figures to laboratory experiences. The data collected in the pre- and post- test indicated that R and R is at least as effective as the traditional approach to teaching significant figures. In his introductory ecology course, Lauer (2003) used games and simulations, which follow the three-phase learning cycle concept of instruction. For example, to teach population ecology he used a maze puzzle during the exploration phase and then the teacher briefly explained the population ecology in term application phase and finally students were forced to find other examples to population ecology. He suggested that any game with competitive interaction could be used in this activity. The main purposes of using classroom games were to promote the understanding and comprehension of particular terms, and to break up the monotony and drudgery of a long lecture. Although the evaluation of these methods did not do formally in class, anecdotal assessment using test scores and student response reported as positive. And, he noted that students remembered these games and simulations, and learned without a perceived effort.

In 1981, James and Nelson also have developed learning cycles for use in the classroom. They noted several benefits of using learning cycles. For instance, there is more communication in the classroom and the instructor becomes more aware of students difficulties and misconceptions. Reasoning skills seem to be strengthened. Students become active participants in a class and are more involved with the subject matter. Also, Hemler and King (1996) redesigned their approach and used the learning cycle technique to meaningfully teach their students to understand mineral properties while alleviating the tedious nature of identifying mineral specimens. Consequently, they stated that students no longer leave the classes with a negative attitude toward mineral identification. Finally, Mueler (1982) applied the learning cycle approach in an organic chemistry laboratory program. His comparison is drawn between students from the previous lab program and the current program and is subjective. In the study, the program appears to be successful and the choice of the learning cycle format appears to have been appropriate.

Several studies listed the strengths and weaknesses of learning cycle science curricula. For instance, Bryant and Marek (1987) identified the strengths of learning cycle science curricula as (1) greater student involvement in the learning process, (2) more enjoyable and stimulating classes, (3) thorough understanding of the science concepts and (4) more critical thinking by the students. And they reported the weakness as the lack of vast content coverage. In a similar study (Westbrook, and Bryant, 1989), classroom observations of teachers indicated that learning cycle teachers spent up to 90% of class time each week actively involved with their students in laboratory investigations or the discussion of these investigations. In contrast observation of non-learning cycle teachers implied that as little as 7% of class time was spent each week engaged in classroom activities with their students.

A few researchers have considered a revised learning cycle (i.e., Good, 1989; Barman, 1997; Lavoie, 1999; Blank, 2000). Good and Lavoie investigated the effects of adding the prediction step to the SCIS Learning Cycle. Good (as cited in Blank, 2000) probed whether the addition of predictions at the beginning of the learning cycle, with feedback loops among the three stages, could better assess misconceptions held by the students and increase student involvement in the exploration and dialogue. The result indicated that using student prediction sheets resulted in teachers and students becoming more aware of student misconceptions, and in students becoming more involved in the class discourse. Similarly, Lavoie (1999) searched the effects of adding a prediction/discussion phase at the beginning of a three-phase learning cycle involving exploration, term introduction, and concept application. The intent was to determine the power of the added phase and develop useful guidelines for effective classroom instruction with prediction/ discussion-based learning cycles. The added phase required high-school biology students to individually write out predictions with explanatory hypotheses concerning concepts in genetics, homeostasis, ecosystems, and natural selection. This was followed by interactive debate of predictions and reasons. Five tenth grade science teachers, who had previous experience with learning-cycle instruction, were each selected to teach one prediction/discussion-based learning cycle biology class and one traditional learning cycle biology class for an entire semester. For this study, data sources were questionnaires, field observations, teacher/researcher daily log reports, and a battery of tests to assess cognitive changes. The finding indicated that the prediction /discussion-based learning cycle instruction, when compared with traditional learning cycle instruction, achieved significantly greater gain scores for science process skills, logical-thinking, science concepts, and scientific attitudes.

Barman (1997) stated another modified version for the SCIS Learning Cycle. He suggested that the SCIS Learning Cycle model does not include a specific component to reveal prior knowledge because it’s originated before misconception research. His four-phase model is the same as the SCIS model with the exception that teachers make students’ conceptions of science concepts explicit before instruction begins (Blank, 2000). Blank (2000) stated that no work has examined the effectiveness of incorporating a metacognitive component within the learning cycle, in which students intentionally reflect on their science ideas. And, she proposed a revised learning cycle model, called the Metacognitive Learning Cycle, which emphasizes formal opportunities for teachers and students to discuss their science ideas. Working collaboratively, the researcher and a seventh-grade science teacher developed a 3-month ecology unit based on the revised model. Two science classrooms studied identical ecology content using different pedagogical orientations. One class was taught using the Science Curriculum Improvement Study Learning Cycle (SCIS) approach and one was taught using the Metacognitive Learning Cycle (MLC) approach. Only in the metacognitive classroom were students asked to reveal their science ideas and to discuss the status of their conceptions throughout the instruction. Results showed that students in the metacognitive classroom did not gain a greater content knowledge of ecology, but the author stated that students in the metacognitive classroom may have more successfully accommodated the ideas of ecological processes into their long-term memory because of the formal metacognitive instruction. Further, the other major finding of this study was that student dialogue differed across the two classrooms. The MLC discussions were particularly engaging and thoughtful.

Moreover, as the learning cycle has been used, researched, and refined over the years, some practitioners have extended the three stages SCIS learning cycle into five, known as the 5E learning cycle, then into seven (7Es) (Trowbridge et al. 2000).

Bybee et.al. (2006) probed the commonalities between the SCIS learning cycle and the BSCS 5E Instructional Model. They indicated that the theory underlying both models views learning as dynamic and interactive. Individuals redefine, reorganize, elaborate, and change their initial concepts through interaction with their environment, other individuals, or both. In brief, the students' construction of knowledge can be assisted by using sequences of lessons designed to challenge current conceptions and provide time and opportunities for reconstruction to occur Bybee et.al. (2006). In our study, 5E Learning Cycle Model, developed by Biological Science Curriculum Study (BSCS) (Bybee, 1997), was selected because of its connections to constructivism and conceptual change.

### 2.4 5E Learning Cycle Model

The 5E instructional model was developed in the late 1980's as a component of the Science for Life and Living curriculum created through the Biological Sciences Curriculum Study (BSCS) (Bybee and Landes, 1990). This model is rooted in constructivism and it is accepted as an instructional approach that supports inquiry-based science learning in a classroom setting (Bybee and Landes, 1990; Wilder and Shuttleworth, 2005). The main objective in a constructivist program is to challenge students' current conceptions by providing data that conflict with students' current thinking or experiences that provide an alternate way of thinking about objects and phenomena (Bybee and Landes, 1990). To this end, the 5E model meets these conditions for conceptual change by having students redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment (Bybee, 1997). Since its 1980's, BSCS has used 5E Instructional Model extensively in the development of new curriculum materials and professional development experiences. The "Five E" Learning Cycle model consists of five phases called as; Engagement, Exploration, Explanation, Elaboration and Evaluation, and each phase has a specific function and contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills (Bybee et.al., 2006).

The engagement phase is used to motivate students by creating some mental disequilibrium or tapping into familiar real–life situations. Typically, this is done with activities, demonstrations, or stories that grab students' attention and help them make connections between the new information and the world they know. Asking questions and posing a problem may be included in the engagement activities. Here, the word "activity" refers to both mental and physical activity. The instructor's role in this phase is to raise questions and problems, create interest, generate curiosity, and elicit responses that uncover students' current knowledge (Bybee, 1997; Carin and Bass, 2000). This phase also give a good opportunity for the teacher to identify students' misconceptions. Quite possibly, this is the most critical phase of the model; if the material is not presented well, students may not make the necessary associations to fully interact with the topic and the remaining phases become meaningless (Campbell, 2000).

Once students are engaged in the learning tasks, exploration activities follow. Indeed, engagement phase brings about disequilibrium, and exploration initiates the process of equilibration (Bybee et.al., 2006). Exploration activities are designed so that the students in the class have common, concrete experiences upon which they continue formulating concepts, processes, and skills (Bybee, 1997). During the Exploration stage, the teacher should facilitate safe, guided or open inquiry experiences and questioning so students might uncover their misconceptions about the concept (Bybee, 1993; Wilder and Shuttleworth, 2005). Also, students should be given opportunities to work together without direct instruction from the teacher. This is the opportunity for students to test predictions and hypotheses and/or form new ones, try alternatives and discuss them with peers, record observations and ideas and suspend judgment. In this phase, students interact directly with the material, concepts, or phenomenon. The teacher's role during this phase is that of a facilitator as he/she encourages cooperative group discussions by asking guiding questions and serves as a resource for students. In a study conducted by Lindgren and Bleicher (2005) preservice teachers who were learning the learning cycle found this stage to be central to the process as they were able to "explore, discover, investigate, and act like a scientist" during this phase. Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.

The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase provides opportunities for teachers to directly introduce a concept, process, or skill. Most teachers recognize the explain phase as "lecturing" or interactive discussion, where teachers give students information they may not be able to glean on their own. At the beginning of the explanation phase, students are encouraged to provide their explanations from events during the explore phase (Bybee, 1997). Students should use observations and recordings in their explanations. In addition to simply providing their own thoughts, students are also expected to listen critically to other students' explanation and those of the teacher. At this stage teacher help students understand scientific explanations and introduce terminology to provide students with a common language about the content (Bybee, 1993). The teacher connected the scientific explanation with the physical evidence from exploration and engagement and relates it to the explanations that the children have formed. Here, verbal methods are mostly used, but the teacher might also use videos, books, multimedia presentations, and computer courseware. This phase continues the process of mental ordering and provides terms for explanations. In the end, students should be able to explain exploratory experiences and experiences that have engaged them by using common terms.

In the elaboration phase students are encouraged to extend their understanding of a scientific concept past what they have experienced through the previous three phases. During this phase, students should apply concepts and skills in new, but similar situations and use formal labels and definitions. Remind students of alternative explanations and to consider existing data and evidence as they explore new situations. Bybee (1997) stated the primary goal of the elaboration phase as the generalization of concepts, processes, and skills. To achieve this goal, additional problems are given to students, which allow them to apply their new knowledge, propose solutions, make decisions and/or draw reasonable conclusions, and teacher encourages students to use formal science terms as they complete related activities and identify alternative ways to explain phenomena. Those who still hold misconceptions or have not yet achieved dissatisfaction with their current ideas may be able to clarify their perceptions through this extension of learning (Bybee, 1997). In brief, the elaboration phase of the 5E model allows students to apply knowledge they have gained to new situations so they can expand their conceptual understanding and skills (Bybee, 1993).

The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives. Although evaluation presented as a final stage of the 5E model, it should take place at each stage of the instructional unit. Evaluations should focus on students' conceptual understandings, skills development or other learning outcomes.  This may be done formally or informally. Appropriate assessment strategies might include performance assessments, evaluation of drawings or physical models made by students, interviews with groups of students or individuals; creative writing exercises using science concepts, creation of concept maps by students, or examination of student laboratory notebooks or portfolios. To sum up, this phase is essential to determine if students obtained a scientifically correct understanding of the concept and if they were able to generalize to other contexts. Students should assess their own learning. Table 1 showed the salient characteristics of each stage of the 5Es. To develop this table, we benefited by several studies (Carin and Bass, 2000; Bybee et.al., 2006).

**Table 2.1** The characteristics of each stage of the 5Es

| PHASES | 5E Instructional Model | | |
|---|---|---|---|
| | **What the Teacher Does** | **What the Student Does** | **Suggested Activities** |
| **ENGAGEMENT** | - Creates interest<br>- Generates curiosity<br>- Raises questions<br>causes disequilibria or doubt<br>- Elicits responses that uncover what the students know or think about the concept or topic (i.e., misconceptions) | - Asks questions (Why did this happen? What can I find out about this?<br>- Shows interest in the topic<br>- Calls up prior knowledge<br>- Experiences disequilibria<br>- Identifies problems to solve | - Demonstration<br>- Reading from a current media release, science journal or book<br>- Free write<br>- Analyzing a graphic organizer |
| **EXPLORATİON** | - Encourages students to work without direct instruction from the teacher<br>- Observes and listens to students as they interact<br>- Asks probing questions to redirect students' investigations when necessary<br>- Provides time for students to puzzle through problems.<br>- Acts as a consultant for students<br>- Creates a "need to know" setting | - Thinks freely, but within the limits of the activity.<br>- Tests predictions and hypotheses.<br>- Forms new predictions and hypotheses<br>- Tries alternatives and discusses them with others.<br>- Records observations and ideas.<br>- Suspends judgment<br>- Asks related questions | - Reading authentic resources to collect information for answer to an open-ended question<br>- Solve a problem<br>- Construct a model<br>- Investigation |
| **EXPLANATION** | - Encourages students to explain concepts and definitions in their own words<br>- Asks for justification and clarification from students.<br>- Formally provides definitions, explanations and new labels.<br>- Uses students' previous experience as the basis for explaining concepts<br>- Assesses students' growing understanding | - Explains possible solutions or answers to the others.<br>- Listens critically to one another's explanations.<br>- Questions others explanations.<br>- Listens to and tries to comprehend explanations offered by the teacher.<br>- Refers to previous activities.<br>- Uses recorded observations in explanations.<br>- Assesses own understanding | - Student analysis and explanation<br>- Supporting ideas with evidence<br>- Structured questioning<br>- Reading and discussion<br>- Teacher explanation<br>- Thinking skills activities |

**Table 2.1** (Continued)

| | | | |
|---|---|---|---|
| ELABORATİON | - Expects students to use formal labels, definitions, and explanations provided previously.<br>- Encourages students to apply or extend the concepts and skills in new situations.<br>- Reminds students of alternative explanations<br>- Refers students to existing data and evidence and asks: “What do you already know?” “Why do you think…?” | - Applies new labels, definitions, explanations, and skills in new, but similar, situations<br>- Uses previous information to ask questions, propose solutions, and make decisions, design experiments.<br>- Draw reasonable conclusions from evidence.<br>- Records reasonable conclusions from evidence.<br>- Records observations and explanations.<br>- Checks for understanding among peers | - Problem solving<br>- Decision-making<br>- Experimental Inquiry<br>- Thinking Skill activities |
| EVALUATİON | - Observes students as they apply new concepts and skills.<br>- Assesses students' knowledge and/ or skills.<br>- Looks for evidence that students have changed their thinking or behaviors.<br>- Allows students to assess their own learning and group process skills.<br>- Asks open-ended questions, such as: “Why do you think….?”, “What evidence do you have?”, How would you explain?” | - Answers open-ended questions by using observations, evidence, and previously accepted explanations.<br>- Demonstrates an understanding or knowledge of the concept or skill.<br>- Evaluates her own progress and knowledge.<br>- Asks related questions that would encourage future investigations. | - Any of the above<br>- Development and implementation of scoring tool to measure student performance during activity.<br>- Involvement of students will allow students to set high standards for performance |

Studies show that 5E Learning Cycle approach had a positive effect on students understanding (i.e., Colburn and Clough, 1997; Bevenino, Dengel and Adams, 1999; Lord, 1999; Coulson, 2002), scientific reasoning (Boddy and Aubusson, 2003) and attitudes toward science (Boddy and Aubusson, 2003; Akar, 2005). For example, Lord (1999) conducted a study that compared two classes taught by traditional methods with two classes taught with 5E Learning Cycle method. 5E Learning Cycle method used involved small heterogeneous groups who worked on thought-provoking scenarios and critical thinking questions or constructed concept maps. The results indicated that the experimental groups had much greater understanding of the information covered especially on questions that required interpretation. Also, a significant difference was found in the feedback from the students. Most of the experimental group students wrote positive comments about the course. However, about half of the students in the control group only wrote any response, and of the comments that were written few were positive.

Akar (2005) compare the effectiveness of 5E learning cycle model over traditionally designed chemistry instruction on students' understanding of acid-base concepts. The subjects for this study were 56 tenth grade students from two classes of a chemistry course. The classes were randomly assigned as control and experimental groups. Students in the control group were instructed by traditionally designed chemistry instruction whereas students in the experimental group were taught by 5E learning cycle model. The results showed that 5E learning cycle model caused a significantly better acquisition of scientific conceptions related to acid-base and produced significantly higher positive attitudes toward chemistry as a school subject than the traditionally designed chemistry instruction. In addition, she found that science process skill was a strong predictor in understanding the concepts related to acid-base.

Campbell (2000) investigated the fifth grade students' understanding of force and motion concepts as they engaged in inquiry-based science investigations through the use of the 5E Learning Cycle. Initially, pretest was applied to students to assess their understanding of force and motion concepts. Then, students participated in investigations related to force and motion concepts. Their subsequent understanding of these concepts and their ability to generalize their understandings was evaluated by a posttest. In addition, a review of lab activity sheets, other classroom-based assessments, and filmed interviews were used to draw conclusions from the study. Findings showed that student knowledge of force and motion concepts did increase although their understanding as demonstrated on paper lacked completeness versus understanding in an interview setting. Survey results also showed that after the study students believed they did not learn science best via textbook-based instruction.

Balci, Cakiroglu, and Tekkaya (2006) probed the effects of three types of instruction, the 5E learning cycle method, the conceptual change text instruction method, and traditional instruction, on eighth grade students' understanding of photosynthesis and respiration in plants. Three classes including 101 students were involved in the study. Students in all groups were exposed to same content for the same duration. The three classes were instructed by the same science teacher. The instructional methods were randomly assigned to the classes. In their study, there are two experimental groups and one control group. The first experimental group ($n$=33) instructed with the 5E learning cycle method. The second experimental group ($n$ = 34) was instructed with the conceptual change text instruction method. The control group ($n$ = 34) was instructed with the traditional instruction method. The authors used two instruments to collect data: a Photosynthesis and Respiration in Plants Concept test and an Attitudes Scale toward Science as a School Subject test. The finding of the present study seem to imply that both the 5E learning cycle method and the conceptual change text instruction method caused a significantly better acquisition of scientific conceptions related to photosynthesis and respiration in plants than traditional instruction. However, no statistically significant difference between two experimental groups (5E versus conceptual change text instruction) was noted. Consequently, this study provides evidence that teacher-centered and textbook-oriented science instruction fail to improve students' conceptual understanding and leave many misconceptions unchanged. To promote meaningful learning, it is necessary to overcome misconceptions with the help of different instructional methods rather than the traditional one.

Caprio (1994) conducted a study that compared a class which he taught with traditional methodology in 1985 to one in which he taught with 5E Learning Cycle method in 1994. The students in both groups had the same prerequisites, and the same exam was used for comparison. The exam grades were much higher for the class taught via the constructivist methodology. The research was carried out with an experiment and control group design. The control (traditional) group's average grade was 60.8 percent, while the experimental (5E Learning Cycle) group averaged 69.7 percent. In addition, the results indicated that the experimental group had a high energy level and gave positive feedback on the course.

Another comparative study by Garcia (2005) was conducted with 160 seventh-grade life science students. Garcia (2005) compared the effect of the 5Es learning cycle with the traditional approach to teaching evolution on student learning and attitudes .Data from the post-test scores indicated that the treatment groups did not show a statistically significant difference in understanding evolution or in attitudes towards the subject of science. However, paired pre-test and post-test evolution score comparison show a significant change, indicating that the test measure detected learning for both treatment groups. As a result, the author suggested that there is a need for better evolution learning activities and the 5Es model merits further research because of some positive improvements on lower scoring students.

Apart from the comparative ones, researchers have conducted some studies concerning the 5E learning cycle. For example, Withee and Lindell (2005) designed a survey to determine Science and Mathematics methods course instructors' views on inquiry, as well as to explore the success and difficulties associated with teaching this difficult concept. Furthermore, because many reforms to the "5E's" exist, the authors surveyed the instructors' views on the "5E's" in order to obtain a relationship between their views on inquiry and the inquiry-based methods they teach. Also, by investigating these instructors' views on inquiry, the authors hope to discover why so many in-service and preservice teachers appear to have such diverse methods of implementing inquiry with varying degrees of success. Five science and mathematics educators participated to the study. The first phase of this study consisted of an open ended survey, designed to elicit the educators views on what inquiry is, how inquiry is related to conceptual change, and their views on the "5E's" method. After initial analysis, the authors determined four major themes: Views on conceptual change, views on inquiry, inquiry in practice and views on the “5E’s”. In conclusion, the methods course instructors expressed several strengths of inquiry as a method of instruction but at the same time had several comments about the difficulties in implementing the “5E’s” method. Furthermore, surveyed course instructors stated different view of the term inquiry than the National Research Council (1996), and they agreed that there is no one prescribed method that works in all situations. When analyzing the survey responses, two of the instructors responded they were unfamiliar with the “5E’s” method. Despite this, all five responding surveys demonstrated some understanding of the phases of the “5E’s” as defined by the BSCS. Briefly, the methods instructors’ overall opinion of the “5E’s” was that it is a convenient tool to construct inquiry based lessons. Also, they stated the “5E’s” are a “well prescribed method for enacting conceptual change” and the method “naturally lends itself to use of inquiry”. Moreover, the surveyed instructors stated several important views when asked about the weaknesses of the “5E’s”. These were:

- It is not always easy to clearly separate the stages.
- An instructor may be fixed on a particular interpretation of the phase.
- There is a linear sequential flow to what is inherently a cyclic and recursive process.
- It is difficult to keep the class on the desired track while validating the student’s desire to explore.
- There can be an abrupt disjunction when the course progresses to the next objective.
- One form or model is never good in all situations.

MaryKay and Megan (2007) suggested that analogies can be useful instructional tools in each phase of the 5E model. In their article, they briefly described the phases in the 5E model and provided suggestions for using analogies in each phase.

Coulson (as cited in Bybee et.al., 2006) explored how varying levels of fidelity to the BSCS 5E model affected student learning. Coulson found that students whose teachers taught with medium or high levels of fidelity to the BSCS 5E Instructional Model experienced learning gains that were nearly double that of students whose teachers did not use the model or used it with low levels of fidelity.

Eisenkraft (2003) supported that 5E learning cycle model should be expanded to a 7E model, and described the 7E model in his study. In 7E model, engage element expands into two components—elicit and engage. Similarly, the 7E model expands the two stages of elaborate and evaluates into three components— elaborate, evaluate, and extend. He stated that 7E model are not suggested to add complexity, but rather to ensure instructors do not omit crucial elements for learning from their lessons while under the incorrect assumption they are meeting the requirements of the learning cycle. He indicated that this enhancement should not be rejected because also highly successful 5E learning cycle model is itself an enhancement of the three-phrase learning cycle.

One dilemma that science teachers face every day is to balance helping the students learn all the content while providing them opportunities for inquiry. Also, the recent literature on learning verifies that students learn by being involved in meaningful inquiry experiences. However, they do not mention whether students learn enough content to be successful on the state mandated tests (Wilder and Shuttleworth, 2005). Wilder and Shuttleworth (2005) suggested that using the 5E learning cycle model is an effective, realistic way to address this dilemma. Also, they stated that this instructional sequence structures inquiry while addressing specific content.

### 2.5 Nature of Science

The objective of helping students develop adequate understandings of nature of science continues to be advocated widely as a desired outcome of science teaching

(Lederman, 1992; McComas, Almazroa, and Clough, 1998; Abd-El-Khalick, 2000; Saunders, 2001), and also it has recently been reemphasized in the major reform efforts in science education (American Association for the Advancement of Science, 1990, 1993; National research Council, 1996). Indeed, although there is no consensus exists around the world concerning the content of science curricula, or concerning the most desirable methods of delivering their content, there is a strong agreement on the importance of understanding the nature of science (Tsai, 1999; Tairab, 2001).

The understanding of the nature of science is thought to be imperative for future citizens (Smith and Scharmann, 1999; Erdoğan, 2004). Future citizens in a democracy need to have a very fundamental knowledge of the nature of science in order to participate in intelligent debate and decision-making with respect to the many social issues arising from science and technology (Saunders, 2001). It is acceded that in order to grasp the role of science in society, and to be intelligent decision makers in democracy, students need to acquire a meaningful understanding of the nature of science (Collette and Chiappetta, 1984; cited in Saunders 2001). Moreover, developing an understanding of the nature of science is a key element to achieving scientific literacy (American Association for the Advancement of Science, 1990; NRC, 1996; Bybee, 1997; Hand et. al., 1999; Meichtry, 1999; Bell and Lederman, 2003). This outcome is also widely advocated by science educators (Bybee et. al., 1991, Boujaoude, 1995). Because, a scientifically literate individual is commonly portrayed as one who makes informed decisions within a science/technology context by drawing upon their rich scientific knowledge, such as an understanding of the concepts, principles, theories, and processes of science (Abd-El-Khalick, Bell and Lederman, 1997). Indeed, the achievement of scientific literacy for individuals is viewed by many science educators as the educational solution to the many economical, social, and environmental challenges of the 21st century (Eisenhart et al. 1996).

There are no consensus presently exists among philosophers of science, historians of science, scientists, and science educators on a specific definition for nature of science (Cleminson, 1990, Slezak 1994, Lederman 1995; Alters 1997; Craven III, Hand and Prain, 2002). Such disagreement, however, should not be surprising given the multifaceted, complex, and dynamic nature of the scientific endeavor (Abd-El-Khalick, 2000). According to Abd-el-Khalick, Bell and Lederman (1998), the phrase “nature of science” typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge. Also, McComas, Clough, and Almazroa (1998) stated that the nature of science is a fertile hybrid arena including the history, sociology, and philosophy of science combined with research from the cognitive science such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors. The intersection of the various social studies of science is where the richest view of science is revealed for those who have but a single opportunity to take in the scenery (McComas, Clough, and Almazroa, 1998).

Different aspects of nature of science are emphasized by different science curricula and science standards documents, although commonalities do exist (Tao, 2003). Science education efforts (i.e., Ryan and Aikenhead, 1992; American Association for the Advancement of Science, 1993; National Research Council, 1996; Matthews, 1998; Millar and Osborne, 1998; Lederman 1998; Osborne et.al., 2003) present descriptions of nature of science that include common generalities and pose little disagreement according to current philosophical perspectives (Schwartz and Lederman, 2008). Chief among these is that scientific knowledge, including “facts,” “theories,” and “laws,” is tentative. Reasons for this stem from several other aspects, such as (a) scientific knowledge has a basis in empirical evidence, (b) empirical evidence is collected and interpreted based on current scientific perspectives as well as personal subjectivity due to scientists’ values, knowledge, and prior experiences, (c) scientific knowledge is the product of human imagination and creativity, and (d) the direction and products of scientific investigations are influenced by the society and culture in which the science is conducted (Schwartz and Lederman, 2002). Common aspects of nature of science are also explained as following by Lederman, Abd-El-Khalick, Bell and Schwartz (2002);

*The Empirical Nature of Scientific Knowledge:* Science at least partially based on observations of the natural world, but scientists do not have direct access to most natural phenomena. Observations of nature are always filtered through our perceptual apparatus and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie functioning of scientific instruments.

*Observations, Inference, and Theoretical Entities in Science:* Students should be able to know the differences between observation and inference. Observations are descriptive statements about natural phenomena that are directly accessible to the senses and about which observes can reach consensus with relative ease. Inferences, by contrast, are statements about phenomena that are not directly accessible to the senses.

*Scientific Theories and Laws:* Closely related to the distinction between observation and inference is the distinction between scientific theories and laws. In general, laws are descriptive statements of relationships among observable phenomena. In contrast, theories are inferred explanations for observable phenomena or regularities in those phenomena.

*The Creative and Imaginative Nature of Scientific Knowledge***:** The development of scientific knowledge involves making observations of nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not a lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. This aspect of science, coupled with its inferential nature, entails that scientific entities such as atoms and species are functional theoretical models rather than faithful copies of reality.

*The Theory-Laden Nature of Scientific Knowledge***:** Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mindset that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they interpret their observations.

*The Social and Cultural Embeddedness of Scientific Knowledge***:** Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded.

*The Tentative Nature of Scientific Knowledge*: Scientific knowledge is subject to change. Scientific claims change as new evidence, made possible through advances in thinking and technology, is brought to bear on these claims, and as extant evidence is reinterpreted in the light of new theoretical advances, changes in the cultural and social spheres, or shifts in the directions of established research programs.

Clough (2000) also stated some ideas for helping students better understand the nature of science. These ideas are elaborated below:

- Science is not the same as technology
- A universal scientific method does not exist
- Science is not completely objective
- Knowledge is not democratic
- Words used in science may not mean what students think they do
- Science is bounded
- Anomalies do not always result in rejection of an idea
- Scientific thinking often departs from everyday thinking

A number of studies documented the incorrect ideas about the nature of science (Rubba, Horner, and Smith, 1981; Rowell and Cawthron, 1982; Ryan and Aikenhead, 1992). For instance, McComas (1998; cited in Erdoğan 2004) investigated the myths about the nature of science as indicated below:

- Hypotheses become theories that in turn become laws.
- Scientific laws and other such ideas are absolute.
- A hypothesis is an educated guess.
- A general and universal scientific method exists.
- Evidence accumulated carefully will result in sure knowledge.
- Science and its methods provide absolute proof.
- Science is procedural more than creative.
- Science and its methods can answer all questions.
- Scientists are particularly objective.
- Experiments are the principal route to scientific knowledge.
- Scientific conclusions are reviewed for accuracy.
- Acceptance of new scientific knowledge is straightforward.
- Science models represent reality.
- Science and technology are identical.
- Science is a solitary pursuit

Grasping the nature of science is critical because the significant misunderstandings that both students and teachers hold regarding the nature of science are particularly affect students' attitudes toward science and science classes, and that clearly has an impact on student learning and the selection of further science classes (Clough, 2000). According to McComas, Clough, and Almazroa (1998), a better understanding of scientists and the scientific community will enhance; an understanding of science's strengths and limitations; interest in science and science classes; social decision making; instructional delivery; and the learning of science content.

Although an understanding of the nature of science is considered to be one of the primary goals of science education during this century, efforts to integrate an authentic view of the nature of science into the curriculum have often met with little success (Lederman, 1992; Rudolph, 2000; Akerson, Abd-El-Khalick and Lederman, 2000). Lederman (1992) presented a comprehensive review of researches related to the nature of science, and he noted that these researches were conducted along four related, but distinct, lines. These lines were: (a) Assessment of student conceptions of the nature of science; (b) development, use, and assessment of curricula designed to 'improve' student conceptions of the nature of science; (c) assessment of, and attempts to improve, teachers' conceptions of the nature of science; and (d) identifications of the relationship among teachers' conceptions, classroom practice, and students' conceptions (Lederman 1992).

In this study, we investigated Turkish students' understanding of nature of science. In Turkey, understanding of the nature of science as one of the most important aspect of science teaching, have not been investigated enough yet (Erdogan, 2004). According to Third International Mathematics and Science Study (1999, cited in Erdoğan 2004), the emphasis given on to nature of science in Turkey evaluated as moderate (Erdogan, 2004).

In literature, research has shown that students typically have not acquired valid understandings of the nature of science (i.e., Broadhurst 1970; Aikenhead 1973; Rubba et al. 1981; Lederman and O'Mally 1990; Tamir and Zohar 1991; Alters 1997; Lederman, 1999). Students' naive conceptions of the nature of science were attributed, at least in part, to learners' lack of experience conducting scientific investigations (Welch et al., 1981; Gallagher, 1991). Further, Saunders (2001) suggested that what students learn about the nature of science is a result of the experiences they have in their science classes. If the emphasis is upon memory of science content, they will conclude that science is the study of truth or immutable laws. If the emphasis is upon data collection (lab work) and the tentative, inductive inferences which can be drawn from the data, they may conclude that science is a continuously changing body of explanations based upon empirical data. Specially, Matthews (1998) argues that practices in the classroom should aim to have students develop an interest in the nature of science by exploring appropriate epistemological questions that empower them to think more critically. However, science instruction and evaluation consists largely of lecture, rote memorization, and objective tests. To require science students to memorize the steps in the scientific method seems to be the ultimate hypocrisy (Saunders, 2001).

There are several instruments that have been developed to assess the views on nature of science (i.e., Cooley and Klopfer, 1961; Billeh and Hasan, 1975; Meichtry, 1992; Alridge, Taylor and Chen, 1997; Tairab, 2001; Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). In our study, we used “Views on Science-Technology-Society (VOSTS) developed by Aikenhead, Ryan and Fleming (1989) to examine students’ understanding of the nature of science.

In the literature, the studies conducted to assess students’ views were performed in several levels of education; from primary school level to university level (Kang, Scharmann and Noh, 2005). Some studies investigating students’ views on the nature of science have focused on middle school (i.e., Carey et al., 1989; Songer and Linn, 1991), high school (i.e., Ryan and Aikenhead, 1992; Griffiths and Barman, 1995; Moss, Abrams, and Robb, 2001), and college levels (i.e., Schoneweg-Bradford, Rubba, and Harkness, 1995; Dagher and BouJaoude, 1997; Ryder and Leach, 1999). Also, a few studies were conducted to examine younger students’ understanding of the nature of science (i.e., Smith et al., 2000).

Moss (2001) conducted a study to investigate pre-college students’ understandings of the nature of science and to track those beliefs over the course of an academic year. Students’ conceptions of the nature of science were examined using a model of the nature of science developed for use in this study. The model has eight tenets which address both the nature of the scientific enterprise and the nature of scientific knowledge. Results from his study indicated that participants generally held fully formed notions of the nature of science consistent with approximately one-half of the premises set out in the model. Students held more complete understandings of the nature of scientific knowledge than the nature of the scientific enterprise. Also, it is observed that students' conceptions remained mostly unchanged over the year despite their participation in the project-based, hands-on science course.

Another study by Tao (2003) was conducted to elicit junior secondary students' understandings of nature of science and to investigate how students reacted to the science stories in the peer collaboration setting. The results show that many students held a serendipitous empiricist view of experimentation and took scientific theories as absolute truth representing reality. Although the science stories impacted on students in substantial ways and the peer collaboration setting helped them develop shared understandings, many students changed from one set of inadequate views of nature of science to another rather than to adequate views. The author attributed this result to students interpreting the stories in idiosyncratic ways other than those intended by the instruction and focusing their attention selectively on certain aspects of the stories that appeared to confirm and reinforce their inadequate views.

Sadler (2004) also examined student conceptualizations of the nature of science (NOS) and how students interpret and evaluate conflicting evidence regarding a socioscientific issue. A total of 84 high school students enrolled in the study by reading contradictory reports about the status of global warming and responding to questions designed to elicit ideas pertinent to the research goals. Additionally, a subsample of 30 students was interviewed in order to triangulate data from the written responses. The participants displayed a range of views on three distinct aspects of the nature of science: empiricism, tentativeness, and social embeddedness. Qualitative methodological approach was used to analyze. Results of this study revealed that interpretation and evaluation of conflicting evidence in a socioscientific context is influenced by a variety of factors related to the nature of science such as data interpretation and social interactions including individuals' own articulation of personal beliefs and scientific knowledge.

Kang, Scharmann and Noh (2005) argued that there exist needs to examine students' epistemological views, to diagnose their understanding, and to reveal their alternative frameworks about the nature of science before implementing any new curriculum/instruction intended to develop students' understanding of the nature of science. In their study, the authors first explored and characterized 6th-grade students' views on the nature of science through the use of a large-scale survey. Another purpose of their study was to compare students' views on the nature of science across grade levels and to examine the relationship between students' views on the nature of science and their school science experiences. The final focus of this study was to characterize potential notable similarities and differences between the respective views on nature of science possessed by Korean students and students of Western countries. In this study, a total of 1702 Korean 6th, 8th, and 10th graders took an empirically derived multiple-choice format questionnaire. The questionnaire consisted of five items that respectively examined students' views on five constructs concerning the nature of science: purpose of science, definition of scientific theory, nature of models, tentativeness of scientific theory, and origin of scientific theory. Students were also asked to respond to an accompanying open-ended section for each item in order to collect information about the rationale(s) for their choices. Their results seem to imply that the majority of Korean students possessed an absolutist/empiricist perspective about the nature of science. It was also found that, on the whole, there were no clear differences in the distributions of 6th, 8th, and 10th graders' views on the nature of science. In some questions, distinct differences between Korean students and those of Western countries were found.

Marx, Mian and Pagonis (2005) investigated general science students' attitudes regarding the acquisition of scientific knowledge and the nature of science. 32-item attitudinal survey was administered to about 250 students from nineteen sections of three general science courses. The authors identified the instructional styles for each course using three broad categories: Traditional, Transitional, and Learning-centered. Then, they investigated the impact those different instructional styles had on students' epistemological beliefs. Overall, no appreciable gain in attitudes was determined. Also, looking at the three instructional styles independently, the authors observed no real improvement for the Transitional and Learning centered courses.

Zeidler, Walker, Ackett, and Simmons (2000) examined the relationships between students' conceptions of the nature of science and their reactions to evidence that challenged their beliefs about socio-scientific issues. The sample of the study was 41 pairs of students that were drawn from a larger sample of 248 students from 9th and 10th grade general science classes, 11th and 12th grades honor biology, honors science, and physics classes, and upper level collage preservice science education classes. During the first phase of the study, students were asked to respond to open-ended questions in order to assess their conceptions relating to the nature of science. During the second phase, students were presented with a socio scientific scenario that required decisions based on their moral reasoning or ethical beliefs. In the third phase, pairs were constructed from different levels of variation about the subject. Then, they were allowed to freely interact, challenge, and question each other during the interview process. Results of this study revealed that students' conceptions of nature of science ranged from theories as static and fixed to the idea that they change in quick response to social utility and technological advances. Status of scientific knowledge versus opinion, students' responses distinguished between the subjectiveness of opinion and the objectivity of scientific knowledge. In general, subjectiveness was equated with personal opinions whereas scientific knowledge was associated with proven, tested, or constructed knowledge. Also, students generally perceived connections between art and science in terms of the creativity. However, a distinction seems to be made between the spirit of art that is more directly linked to emotion activity" and of science.

Lederman and O'Malley (1990) investigated the students' perceptions of tentativeness in science. The sample was 36 males and 33 females spanned grades 9-12. Students are enrolled in physical science, biology, chemistry, and physics classes. All students were asked to complete a seven item open-ended questionnaire concerned with their beliefs about the tentative nature of science during the second week of the school year. Also, the same questionnaire was repeated during the final month of the school year. At the end, researchers reviewed the completed questionnaires and identified 20 students to participate in videotaped follow-up interviews. Data from the pretest indicated that the students, as a group, do not uniformly adhere to either an absolute or tentative view of scientific knowledge. By contrast, the results of the post-test more clearly adhere to the tentative view of scientific knowledge. In the interview part, all students correctly interpreted the intent of each of the questionnaire items. Consequently, the study indicated that more care must be taken in the assessment of students' perceptions of science. Language is often used differently by students and researchers and this mismatch has almost certainly led to misinterpretations of students' perceptions in the past.

Solomon, Scott, and Duveen (1996) reported a questionnaire study of British pupils' understanding of several aspects of the nature of science. The sample of the study was about 800 pupils aged 14-15 years. Interviews with teachers and questionnaire were used for this study. Results showed a strikingly relation between the class in which the pupils were taught and how they answered most of the questions. This shows what may be both the effect of the teacher on the pupils' views and also an indication of the relative effect of in-school and out-of-school knowledge.

Previous researches have argued that the teachers' understanding of the nature of science is necessary, but not sufficient, condition for helping students understand the nature of science (Hanuscin, Akerson, and Phillipson-Mower, 2006). Lunn (2002) also supported that teachers' views of the nature of science form part of a hidden curriculum in their science teaching, thus an understanding of them is necessary to an understanding of learners' experiences of science teaching. Unfortunately, research over the past several decades has found teachers' views of the nature of science to be largely inconsistent with contemporary characterizations of the scientific endeavor (Billeh and Hasan 1975, Bloom 1989, King 1991; Lederman, 1992; Zimmermann and Gilbert, 1998; Murcia and Schibeci, 1999; Haidar, 1999; Abd-El-Khalick and Lederman, 2000; Abell, 2001; Irez, 2006). Several attempts were undertaken to improve teachers' nature of science views (i.e., Akindehin 1988; Scharmann and Harris 1992). However, these efforts were generally not successful in helping teachers develop understandings that would enable them to effectively teach about nature of science (Abd-El-Khalick, 2005).

Erdoğan (2004) investigated the views of Turkish preservice science teachers on nature of science (NOS). The sample of the study was 166 preservice science teachers. She utilized 21-item "Views on Science- Technology-Society (VOSTS)" instrument, translated and adapted into Turkish, to assess teachers' views on the nature of science. The VOSTS (Aikenhead, Ryan and Fleming, 1989) is a pool of 114 empirically developed multiple-choice items with nine categories. For this study, 21 items were selected from the epistemology of science category corresponded to the purposes of the assessment. Also, semi-structured interviews were also conducted by 9 volunteer preservice science teachers in order to understand their views on nature of science in depth. The results gave a picture of the preservice science teachers' views on nature of science. Results of this study showed preservice science teachers' misconceptions on nature of science. Results of the study revealed that preservice science teachers held traditional views (naive) regarding the definition of science; the nature of scientific models; the relationships between hypotheses, theories, and laws; fundamental assumptions for all science; the scientific method; uncertainty in scientific knowledge; epistemological status of scientific knowledge; coherence of concepts across disciplines. On the other hand participants have contemporary views (realistic) on the nature of observation; the nature of classification schemes; the tentativeness of scientific knowledge; cause and effect relationship. In conclusion, the author suggested that the current science teacher education programs should be modified in the direction for enhancing science teachers' understanding on the nature of science. Also, she stressed that the findings of the study can guide the design of lessons and also offer teachers a way of assessing their students' views on the nature of science.

In 1999, Haidar investigated Emirates pre-service and in-service views about the nature of science. A questionnaire was developed and administered to 31 female pre-service science teachers, and 224 in-service chemistry teachers. The questionnaire covered five aspects of the nature of science identified by Palmquist and Finley (1997). These are scientific theories and models; role of a scientist; scientific knowledge; scientific method; and scientific laws. The results indicated that Emirates teachers' views are neither clearly traditional nor clearly constructivist they held mixed views about the nature of science. The study attributed the existence of the traditional views to historical reasons and the educational system. The presence of constructivist views was attributed to religious factors, where some of students' religious beliefs agree with some constructivist views. This study also provides evidence that the traditional view about the nature of science is in conflict with the teachers' religious beliefs.

In the light of related literature, it can be indicated that students' misconceptions influence their understanding of science concepts. Especially, acid-base concept is one of the most challenging concepts for students. Therefore, further research is needed for improving students' understanding of acid-base concepts and removing students' misconceptions. 5E learning cycle method should be favored in order to obtain greater student understanding in chemistry. For this reason, in the present study, we aimed to determine the effect of 5E learning cycle method on students' understanding of acid-base concepts and their attitudes toward chemistry as a school subject when their science process skill was taken as a covariate. Moreover, the goal of science education is not only to help students acquire scientific knowledge. Like scientific knowledge, helping students develop adequate understandings of nature of science is another desired outcome of science teaching. Therefore, in this study, we also investigated students' views on nature of science.

# CHAPTER 3

# PROBLEMS AND HYPOTHESES

## 3.1 The Main Problem and Subproblems

### 3.1.1 The Main Problem

The purpose of this study is to compare the effectiveness of instruction based on 5E learning cycle model over traditionally designed chemistry instruction on 11th grade students' understanding of acid-base concepts and attitudes toward chemistry as a school subject. Also views of experimental and control group students on nature of science were investigated.

### 3.1.2 The Subproblems

1. Is there a significant difference between the effects of 5E learning cycle model and traditionally designed chemistry instruction on students' understanding of acid-base concepts when their science process skills are controlled as a covariate?

2. Is there a significant difference between males and females in their understanding of acid-base concepts, when their science process skills are controlled?

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

4. What is the contribution of students' science process skills to their understanding of acid-base concepts?

5. Is there a significant difference between students taught through 5E learning cycle model and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject?

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

7. Is there a significant effect of interaction between gender difference and treatment with respect to their attitude toward chemistry as a school subject?

**3.2 Hypotheses**

$H_0 1$: There is no significant difference between post-test mean scores of the students taught with instruction based on 5E learning cycle and taught with traditionally designed chemistry instruction in terms of understanding acid-base concepts when their science process skills are controlled as a covariate.

$H_0 2$: There is no significant difference between the posttest mean scores of males and females in terms of understanding acid-base concepts when their science process skills are controlled.

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

$H_0 4$: There is no significant contribution of students' science process skills to understanding of acid-base concepts.

$H_05$: There is no significant difference between post-test mean scores of students taught with 5E learning cycle oriented instruction and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject.

$H_06$: There is no significant difference between post-test mean scores of males and females with respect to their attitudes toward chemistry as a school subject.

$H_07$: There is no significant effect of interaction between gender difference and treatment with respect to their attitudes toward chemistry as a school subject.

# CHAPTER 4

# DESIGN OF THE STUDY

In this study, the quasi-experimental design was used (Gay, 1987). The random assignment of already formed classes to experimental and control groups was employed to examine treatment effect. Intact classes were used because it would have been too disruptive to the curriculum and too time consuming to have students out of their classes for treatment. In addition, due to administrative rules the classes were chosen randomly not students.

## 4.1 The Experimental Design

**Table 4.1** Research design of the study

| Groups | Pretest | Treatment | Posttest |
|---|---|---|---|
| EG | ABCT<br>ASTC<br>SPST | 5E | ABCT<br>ASTC<br>T-VOST |
| CG | ABCT<br>ASTC<br>SPST | TDCI | ABCT<br>ASTC<br>T-VOST |

In Table 4.1, EG represents the Experimental Groups instructed by 5E Learning Cycle Model. CG represents the Control Groups receiving traditionally designed chemistry instruction. ABCT is Acid-Base Concept Test. 5E is instruction based on 5E learning cycle model and TDCI is Traditionally Designed Chemistry Instruction. SPST refers to Science Process Skill Test. ASTC represents Attitude Scale Toward Chemistry, and T-VOST represents Turkish version of Views on Science-Technology-Society instrument.

## 4.2 Subjects of the Study

The subjects of this study consisted of 130 eleventh grade students (62 male and 68 female) from six intact classes of two different types of high schools in Balıkesir taught in the 2007-2008-fall semester. Two instruction methods used in the study were randomly assigned to groups. Three of the classes were assigned as the experiment groups and the other three classes were assigned as the control groups in two schools. Two of the experimental groups and two of the control groups were assigned in an Anatolian High School. Also, one experiment and one control group were assigned in an Anatolian Teacher High School. The data analyzed for this research were taken from 65 students (43 Anatolian High School students and 22 Anatolian Teacher High School students) participating instruction based on 5E Learning Cycle model and 65 students (45 students from an Anatolian High School and 20 students from an Anatolian Teacher High School) participating in the Traditionally Designed Chemistry Instruction.

## 4.3 Variables

### 4.3.1 Independent Variables:

The independent variables in this study were method of instruction; 5E learning cycle model oriented instruction and traditionally designed chemistry instruction, gender, science process skill.

### 4.3.2 Dependent Variables:

The dependent variables were students' understanding of acid-base concepts, their attitudes toward chemistry as a school subject, and nature of science views of students.

## 4.4 Instruments

### 4.4.1 Acid Base Concepts Test (ABCT):

This test was developed by the researchers. While some questions were taken from the University Entrance Exam questions in Turkey, others were developed by the authors considering misconceptions and difficulties related to acid-base concepts in the literature (Ross, 1989; Hand and Treagust, 1991; Ross and Munby, 1991; Schmidt, 1991; Nakhleh and Krajcik, 1994; Sheppard, 1997; Demircioğlu et.al., 2004). Since the language of the instruction of the schools is Turkish, the test was constructed in Turkish. The content was determined by examining textbooks, instructional objectives for the acid-base unit and related literature. During the developmental stage of the test, the following steps were taken into consideration. First, instructional objectives related to the acids and bases topic were determined (see Appendix A), and each item in the test was constructed according to instructional objectives. Second, students' misconceptions related with acid-base concepts were stated from related literature and opinion of chemistry teachers and a classification was constructed (Table 4.2).

The test included 30 items based on the multiple-choice format (see Appendix B). The items used in ABCT were conceptual questions that revealed students' understanding and misconceptions related with acid-base concepts. Each item consists of five choices. These alternatives include one scientifically acceptable answer supporting the desired content knowledge and four distracters. For the content validity, each item in the test was examined by a group of experts in science education, chemistry and by the classroom teachers. The reliability coefficient computed by Cronbach alpha estimates of internal consistency of this test was found to be 0.8.

This test was given to students in both groups as a pre-test to control students' understanding of acid-base concepts at the beginning of the instruction. It was also given to both groups as a post-test to compare the effects of two instructions (5E & TDCI) on understanding of acid-base concepts. The test was piloted with 150 11$^{th}$ grade students and its Cronbach alpha reliability was found to be 0.81.

**Table 4.2** Classification of Students' Misconceptions in Acid-Base

| **ACIDS & BASES** | **Item** |
|---|---|
| All substances containing $H^+$ have acidic characteristics | **2** |
| Acids have bitter taste | **2** |
| Acids do not react with carbonates | **2** |
| Acids do not react with active metals | **2** |
| Acids rust metals | **5** |
| Acids are more toxic than bases | **5** |
| Acids melt metals hence gas is not released | **14** |
| Acids turn red litmus paper into blue | **6, 18** |
| Only basic solutions contain $OH^-$ ions | **20** |
| Bases always contain $OH^-$ ions | **1** |
| Bases turn blue litmus paper into red | **3,6,18** |
| Bases are blue | **3** |
| Bases are harmless | **3** |
| A base is something which makes up an acid | **3** |
| Acids are more "powerful" than bases | **17** |
| **ACIDS & BASES IN DAILY LIFE** | |
| Common household products are incorrectly classified | **6** |
| Powerful acting chemicals are acids | **5** |
| Soil cannot be acidic because things grow in it | **5** |
| **IONIZATION OF WATER/ pH & pOH** | |
| Wrong proportion about pH and acids/bases | **7, 8** |
| A solution with pH of 10 is neutral | **8** |
| pH=0 is neutral | **7** |
| The pOH value is used only for base solutions | **7** |
| The pH value is used only for acid solutions | **9, 11, 19** |
| pH and pOH refer to the same number in both acid and base solutions | **7** |
| Confusion the relationship between pH/pOH and $[OH^-]$ / $[H^+]$ | **8,18,19,20, 22,23, 25,27** |
| Confusion the relationship between the ions in the solution and Ka/Kb | **28, 30** |
| **THE STRENGTH OF AN ACIDS/BASES** | |
| Equal amount of strong and weak base solutions contain the same amount of $OH^-$ ions | **9** |

**Table 4.2 (Continued)**

| | |
|---|---|
| Concentration and strength are the same | **11, 12** |
| Electrical conductivity of strong and weak bases are the same | **9** |
| pH/pOH and strength are the same | **11, 12** |
| The strength of bases increases with an increase in pH | **12** |
| The strength of solutions are directly proportional with the number of ions in the solution | **11, 12** |
| The strength of an bases increases with an increase in pOH | **12** |
| Molecules of strong acids should contain more H+ ions than that of weak acids | **10** |
| A strong acid has a higher pH than a weak acid | **10** |
| A strong acid reacts more slowly than a weak acid | **14** |
| The strength of acids do not affect the speed of reaction with metals | **13, 14** |
| Gas is not released after a reaction of an acid and magnesium | **13** |
| Strong acids melt metals better than weak acids | **10** |
| When acetic acid and magnesium react gas is released more quickly than when hydrochloric acid reacts with magnesium | **13** |
| When hydrochloric acid and magnesium react gas is released more quickly than when acetic acid reacts with magnesium because more hydrogen bonds need to be broken | **14** |
| Strong acids produce more hydrogen when reacted with a metal than do weak acids | **10** |
| Different amount of H+ ions required to neutralize equal amount of KOH and NH3 | **9** |
| **NEUTRALIZATION & HYDROLYSIS** | |
| Neutralization is a physical change not a chemical one | **4** |
| A gas is released after a reaction of an acid and a base | **4** |
| Neutralization always results in a neutral solution | **1,16,17,19** |
| The product of neutralization are acidic/basic | **16** |
| In a neutralization reaction, when one of the reactants (acid or base) is weak, the neutralization does not completely take place | **17** |
| Salt formed at the end of a neutralization reaction is always acid | **15** |
| Salt formed at the end of a neutralization reaction is always basic | **15, 27** |
| Salt formed at the end of a neutralization reaction is always neutral | **15, 17, 27** |

### 4.4.2 Attitude Scale Toward Chemistry (ASTC)

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

### 4.4.3 Science Process Skill Test (SPST)

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

### 4.4.4 Interview Questions

After the implementation of 5E and TDCI, interviews were prepared related to students' misconceptions obtained from post-test results after the treatment. Five students from the experimental groups and five students from the control groups were selected based on their achievement on Acid-Base Concept Test scores. Students were randomly selected. These students participated in 15-20 minutes semi-structured interview schedule designed to elucidate their beliefs and misconceptions about the concept of acids and bases. The schedule was left flexible to allow students to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. Interview questions focused following areas: (a) Acids and Bases; (b) pH/pOH; (c) The Strength of Acids and Bases; (d) Neutralization and Hydrolysis (see Appendix E). Researchers conducted and videotaped the interview.

### 4.4.5 Turkish Version of Views on Science-Technology-Society (T-VOSTS)

In this study, Turkish version of Views on Science-Technology-Society (T-VOSTS), which contain twenty-one selected and adapted items from VOSTS item pool, were utilized to investigate the views of students on nature of science. Originally, Aikenhead, Ryan and Fleming (1989) developed the VOSTS (Views on

Science- Technology-Society) that is an inventory of student viewpoints about science, and about how science is related to technology and society. During the developmental stage of this inventory, the authors firstly designed a study to understand the viewpoints that high school students hold on the complex topic science, technology and Canadian society. Researchers studied with thousands of grade 12 students from across Canada, and they asked students to write paragraphs about various issues on this topic. Then, they analyzed all paragraphs closely and found some common viewpoints. Researchers called these common viewpoints "student positions". Also, they interviewed over 100 students and discovered that most students were able to express their true beliefs better by choosing one of the "student positions" than by writing a paragraph. After that, they made a questionnaire out of these "student positions" (Aikenhead, Ryan and Fleming, 1989). Aikenhead and Ryan (1992) stated that this is the major difference between the VOSTS and many other instruments, which typically are composed by researcher working under the erroneous assumption that respondents will perceive and interpret the language in the items in the same way as the researcher does. They also suggested that it is inappropriate to speak out about the validity of empirically developed instruments, such as the VOSTS, in the traditional sense because the validity of empirically developed instruments arises from a qualitative research paradigm. According to them, empirically developed instruments seek to uncover the perspective of the respondent and reveal the legitimacy of that perspective from the respondent's point of view, not the imposed viewpoint of the researcher. As in the qualitative research, it is assumed with empirically developed instruments that the respondents understand the complex interactions being studied and account for the influence of values on the interactions better than the investigator. Additionally, Aikenhead and Ryan (1992) stated that the validity of an empirically developed instrument is established by the "trustworthiness" of the method used to develop the items as the validity of the process and of the final instruments lies in the trust which subsequent researchers place in the development process which has been described. Therefore, it was assumed that the VOSTS items possessed an inherent validity that originated from the process used to develop them. Similarly, the concept reliability as it applies to empirically developed instruments such as the VOSTS follows from the qualitative research paradigm, where in the dependability of the results is of major concern; that is, the validity and reliability of qualitative data depend to a great extent on the methodological skill, sensitivity, and integrity of the researcher. Rather than demanding that others get the same results, one wants to concur that, given the data collected, the results make sense that the results are dependable. In addition, Aikenhead and Ryan (1992) also argue that empirically developed items yield non-parametric data that does not fulfill the continuity and equal intervals of measures assumption that underlies parametric analysis procedures. Hence, they add traditional procedures such as Coefficient Alpha that are used to assess the reliability of instruments that yield parametric scores and are based on assumptions that are not tenable in the case of empirically developed instruments, are not appropriate for the VOSTS. As a result, VOSTS items were assumed to be reliable and based upon agreement that the data presented Aikenhead and Ryan made sense (Erdoğan, 2004).

The VOSTS (Aikenhead, Ryan and Fleming, 1989) is a pool of 114 empirically developed multiple-choice items with nine categories. These categories are: Science and Technology, Influence of Society on Science/Technology, Future Category, Influence of Science/Technology on Society, Influence of School Science, Characteristics of Scientists, Social Construction of Scientific Knowledge, Social Construction of Technology and Nature of Scientific Knowledge. The VOSTS was developed in a six-year period of time.

Each question of the VOSTS inventory begins with a statement about science technology-society topic. Most of these statements express an extreme view on the topic. Students may happen to agree strongly with this view; they may happen to disagree vigorously; or their position may be in between the two. Next, there is a list of positions (or viewpoints) on the issue. These usually go from one extreme to the other. Students are asked to choose one of these positions (Aikenhead, Ryan and Fleming, 1989).

Turkish version of Views on Science-Technology-Society (T-VOSTS) constructed by Erdoğan (2004). She firstly selected 22 items from the ninth part epistemology of science (or the nature of scientific knowledge) of the VOSTS item pool. Then these selected items were translated and adapted by the researcher and two science educators. In addition, a linguist in Academic Writing Center in METU checked selected items' translations. Then the pilot study was done using 19 third-year students of Elementary Science Education Department of METU. According to pilot study, two items were omitted for the actual administration. In addition to this, after the pilot study one item selected from the first part about the definition and meaning of science. Finally, after necessary changes upon the pilot study, the researcher developed Turkish version of VOSTS (T-VOSTS) with 21 items (Table 4.3, Appendix F).

**Table 4.3** Subscales of the items used in the Turkish version of VOSTS (Erdoğan, 2004).

| Item | Items' root | Subscales |
|---|---|---|
| 1 | Defining science is difficult because science is complex and does many things. But MAINLY science is: | Defining science |
| 2 | Scientific observations made by competent scientists will usually be different if the scientists believe different theories. | Nature of observations |
| 3 | Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality. | Nature of scientific models |
| 4 | When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong. | Nature of classification schemes |
| 5 | Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future. | Tentativeness of scientific knowledge |
| 6 | Scientific ideas develop from hypotheses to theories, and finally, if they are good enough to being scientific laws. | Hypotheses, theories & laws |
| 7 | When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions *must be true* in order for science to progress properly. | |
| 8 | Good scientific theories explain observations well. But good theories are also *simple* rather than complex. | |

**Table 4.3.** (Continued)

| | | |
|---|---|---|
| 9 | When scientists investigate, it is said that they follow the scientific method. The scientific method is: | |
| 10 | The best scientists are those who follow the steps of the scientific method | |
| 11 | Scientific discoveries occur as a result of series of investigations, each one building on an earlier one, and each one leading logically to the next one, until the discovery is made. | Scientific approach to investigations |
| 12 | Scientists publish the result of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way. | |
| 13 | Scientists should NOT make errors in their work because these errors slow the advance of science. | Scientific approach to investigations |
| 14 | Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what p*robably* might happen. They cannot tell what will happen for certain. | Precision & uncertainty in scientific technological knowledge. |
| 15 | If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer. | Logical reasoning |
| 16 | Science rests on the assumption that the natural world cannot *b*e altered by a supernatural being (for example, a deity). | Fundamental assumptions for all science |
| 17 | For this statement, assume that a gold miner “discovers” gold while an artist “invents” a sculpture. Some people think that scientists d*iscover* scientific LAWS. Others think that scientists invent them. What do you think? | |
| 18 | For this statement, assume that a gold miner “discovers” gold while an artist “invents” a sculpture. Some people think that scientists d*iscover* scientific HYPOTHESES. Others think that scientists invent them. What do you think? | Epistemological status of scientific knowledge |
| 19 | For this statement, assume that a gold miner “discovers” gold while an artist “invents” a sculpture. Some people think that scientists d*iscover* scientific THEORIES. Others think that scientists invent them. What do you think? | |
| 20 | Scientists in different fields look at the same thing from very different points of view (for example, $H^+$ causes chemists to think of acidity and physicists to think of protons). This makes it difficult for scientists in different fields to understand each others’ work. | Paradigms versus coherence of concepts across disciplines |
| 21 | Scientists in different fields look at the same thing from very different points of view (for example, $H^+$ causes chemists to think of acidity and physicists to think of protons). This means that one scientific idea has different meanings, depending on the field scientist works in. | |

### 4.5 Treatment

This study was conducted over approximately seven weeks during the 2007-2008-fall semester. In two different types of high schools in Balıkesir, two teachers and their six eleventh grade chemistry science classes were enrolled. The instructional methods were randomly assigned to the classes. In detail, one of the two classes of a teacher in an Anatolian Teacher High School was randomly selected as an experiment group and the other was selected as a control group. Similarly, two of the four classes of a teacher from an Anatolian High School were randomly selected as experiment groups and the other classes were stated as control groups. In summary, three of the classes were assigned as the experimental groups, instructed through the 5E learning cycle model, and the other classes were assigned as the control group, instructed through traditional instruction. Both control and experiment groups were instructed on the same content of the chemistry course. The classroom instruction of the groups was three 40-minute sessions per week. Before the study, teachers were informed about 5E learning cycle model. Sample lesson plans and activities of 5E learning cycle model were presented to teachers and discussed with them. During the treatment, the acid-base topics were covered as a part of the regular curriculum in the chemistry schedule course. The researcher observed classes in the control and experimental groups randomly. The teacher introduced the following topics: the definition and the properties of acids and bases; pH/pOH concept; the strength of acids and bases; acid-base titrations neutralization; hydrolysis and buffer solutions.

At the beginning of the study, all groups in the sample were administered ABCT to determine whether there was any difference among the groups with respect to understanding of acid-base prior to instruction. Also, ASTC was distributed to measure students' attitudes toward chemistry as a school subject prior to instructions, and SPST was given to all students to assess their science process skills.

In the control group, the course was traditional in format, having lectures, discussions, and solving standard quantitative problems, such as those at the end of the chapter in a typical chemistry textbook. In this group, information and conceptual language about the acid-base concepts were orally delivered to students. Teaching strategies were dependent on teacher exploration without consideration of students' prior experiences. Also, reading textbook had a prominent position in this teaching procedure. In other words, exposition requires that the teacher inform the students of what is to be learned. For this group, laboratory experiences were also used as a verification of the material presented in the acid-base lectures. Marek and Cavallo (1997) suggested that such kinds of exercises are not true experiments because the outcome is known before the activity is performed. At the end of the laboratory, control group students filled the experiment sheets (see Appendix K) and answered teacher's questions.

Students in the experimental groups instructed through 5E learning cycle model. Because 5E learning cycle instruction is new for the students, before its implementation, the researcher briefly explained it in the experimental groups. In the first phase of 5E model, engagement, teachers promoted the students' interest and motivation by asking questions and/or making demonstration. Also, raising questions and eliciting responses from the experimental group students in this phase would give teachers an idea of what the students already know. A second phase (exploration) of the 5E was designed to give students common, practical experiences, allowing them to build on their developing concepts and skills. In this phase, students were permitted to discuss the question by using their previous experiences related to acid-base concepts. During these discussions the teacher was the facilitator and observed and listened to students as they interact. Moreover, students gathered information, tested out ideas, recorded observations, experimented, and so on. In the meantime, teacher provided directions and materials, answered and asked questions, gave hints and clues, and generally kept the exploration going. In sum, exploration phase enables students to learn through their own actions and reactions by exploring materials and testing their previous ideas on the subject with minimum guidance. The explanation phase (third phase) permitted students to make sense of their explorations. Students were encouraged to find patterns, relationships, and answers to questions. The teacher established the discussion environment, encouraged the students to explain concepts and definitions in their own words, asked for justification and clarification, formally clarified definitions, explanations, and new labels when needed, used students' previous experiences as the basis for explaining concepts, assessed students' growing understanding, and ultimately introduced the scientific terminology for the concept. A fourth phase (elaboration) gave students the opportunity to extend their knowledge of concepts to other contexts. This phase is vital in developing more general views of phenomena as students identify similarities in different contexts. The roles of the teacher and students in this phase were like those in the exploration phase. The purpose of the teacher was to extend conceptual understanding; practice desired skills; deepen understanding. In addition, the teacher used the terminology of the concept and insisted that the students use it also. As a fifth phase (evaluation) the teacher looked for evidence that the students have changed their thinking or behaviors. Students were also encouraged to assess their understanding and abilities; and evaluated their learning**.** In this respect, teacher assessed his/her students with them according to their experiment sheets (Appendix L and Appendix M), and also students asked to solve more questions such as those in a typical chemistry textbook. An example of 5E lesson implementation is given in Appendix N.

In the experiment and the conrol groups, students conducted five separate experiments/activities, which were about: general properties of acid and bases; pH/pOH concepts; Strengths of acids and bases; Acid-base titration and neutralization; Hydrolysis and buffer solutions.

At the end of the treatment, all students were given ABCT as a post-test. They were also administered ASTC to identify the students' attitudes toward chemistry as a school subject after the treatments, and T-VOSTS to investigate the students' views on nature of science. Lastly, to understand students' understanding of acid-base concept in depth, semi-structured interviews were also conducted at the end of the study by 10 volunteer from experiment and control group students.

### 4.6 Analysis of Data

In this study, two-way ANCOVA was used to determine effects of two different instructional methods and gender difference related to understanding of acid-base concepts by controlling the effect of students' science process skills as a covariant. Also this statistical technique revealed the contribution of science process skills to the variation in understanding and the effect of gender difference on students' understanding acid-base concepts. To test the effect of treatment on students' attitudes toward chemistry as a school subject and the gender effect on students' attitudes toward chemistry, two-way ANOVA was used. In addition, descriptive analyses were performed in this study for data of Turkish version of VOSTS. Frequency and percentage distribution of each alternative under each one of the items were calculated and they were analyzed.

### 4.7 Assumptions and Limitations

#### 4.7.1 Assumptions:

1. All the students were accurate and sincere in answering the questions of measuring instruments.
2. Teachers who applied this study were not biased during the treatment.
3. There was no interaction among groups.
4. The treatment was applied under standard conditions.

#### 4.7.2 Limitations:

1. This study was limited to the unit of "Acids and Bases".
2. The subjects of the study were limited to 130 eleventh grade students from two different types of high schools in Balıkesir.

# CHAPTER 5

# RESULTS AND CONCLUSIONS

## 5.1 Results

The hypotheses stated in Chapter 3 were tested at a significance level of $\alpha=0.05$. Two way analysis of covariance (ANCOVA) and two way analysis of variance (ANOVA) were used to test the hypotheses. In this study, statistical analyses were carried out by SPSS/PC (Statistical Package for Social Sciences for Personal Computers) (Norusis, 1991).

The analyses of the total results (an Anatolian High School and an Anatolian Teacher High School) showed that there was no significant difference at the beginning of the treatment between the 5E groups and the TDCI groups in terms of students' understanding of acid-base concepts ($t = 0.663$, $p>0.05$), students' attitudes toward chemistry ($t=0.416$, $p>0.05$) and their science process skills ($t=1.45$, $p >0.05$).

The analyses of the results for the Anatolian High School indicated that there was no significant difference at the beginning of the treatment between the 5E groups and the TDCI groups in terms of students' understanding of acid-base ($t=1.263$, $p>0.05$), students' attitudes toward chemistry ($t=1.146$, $p>0.05$) and their science process skills ($t =0.913$, $p >0.05$).

In addition, the analysis for the Anatolian Teacher High School showed that there was no significant difference at the beginning of the treatment between the 5E groups and the TDCI groups in terms of students' understanding of acid-base ($t=0.608$, $p>0.05$), students' attitudes toward chemistry ($t=0.937$, $p>0.05$) and their science process skills ($t=1.768$, $p>0.05$).

Descriptive analyses for all groups in two schools, for Anatolian High School, and for Anatolian Teacher High School are presented respectively in Table 5.1, Table 5.2, and Table 5.3.

**Table 5.1** Descriptive statistics for all groups in two schools

| | | Pre-ABCT | | Pre-ASTC | | | Post-ABCT | | Post-ASTC | | | SPST | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Group** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** |
| **5E** | 63 | 12.87 | 4.27 | 52.14 | 10.66 | 64 | 24.45 | 3.39 | 55.54 | 9.73 | 58 | 25.03 | 3.54 |
| **TDCI** | 65 | 12.35 | 4.51 | 52.96 | 11.87 | 54 | 18.94 | 3.62 | 53.65 | 8.98 | 61 | 24.10 | 3.46 |

**Table 5.2** Descriptive statistics for Anatolian High School

| | | Pre-ABCT | | Pre-ASTC | | | Post-ABCT | | Post-ASTC | | | SPST | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Group** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** |
| **5E** | 43 | 12.78 | 4.30 | 52.25 | 11.56 | 42 | 23.62 | 3.60 | 55.30 | 8.55 | 43 | 25.20 | 3.37 |
| **TDCI** | 45 | 11.64 | 4.12 | 49,60 | 10,15 | 39 | 17.97 | 3.03 | 51.66 | 8.07 | 40 | 22.98 | 3.75 |

**Table 5.3** Descriptive statistics for Anatolian Teacher High School

| | | Pre-ABCT | | Pre-ASTC | | | Post-ABCT | | Post-ASTC | | | SPST | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Group** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** | **Mean** | **SD** | **n** | **Mean** | **SD** |
| **5E** | 20 | 13.05 | 4.31 | 54.50 | 12.68 | 22 | 26.04 | 2.23 | 55.95 | 11.88 | 16 | 26.43 | 1.93 |
| **TDCI** | 20 | 13.95 | 5.03 | 57.85 | 9.73 | 15 | 21.46 | 3.90 | 57.73 | 9.57 | 20 | 24.80 | 3.27 |

**Hypothesis 1:**

To answer the question posed by hypothesis 1 stating that there is no significant difference between the post-test mean scores of the students taught by 5E and those taught by TDCI with respect to understanding acid-base concepts when science process skill is controlled as a covariate, two way analysis of covariance (ANCOVA) was used. The measures obtained for all students in the study, for Anatolian High School students, and Anatolian Teacher High School students are presented respectively in Table 5.4, Table 5.5, and Table 5.6.

**Table 5.4** ANCOVA Summary for all students (Understanding)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Covariate (Science Process Skill) | 1 | 218.569 | 218.569 | 20.700 | 0.000 |
| Treatment | 1 | 579.177 | 579.177 | 54.852 | 0.000 |
| Gender | 1 | 4.200 | 4.200 | 0.398 | 0.530 |
| Treatment*Gender | 1 | 12.090 | 12.090 | 1.145 | 0.287 |
| Error | 102 | 1076.998 | 10.559 | | |

**Table 5.5** ANCOVA Summary for Anatolian High School students (Understanding)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Covariate (Science Process Skill) | 1 | 78.343 | 78.343 | 8.123 | 0.006 |
| Treatment | 1 | 542.521 | 542.521 | 56.248 | 0.000 |
| Gender | 1 | 36.091 | 36.091 | 3.742 | 0.057 |
| Treatment*Gender | 1 | 0.893 | 0.893 | 0.093 | 0.762 |
| Error | 71 | 684.802 | 9.645 | | |

**Table 5.6** ANCOVA Summary for Anatolian Teacher High School students (Understanding)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Covariate (Science Process Skill) | 1 | 62.698 | 62.698 | 8.693 | 0.007 |
| Treatment | 1 | 82.273 | 82.273 | 11.408 | 0.002 |
| Gender | 1 | 23.029 | 23.029 | 3.193 | 0.086 |
| Treatment*Gender | 1 | 17.517 | 17.517 | 2.429 | 0.131 |
| Error | 26 | 187.516 | 7.212 | | |

The overall result showed that there was a significant difference between the posttest mean scores of the students taught by 5E and those taught by TDCI with respect to the understanding of acid-base concepts. The 5E groups scored significantly higher than TDCI groups for all students ($\overline{X}$(5E) = 24.45, $\overline{X}$(TDCI) = 18.94). Further, for Anatolian High School students, 5E group students scored significantly higher than TDCI group students ($\overline{X}$(5E) = 23.62, $\overline{X}$(TDCI) = 17.97), and for Anatolian Teacher High School, 5E groups scored significantly higher than TDCI groups ($\overline{X}$(5E) = 26.04, $\overline{X}$(TDCI) = 21.46).

Figure 5.1 shows the proportions of correct responses to the questions in the posttest for experiment and control groups.

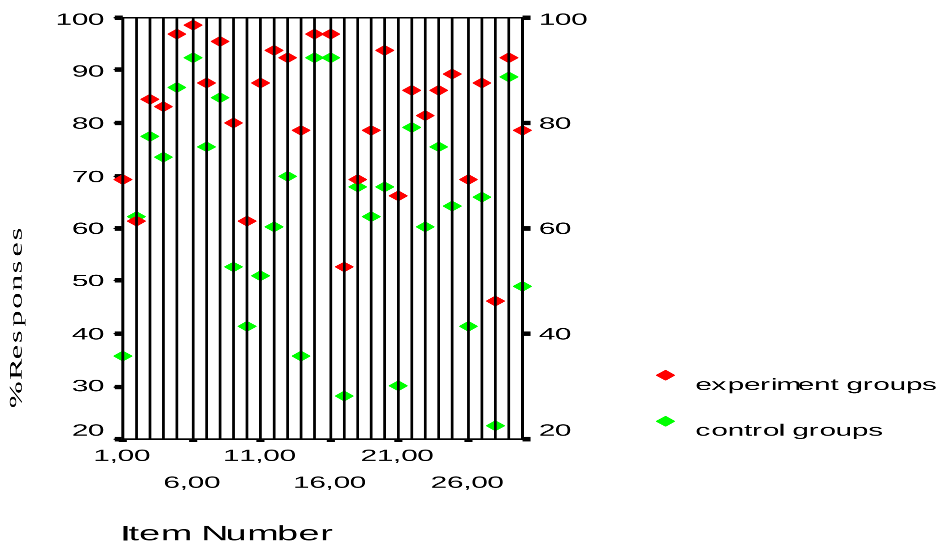


**Figure 5.1** Comparison of post-test scores of experiment groups and control groups

There was a difference in responses between the experiment and control groups to the items in ABCT (see Appendix G and Appendix H). Items 1, 9, 10, 11, 12, 14, 17, 21, 26, 28, 30, where the poorer student results were obtained, were selected to discuss in this chapter. Question 1 was related to the properties of the bases. Before the treatment, 19.4 % of the experiment group students, and 26.8 % of the control group students responded this question correctly. After the treatment, whereas 69.2 % of the experimental group students correctly answered the question, only 35.8 % of the control group students selected the correct alternative for this question. For item 1, two misconceptions were found among students. The first one, selected by 26.4% of the control group students, was that neutralization always results in a neutral solution. The second misconception, selected by 26.4% (9.4 % + 17.0%) of the control group students, was that bases should contain $OH^-$ ions. Moreover, 23.1 % of the experimental group students and 11.3 % control group students had both of these misconceptions. The misconceptions that this item measured and the percentages of the experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.7** Percentages of students' selection of alternatives for item 1

| Aşağıdakilerden hangisi ya da hangileri bazlar için <u>her zaman</u> doğrudur?<br>I- Suda iyonlaşırlar<br>II- Yapılarında $OH^-$ iyonu bulundururlar<br>III- Asitlerle nötrleşip nötr çözelti oluştururlar | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| *a) Yalnız I | 69.2 | 35.8 |
| b) Yalnız II | 1.5 | 9.4 |
| c) Yalnız III | 3.1 | 26.4 |
| d) I ve II | 3.1 | 17.0 |
| e) I, II ve III<br>*** Correct alternative** | 23.1 | 11.3 |

For the question nine, 80.0 % of the students in the 5E groups and 52.8% of the students in the TDCI groups correctly stated that the same amount of $H^+$ ions required to neutralizing equal amount of KOH and $NH_{3.}$ That is, 18.4 % of the experimental group students and 37.8 % control group students believed that different amount of $H^+$ ions required to neutralize the equal amount of KOH and $NH_{3.}$ The other misconceptions among the control group students for this item was that electrical conductivities of strong and weak bases are the same (15.1%), and equal amount of strong and weak base solutions should contain the same molarities of $OH^-$ ions (11.3%). Pretest results for this item were 56.7 % for the experimental groups, and 49.1 % for the control groups. The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.8** Percentages of students' selection of alternatives for item 9

| KOH kuvvetli baz, $NH_3$ ise zayıf bazdır. Eşit hacim ve derişimdeki KOH ve $NH_3$ çözeltileri için aşağıdakilerden hangisi aynı olur? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) İyonlaşma yüzdesi | 1.5 | 5.7 |
| b) $OH^-$ iyonu molar derişimi | 4.6 | 11.3 |
| c) pH değeri | 4.6 | 5.7 |
| d) Elektrik iletkenliği | 7.7 | 15.1 |
| *e) Nötrleştirmek için gereken $H^+$ in miktarı<br>*** Correct alternative** | 80.0 | 52.8 |

In item 10, students were asked to compare the properties of equal amounts of weak and strong acids. Before the treatment, 17.9 % of the experimental group students and 12.5 % of the control group students responded correctly to this question. After treatment, 61.5 % of the students taught by the 5E Model and, 41.5 % of the students taught by the TDCI seemed to be comfortable with the right idea that the electrical conductivity of weak acid should be less than that of strong acid when the amounts of these acids are equal. Moreover, it was indicated that 13.8 % of the experimental group students and 13.2 % control group students wrongly thought that molecules of strong acid should contain more $H^+$ ions than that of weak acid. Further, 16.9 % of the experimental group students and 32.1 % control group students had a misconception that strong acid melt metals better than weak acid. In Table 5.9, the percentages of experimental and control group students' selection of alternatives in the post-test are presented:

**Table 5.9** Percentages of students' selection of alternatives for item 10

| Aynı hacim ve derişimdeki zayıf asit ile kuvvetli asit karşılaştırıldığında, aşağıdakilerden hangisi her zaman doğru olur? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Kuvvetli asidin, Mg metali ile tepkimesinden daha fazla $H_{2(g)}$ açığa çıkar. | 4.6 | 3.8 |
| b) Kuvvetli asidin pH ı, zayıf asitten daha fazladır. | 1.5 | 5.7 |
| *c) Zayıf asidin elektrik iletkenliği daha azdır. | 61.5 | 41.5 |
| d) Kuvvetli asidin bir molekülü daha fazla $H^+$ içermelidir. | 13.8 | 13.2 |
| e) Kuvvetli asit metali daha iyi eritir.<br>* Correct alternative | 16.9 | 32.1 |

Question 11 was related to the weak base and strong base solutions. Students were asked to select the necessary information to differentiate the weak base solution from the strong base solution when the volumes of these solutions were the same. 87.7% of the experimental group students and 50.9% of the control group students correctly stated that knowing the percentages of the ionization of these two bases in water is enough to differentiate the strong and weak solutions. Pretest results for this item were 56.7 % for the experimental groups, and 58.5 % for the control groups. As it is seen, the percentage of the correct responses of the control group students was decreased from pretest to posttest. This might because students in the control groups were confusing the pOH and pH values with the strength. Table 5.10 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

**Table 5.10** Percentages of students' selection of alternatives for item 11

| Farklı iki kapta eşit hacimlerde zayıf baz ve kuvvetli baz çözeltileri vardır. Bu çözeltilerden hangisinin kuvvetli baz çözeltisi olduğunu anlamak için aşağıdakilerden hangisinin verilmesi tek başına yeterlidir? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Çözeltilerin pOH değerleri | 6.2 | 15.1 |
| b) Çözeltilerin pH değerleri | 3.1 | 18.9 |
| c) Çözeltilerin derişimleri | - | 3.8 |
| *d) Çözeltilerdeki bazların iyonlaşma yüzdeleri | 87.7 | 50.9 |
| e) Çözeltilerdeki toplam iyon sayıları<br>*** Correct alternative** | - | 9.4 |

Item 12 asked to students the reason of their response for the item 11. Before the treatment, 46.3 % of the experimental group students and 37.5 % of the control group students responded to this question correctly. After the treatment, 93.8 % of the students taught by the 5E Model and, 60.4% of the students taught by the TDCI selected the correct alternative for this item. Among control group students, the common misconceptions were that the strength of the bases increases with an increase in pOH (11.3 %), and the strength of bases increases with an increase in pH (11.3%). In addition, 9.4 % control group students thought that concentration and strength are the same. The misconceptions that this item measured and the percentages of experimental and control group students' selection of alternatives in the posttest are given below.

**Table 5.11** Percentages of students' selection of alternatives for item 12

| 11. soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisidir? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Çözeltinin pOH değeri artıkça bazın kuvveti de artar | 1.5 | 11.3 |
| b) Çözeltinin pH değeri artıkça bazın kuvveti de artar | 4.6 | 11.3 |
| c) Çözeltideki iyon sayısı arttıkça, kuvvette artar | - | 5.7 |
| d) Çözeltideki bazın derişimi azaldıkça kuvveti de azalır | - | 9.4 |
| *e) Bazın iyonlaşma yüzdesi arttıkça kuvveti artar<br>*** Correct alternative** | 93.8 | 60.4 |

Item 14 was related to the reactions between the magnesium metal and acids. In item 13, students were asked that what happened if a piece of magnesium metals were placed in the same amount of hydrochloric acid (HCl) and acetic acid ($CH_3COOH$) solutions respectively. And, in item 14, the reason was asked to students for selecting their alternative among the other alternatives of the item 13. Before the treatment, 29.9 % of the experimental students, and 26.8 % of the control group students responded to this question correctly. After the treatment, whereas 78.5 % of the experimental group students correctly answered the question, only 35.8 % of the control group students selected the correct alternative for this question. For item 14, the most common alternative, selected by 20.0 % of the experimental group students and 34.0 % control group students were that when hydrochloric acid and magnesium react gas is released more quickly than when acetic acid reacts with magnesium because more hydrogen bonds need to be broken. Moreover, it was found that 11.3 % control group students believed that the strength of acids do not affect the speed of reaction with metals. Table 5.12 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

**Table 5.12** Percentages of students' selection of alternatives for item 14

| 13. soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisi olabilir? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Metaller asitlerin içinde erirler ve dışarıya gaz çıkışı olmaz | - | 3.8 |
| b) HCl bulunan kapta daha hızlı gaz çıkışı gözlemlenir çünkü daha çok hidrojen bağı kırılmıştır | 20.0 | 34.0 |
| c) HCl bulunan kapta gaz çıkışı daha yavaştır çünkü kuvvetli asitler daha yavaş reaksiyon verirler | - | 1.9 |
| *d) HCl bulunan kapta daha hızlı gaz çıkışı gözlemlenir çünkü HCl kuvvetli asittir. | 78.5 | 35.8 |
| e) İki çözeltide de asit bulunduğundan, kaplardan eşit hızda $H_{2(g)}$ çıkışı olur.<br>* Correct alternative | - | 11.3 |

Item 17 was related to the neutralization reaction and asked students to their reason for their selection among the alternatives of the item 16. All groups showed low achievement for this question. Only 28.3 % of the control group students gave correct answer to this question whereas 52.3% of the students in the experimental groups answered it correctly. The common misconceptions among the all students were that when one of the reactants (acid or base) is weak in a neutralization reaction, the neutralization does not completely take place, so the solution should shows the acidic or basic property depends on the strength of the acid/base. Pretest results for this item were 6.0 % for the experimental groups, and 7.1 % for the control groups. The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.13** Percentages of students' selection of alternatives for item 17

| 16. soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisi olabilir? | Percentage of students' responses (%) | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Asitlerin kuvveti bazlardan daha fazladır, bu yüzden çözelti asidik olur | 4.6 | - |
| b) Asitliği temsil eden hidrojen iyonuyla, bazlığı temsil eden hidroksit iyonu tamamen reaksiyona girdiğinden, karışım artık iki iyonu da içermez, ve çözelti nötr olur. | 7.7 | 3.8 |
| c) Karışımda, nötr su ve nötr tuz oluşur, bu yüzden nötrdür. | 1.5 | 1.9 |
| *d) Su ve sodyum asetat ($CH_3COONa$) oluşur. Asetat iyonun ($CH_3COO^-$) su ile tepkimesinden sonra, hidroksil iyonlarının derişimi hidrojen'inkinden daha fazla olur. | 52.3 | 28.3 |
| e) Asit yada bazdan biri zayıf olduğu takdirde nötrleşme tamamen gerçekleşemez, bu yüzden asit veya bazdan hangisi daha kuvvetliyse çözelti onun özelliğin gösterir<br>*** Correct alternative** | 33.8 | 58.5 |

Answering the question 21 required to correctly identify the Bronsted-Lowry definition for the acid and base. Pretest results for this item were 16.4 % for the experimental groups, and 17.0 % for the control groups. After the treatments, 66.2 % of the students taught by the 5E Model and, 30.2 % of the students taught by the TDCI seemed to be comfortable with the right idea that acid is an chemical species that is able to lose a hydrogen ion and the base is a species with the ability to gain hydrogen ion. Table 5.14 presents the percentages of experiment and control group students' selection of alternatives in the post-test:

**Table 5.14** Percentages of students' selection of alternatives for item 21

| I- $H_2PO_3^- + H_2PO_4^- \leftrightarrow H_3PO_3 + HPO_4^{-2}$<br>II- $H_2PO_4^- + H_3PO_2 \leftrightarrow H_3PO_4 + H_2PO_2^-$<br>III- $HPO_4^{-2} + HSO_4^- \leftrightarrow H_2PO_4^- + SO_4^{-2}$<br>Yukarıdaki tepkimelerden hangisinde ya da hangilerinde $H_2PO_4^-$ iyonu asit olarak etki etmektedir? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) Yalnız I | 15.4 | 1.9 |
| b) Yalnız II | 3.1 | 7.5 |
| c) I ve II | - | 7.5 |
| *d) I ve III | 66.2 | 30.2 |
| e) I, II ve III<br>*** Correct alternative** | 4.6 | 15.1 |

Item 26 was related to the hydrolysis. Before the treatment, 11.9 % of the experimental students, and 13.2 % of the control group students responded to this question correctly. After the treatment, whereas 69.2 % of the experimental group students correctly answered the question, only 41.5 % of the control group students selected the correct alternative for this question. The reason for selecting the wrong alternatives for this item could be the confusing the base constant with the hydrolysis constant. The percentages of experimental and control group students' selection of alternatives in the posttest are given below:

**Table 5.15** Percentages of students' selection of alternatives for item 26

| Bir T sıcaklığında $NH_4Br$ çözeltisinin pH değeri 5 olduğuna göre çözelti derişimi kaç molardır? ($NH_3$ için $K_b$= 1. $10^{-5}$) | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) 1 | - | 3.8 |
| *b) 0,1 | 69.2 | 41.5 |
| c) $10^{-5}$ | 6.2 | 20.8 |
| d) 0,01 | - | 3.8 |
| e) 10<br>*** Correct alternative** | - | 1.9 |

In item 28, students were asked to calculate the equilibrium constant. Most of the students showed low achievement for this question. Before the treatments, none of the students in the control and the experiment groups gave correct answer to this question. After the treatments, 46.2 % of the students in the experiment groups, and 22.6 % of the students in the control groups answered this item correctly. Table 5.16 presents the percentages of experimental and control group students' selection of alternatives in the post-test:

**Table 5.16** Percentages of students' selection of alternatives for item 28

| Bir X maddesi, oda sıcaklığında, su ile $X_{(suda)} + H_2O_{(sıvı)} \leftrightarrow XH^+_{(suda)} + OH^-_{(suda)}$ tepkimesini veriyor. Dengedeki çözeltide $XH^+$ iyonları derişimi 1,0. $10^{-4}$ M dır. Bu çözeltinin 100 mL'si ile 0,01 mol HCl ile tamamen nötrleştiğine göre, tepkimenin oda sıcaklığındaki denge sabiti kaçtır? (1991-ÖYS) | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| a) 1,0. $10^8$ | 4.6 | - |
| b) 1,0. $10^7$ | 3.1 | - |
| c) 1,0. $10^4$ | - | 1.9 |
| d) 1,0. $10^{-4}$ | 20.0 | 3.8 |
| *e) 1,0. $10^{-7}$<br>*** Correct alternative** | 46.2 | 22.6 |

Item 30 was about the calculations of $[OH^-]$ ions in the buffer solutions. Before the treatment, 4.5 % of the students in the experiment groups and 5.7 % of the students in the control groups gave correct response to this item. After the treatment, whereas 78.5 % of the experimental group students answered it correctly, only 49.1 % of the control group students selected correct alternative. The percentages of the experimental and the control group students' selection of alternatives in the posttest are given below:

**Table 5.17** Percentages of students' selection of alternatives for item 30

| Standart koşullarda $NH_3$ için $K_b$= 1,8. $10^{-5}$ olduğuna göre, litresinde 0,1 mol $NH_3$ ve 0,2 mol $NH_4Cl$ bulunduran çözeltide $OH^-$ kaç molar olur? | **Percentage of students' responses (%)** | |
|---|---|---|
| | **Experiment Groups** | **Control Groups** |
| *a) 9,0. $10^{-6}$ | 78.5 | 49.1 |
| b) 1,8. $10^{-5}$ | 1.5 | - |
| c) 9,0. $10^{-5}$ | 3.1 | 5.7 |
| d) 1,8. $10^{-6}$ | - | 1.9 |
| e) 2,7. $10^{-7}$<br>*** Correct alternative** | 1.5 | 1.9 |

For all of these questions, Table 5.18 shows the difference between the percentages of students' correct responses in the pre-test and in the post-test.

**Table 5.18** Percentages of students' correct responses in the pre-test and post-test for selected items

| **ITEM** | **EXPERIMENT GROUPS** | | **CONTROL GROUPS** | |
|---|---|---|---|---|
| | **Pretest (%)** | **Posttest (%)** | **Pretest (%)** | **Posttest (%)** |
| **1** | 19.4 | 69.2 | 26.8 | 35.8 |
| **9** | 56.7 | 80.0 | 49.1 | 52.8 |
| **10** | 17.9 | 61.5 | 12.5 | 41.5 |
| **11** | 56.7 | 87.7 | 58.5 | 50.9 |
| **12** | 46.3 | 93.8 | 37.5 | 60.4 |
| **14** | 29.9 | 78.5 | 26.8 | 35.8 |
| **17** | 6.0 | 52.3 | 7.1 | 28.3 |
| **21** | 16.4 | 66.2 | 17.0 | 30.2 |
| **26** | 11.9 | 69.2 | 13.2 | 41.5 |
| **28** | 0 | 46.2 | 0 | 22.6 |
| **30** | 4.5 | 78.5 | 5.7 | 49.1 |

It can be seen that more students in the experimental group removed their misconceptions after instruction than students in the control group, and the results indicated that 5E learning cycle model caused a significantly better understanding of acid-base concepts than the traditionally designed chemistry instruction for all students in our study. The experimental and control group students' correct response percentages of each question in the ABCT is presented in Appendix G and Appendix H.

**Hypothesis 2:**

To answer the question posed by hypothesis 2 that states that there is no significant difference between the posttest mean scores of males and females in their understanding of acid-base concepts, two way analysis of covariance (ANCOVA) was run. Table 5.4 also gives the effect of gender difference on the understanding of acid and base concepts. The total findings for both two schools revealed that there was no significant mean difference between male and female students in terms of understanding acid and base concepts ($F = 0.398$; $p > 0.05$). The mean post-test scores for all students were 20.89 for males and 22.50 for females.

In addition, Table 5.5 indicates the effect of gender differences of the Anatolian High School students on the understanding of acid and base concepts. The findings revealed that there was no significant mean difference between male and female students in terms of understanding acid and base concepts ($F = 3.74$; $p > 0.05$). The mean post-test scores were 19.75 for males and 22.05 for females.

Further, Table 5.6 shows the effect of gender differences of Anatolian Teacher High School students on the understanding of acid and base concepts. The findings revealed that there was no significant mean difference between male and female students in terms of understanding acid and base concepts ($F=3.193$; $p>0.05$). The mean post-test scores were 24.42 for males and 23.42 for females.

**Hypothesis 3:**

To test hypothesis 3, which states that there is no significant effect of interaction between gender difference and treatment with respect to students' understanding of acid-base concepts, two-way analysis of covariance (ANCOVA) was used. Table 5.4 gives the interaction effect on understanding of acids and bases. The total findings for both schools revealed that there was not a significant effect of interaction between gender difference and treatment on students' understanding of acid and base concepts ($F = 1.145$; $p > 0,05$).

Table 5.5 indicates the interaction effect on understanding of acids and bases for the Anatolian High School. The findings revealed that there was not a significant effect of interaction between gender difference and treatment on the Anatolian High School students' understanding of acid and base concepts ($F = 0.093$; $p > 0,05$).

Table 5.6 shows the interaction effect on understanding of acids and bases for the Anatolian Teacher High School. The findings revealed that there was not a significant effect of interaction between gender difference and treatment on the Anatolian Teacher High School students' understanding of acid and base concepts ($F=2.429$; $p > 0,05$).

**Hypothesis 4:**

To analyze hypothesis 4 that states that there is no significant contribution of students' science process skills to understanding of acid-base concepts, two way analysis of covariance (ANCOVA) was used. Table 5.4 also represents the contribution of science process skill to the understanding of acids and bases for all students participated in this study. F value indicated that there was a significant contribution of science process skills on students' understanding of acid-base concepts ($F =20.70$; $p <0.05$).

In addition, Table 5.5 shows the contribution of science process skill to the understanding of acids and bases for the Anatolian High School. F value indicated that there was a significant contribution of science process skills on the Anatolian High School students' understanding of acid-base concepts ($F = 8.123$; $p < 0.05$).

Further, Table 5.6 indicates that there was a significant contribution of science process skills on the Anatolian Teacher High School students' understanding of acid-base concepts ($F = 8.693$; $p < 0.05$).

**Hypothesis 5:**

To answer the question posed by hypothesis 5 which states that there is no significant difference between post-test mean scores of the students taught with 5E learning cycle oriented instruction and traditionally designed chemistry instruction with respect to their attitudes toward chemistry as a school subject, two-way analysis of variance (ANOVA) was used. Table 5.19 summarizes the result of this analysis for all students.

**Table 5.19** ANOVA Summary for all students (Attitude)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment | 1 | 71.400 | 71.400 | 0.889 | 0.348 |
| Gender | 1 | 145.655 | 145.655 | 1.813 | 0.181 |
| Treatment*Gender | 1 | 878.029 | 878. 029 | 10.929 | 0.001 |
| Error | 115 | 9239.113 | 80.340 | | |

The total results of two schools showed that there was no significant difference between post-test mean scores of the students taught through instruction based on 5E learning cycle and traditionally designed chemistry instruction with respect to attitudes toward chemistry as a school subject.

In addition, Table 5.20 and Table 5.21 summarize the result of this analysis for Anatolian High School students, and Anatolian Teacher High School students respectively.

**Table 5.20** ANOVA Summary for the Anatolian High School students (Attitude)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment | 1 | 230.514 | 230.514 | 3.707 | 0.058 |
| Gender | 1 | 127.741 | 127.741 | 2.054 | 0.156 |
| Treatment*Gender | 1 | 527.309 | 527.309 | 8.480 | 0.005 |
| Error | 75 | 4663.960 | 62.186 | | |

**Table 5.21** ANOVA Summary for the Anatolian Teacher High School students (Attitude)

| Source | df | SS | MS | F | P |
|---|---|---|---|---|---|
| Treatment | 1 | 60.553 | 60.553 | 0.543 | 0.466 |
| Gender | 1 | 5.630 | 5.630 | 0.050 | 0.824 |
| Treatment*Gender | 1 | 448.644 | 448.644 | 4.022 | 0.052 |
| Error | 36 | 4015.456 | 111.540 | | |

The results indicated that there was no significant difference between post-test mean scores of Anatolian High School and Anatolian Teacher High School students taught through instruction based on 5E learning cycle and traditionally designed chemistry instruction with respect to attitudes toward chemistry as a school subject.

**Hypothesis 6:**

To test hypothesis 6, which claims that there is no significant difference between post-attitude mean scores of males and females, two-way analysis of variance (ANOVA) was run. Table 5.19, Table 5.20 and Table 5.21 also shows the effects of gender difference on students' attitudes respectively for both of the two schools, for an Anatolian High School and for an Anatolian Teacher High School. All of these tables indicated that there was no significant difference between the post-test mean scores of males and females with respect to attitudes toward chemistry as a school subject.

**Hypothesis 7:**

To test hypothesis 7, which states that there is no significant effect of interaction between gender difference and treatment with respect to students' attitudes toward chemistry as a school subject, two-way analysis of variance (ANOVA) was used. Table 5.19, Table 5.20, and Table 5.21 also gives the interaction effect on students' attitudes.

The findings revealed that there was a significant effect of interaction between gender difference and treatment on students' attitudes toward chemistry as a school subject for all students ($F = 10.929$; $p < 0.05$). Female students scored significantly higher than male students at attitudes toward chemistry as a school subject for experiment groups ($\overline{X}$(female) = 58.94, $\overline{X}$(male) = 51.25). However, in the control groups, male students scored significantly higher than female students at attitudes toward chemistry as a school subject ($\overline{X}$(female) = 51.92, $\overline{X}$(male) = 55.16).

There was also a significant effect of interaction between gender difference and treatment on students' attitudes toward chemistry as a school subject for the Anatolian High School students ($F = 8.480$; $p < 0.05$). Female students scored significantly higher than male students for experiment groups ($\overline{X}$(female) = 58.81,

$\overline{X}$(male) = 51.05). However, in the control groups, male students scored significantly higher than female students ($\overline{X}$(female) = 50.17, $\overline{X}$(male) = 52.81).

For the Anatolian Teacher High School, there was no significant effect of interaction between gender difference and treatment on students' attitudes toward chemistry as a school subject ($F = 4.022$; $p > 0.05$).

### 5.2 Interviews

In this study, interviews were applied to ten 11th grade students in two high schools to investigate the students' knowledge of acid-base concepts and the existence of any misconceptions. Five students from the experimental groups and five students from the control groups were selected based on achievement after their Acid Base Concepts Test scores. Students from each group were randomly selected who were middle achiever. Examples of excerpts from the interviews are given in Appendix I. In the appendix, $S_1$-$_5$ represents the students from the experiment groups, and $S_6$-$_{10}$ represents the students from the control groups. Moreover, "I" refers to the interviewer.

Interview was started with asking the descriptions of acids and bases. Responses to these first questions revealed that students in the experimental and the control groups had similar acid-base definition in their mind. Most of the participants described acids and bases by using the pH concept. Also, they frequently used the properties of acids/bases and daily life examples in their definitions. Further, when students were asked to classify the solutions of different compounds as acids and bases ($NH_3$; $HCl$; $Ca(OH)_2$; $CH_3COOH$; $H_2SO_4$), most of them gave correct responses. Then, students were asked to match the properties of acids and bases. Although almost all students in the sample could easily match the properties of acids and bases, they did not match one property of acids that requires the knowing that acids give reactions with carbonates.

As it was mentioned in chapter 4, interview questions were constructed related to the students' misconceptions obtained from Acid Base Concept Test after the treatment. The analysis of the results of the posttest indicated that students mostly had difficulty in the questions related with the weak and strong acids/bases. Therefore, in the interview, students spent a lot of time on answering the questions related with the strengths of acids/bases. For example, in the sixth question of the interview, students were asked to imagine themselves in a laboratory as preparing experiment about the strong acids. Thus, they need a strong acid solution to make an experiment. Here, interviewer stated that there were only two acid bottles without etiquette in the laboratory, one of which contained strong acid, and the other one contained weak acid. Then, interviewer showed some name of the materials on the cartons to the students, and wanted students to comment on the materials according whether they could be used to predict the strong acid bottle or not. These materials were: pH meter, a piece of Magnesium, titration materials with NaOH solutions, and titration materials with HCl solutions.

When students were asked whether the knowing the pH values of acid solutions was enough to predict the strong acid bottle, all of them said yes. Thus, all students in the sample confused the pH value with the strength, and they did not consider the concentration of solutions. For example, if the pH values of 0,1M $CH_3COOH$ and 0,001M HCl solutions is measured, approximately same pH values for these solutions (about pH= 3) will be found. As it is seen, the concentration of the solution is an important factor to make prediction about the strength of the solution. Then, interviewer reminded students that the concentrations of the acid solutions were not given, and asked the same question again, only two students from the experimental groups changed their answers and stated correctly that if the concentration were not given, we could not any comment about the strength of acid solutions.

The other misconception indicated in the interview was about the reactions between the strong/weak acids and Magnesium metal. The responses implied that students had learned that acids gave reaction with active metals, but they did not grasp how the strength of the acid affects this reaction.

In addition, when interviewer asked the titration, experimental group students could easily gave answer; however, control group students did not remember exactly what the titration is. Unfortunately, also it was observed that even experimental group students did not understand that the same amount of bases required in the titration to neutralize the same amount of weak acids and strong acids.

As a second part of the sixth question, interviewer showed some information, instead of materials, written on the cartons and asked to students whether this information could be useful to discriminate the strong acid bottle. The information written on the cartons was: the number of Hydrogen that the molecule of acid contains, pOH value, electrical conductivity, and concentrations of the solutions.

The responses of students in all groups showed that almost all students knew that the number of Hydrogen in the molecule of acid does not affect acid's strength. Moreover, all experimental group students correctly stated that electrical conductivity of the strong acids should be more than that of the weak acids, because ionization of the strong acids is much more than that of the weak acids. However, only one student from the control group students gave the correct answer to this comparison question about the electrical conductivities of strong and weak acids.

In addition, responses of students indicated that students in all groups understood the pOH value. However, all control group students confused the pOH value with the strength. In contrast to the control groups, most students in the experimental groups grasped the differences between the strength and the pOH value of solution.

When students were asked to compare the amount of $OH^-$ ions in the 5 mL solutions of weak and strong bases, all students, except two control group students, gave correct answer that the amount of $OH^-$ ions in the solutions of strong base should be more than that of weak bases. Then, students were asked to compare the amount of $H^+$ ions required to neutralize the same amount of weak and strong base solutions. In the response to this question, whereas all students from the experiment groups correctly stated that the same amount of $H^+$ ions require to neutralize the same amount of weak and strong bases, only one students from the control groups could response accurately to this question.

In the interview, students were also asked to draw and explain the structure of the pure water, $HCl_{(aq)}$, and $CH_3COOH_{(aq)}$. Then, interviewer asked students to make a comment on what happen if NaOH(aq) was added to these $HCl_{(aq)}$, and $CH_3COOH_{(aq)}$ solutions. Drawings of students are also shown in Appendix I.

Whereas almost all students in the experiment groups accurately drew and explained $HCl_{(aq)}$, only one student could correctly showed it. Moreover, more students from the experiment groups could accurately draw and explain $CH_3COOH_{(aq)}$. Drawings indicated that most control group students could not understand the differences between the $HCl_{(aq)}$ and $CH_3COOH_{(aq)}$. These students could easily identified $HCl_{(aq)}$ as a strong acid solution and $CH_3COOH_{(aq)}$ as a weak acid solution. However, they did not show the differences between these two solutions in their drawings.

When students asked questions about the neutralization reaction between the $HCl_{(aq)}$ (strong acid) and $NaOH_{(aq)}$ (strong base), all of them correctly answered. However, when they were asked to comment on the neutralization reaction between the $CH_3COOH_{(aq)}$ (weak acid) and $NaOH_{(aq)}$ (strong base), most of them in the both groups showed low achievement. Unfortunately, most students in the experiment and control groups had misconception that when one of the reactants (acid or base) is weak, the neutralization does not completely take place.

Overall, the results of this interview provides the evidence that using 5E learning cycle model improve students' understanding of acids-base concepts and help students to remove their misconceptions more effectively than the traditional method did.

### 5.3 Descriptive Analyses of T-VOSTS Items

In this study, students' views about the nature of science was investigated descriptively. Each of the VOSTS items was consisted of a stem and different number of alternatives, which reflected some kind of views changing from realistic to naïve. Three-category scoring scheme, described by Bradford, Rubba and Harkness (1995) according to the following definitions, was used: Realistic (R) – the choices expresses an appropriate view on the nature of science relative to the item stem; Has Merit (HM) – while not realistic, the choices expresses a number of legitimate points about the nature of science relative to the item stem; Naive (N) – the choices expresses a view about the nature of science, relative to the item stem, that is inappropriate or not legitimate. The items are examined respondents' views on different topics about the nature of science. These topics and item numbers are given below (Erdoğan, 2004):

- *Definitions of Science*
    - Defining science (Item1).
- *Nature of Scientific Knowledge*
    - Nature of observations (Item 2).
    - Nature of scientific models (Item 3).
    - Nature of classification schemes (Item 4).
    - Tentativeness of scientific knowledge (Item 5).
    - Hypotheses, theories and laws (Items 6, 7, 8).
    - Scientific approach to investigations (Items 9, 10, 11, 12, 13).
    - Precision and uncertainty in scientific/technological knowledge (Item 14).
    - Logical reasoning (e.g., cause/effect problems, epidemiology and etiology (Item 15).
    - Fundamental assumptions for all science (Item 16).
    - Epistemological status of scientific knowledge (Items 17, 18, 19).
    - Paradigms versus coherence of concepts across disciplines (Items 20, 21).

The following results were obtained from the items were answered by all of the students in our sample. The results were summarized in Tables 5.22 -5.42. (See also Appendix J for the results obtained separately from the answers of the students in experimental and control groups). Each table presented the following information on one of the VOSTS items: (1) the item statement; (2) the item’s multiple choice categorized by the Realistic/Has Merit/Naive scheme; and (3) the multiple-choice response percentage data for each sample.

**Defining Science (Item 1)**

Item 1 was about the students’ views on defining science. Students’ images of science will certainly show their views on its epistemology. When students were asked about definition of science, their responses varied. Science was seen by students as: a body of knowledge (18,5%, alternative B), exploring the unknown (29,4%, alternative C), improving the world (36,1%, alternatives E and F), a social institution (3,4%, alternative G), and indefinable (4,2%, alternative H). Students had not acquired uniform view of science.

36,1 percent of the whole sample (alternative E and F) confused the science and technology with each other. 1,7 % of the students thought science as a field of biology, chemistry, and physics. Unfortunately, the most contemporary view about science (alternative G) which gives social aspects of science was selected only 3,4 %. The percentages of all students’ selection of alternatives are given below:

**Table 5.22** Percentage of all students' responses to item 1

| Defining science is difficult because science is complex and does many things. But MAINLY science is: | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **1.7** | **A. A study of fields such as biology, chemistry and physics.** |
| **18.5** | **B. A body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).** |
| **29.4** | **C. Exploring the unknown and discovering new things about our world and universe and how they work.** |
| **3.4** | **D. Carrying out experiments to solve problems of interest about the world around us.** |
| **0.8** | **E. Inventing or designing things (i.e., artificial hearts, computer, space vehicles).** |
| **35.3** | **F. Finding and using knowledge to make this world a better place to live in (i.e., curing diseases, solving pollution and improving agriculture).** |
| **3.4** | **G. An organization of people (called scientists) who have ideas and techniques for discovering new knowledge.** |
| **4.2** | **H. No one can define science.** |
| **Naïve: 60.5 %** **Has Merit: 32.8%** **Realistic: 3.4%** | |

### Nature of Observations (Item 2)

This item was asked to indicate whether the students believed 100% alikeness in scientific observations or not. According to the responses of students, 24,4 (alternative A), and 45,4 (alternative B) percentages thought that scientific observations made by competent scientists will usually be different if the scientists believe different theories. This view is consistent with the contemporary view. Thus, most students had realistic views about scientific observations. On the other hand, alternative C (19,3%), alternative D (6,7%), and alternative E (1,7 %) selected by students who thought that observations of different scientists would be almost identical even when scientists based their questions on different theories.

**Table 5.23** Percentage of all students' responses to item 2

| **Scientific observations made by competent scientists will usually be different if the scientists believe different theories.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **24.4** | **A. Yes, because scientists will experiment in different ways and will notice different things.** |
| **45.4** | **B. Yes, because scientists will think differently and this alter their observations.** |
| **19.3** | **C. Scientific observations will not differ very much even though scientists believe different theories. If the scientists are indeed competent their observations will be similar.** |
| **6.7** | **D. No, because, observations are as exact as possible. This is how science has been able to advance.** |
| **1.7** | **E. No, observations are exactly what we see and nothing more; they are the facts.** |
| **Naïve: 27,7 %** | **Realistic: 69,8%** |

### Nature of Scientific Models (Item3)

Do students see models as duplicates of reality or as human inventions? Responses of the students investigated that students held essentially three positions (Table 5.24): models are copies of reality (47 %, alternatives A, B and C); models come close to being copies of reality (21%, alternative D); and models are not copies of reality (27,8%, alternatives E, F and G). Thus, 68 % of the participants (alternatives A, B, C and D) held a naïve view contrary to the contemporary epistemology of science.

**Table 5.24** Percentage of all students' responses to item 3

| **Many scientific models used in research laboratories (such as the model of DNA, or the atom) are copies of reality.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **-** | **A. Scientific models are copies of reality: Because scientists say they are true, so they must be true.** |
| **21.8** | **B. Scientific models are copies of reality: Because much scientific evidence has proven them true.** |
| **25.2** | **C. Scientific models are copies of reality: Because they are true to life. Their purpose is to show us reality or teach us something about it.** |
| **21,0** | **D. Scientific models come close to being copies of reality, because they are based on scientific observations and research.** |
| **5,9** | **E. Scientific models are not copies of reality: Because they are simply helpful for learning and explaining, within their limitations.** |
| **14,3** | **F. Scientific models are not copies of reality: Because they change with time and with the state of our knowledge, like theories do.** |
| **7,6** | **G. Scientific models are not copies of reality: Because these models must be ideas or educational guesses, since you can't actually see the real thing.** |
| **Naïve: 68%** **Has Merit: 21,9%** **Realistic: 5,9%** | |

### Nature of Classification Schemes (Item 4)

Item 4 was asked students how the scientists classifying the nature. 22,7% (alternatives A and B) of students thought classification schemes matched the way nature really is, whereas 53,7 % (alternatives D, E and F) recognized the human inventive character of scientific classification schemes. Apparently, students were more familiar with the epistemology of classification schemes than they were with models. Table 5.25 presents the percentages of the students' selection of alternatives in T-VOST:

**Table 5.25** Percentage of students' responses to item 4

| When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **6.7** | **A. Classifications match the way nature really is, since scientists have proven them over many years of work.** |
| **16.0** | **B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.** |
| **21.0** | **C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.** |
| **18,5** | **D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.** |
| **17,6** | **E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.** |
| **17,6** | **F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is too diverse. Thus, scientists could correctly use more than one classification scheme.** |
| **Naïve: 22,7%** **Has Merit: 21,0%** **Realistic: 53,7%** | |

### Tentativeness of Scientific Knowledge (Item 5)

As shown in Table 5.26, the majority believed that scientific knowledge changes. One of the important characteristics of the scientific knowledge is its tentativeness. Students selecting the first two alternatives A and B, (86,6 %) were considered to believe that scientific knowledge was subject to change. On the other hand, remaining students selecting alternatives C and D (11,7 %) believed that facts were unchangeably true, in other words, were not tentative. Thus, most students held contemporary views about the tentativeness of scientific knowledge.

**Table 5.26** Percentage of students' responses to item 5

| **Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **58.0** | **A. Scientific knowledge changes: because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigations.** |
| **28.6** | **B. Scientific knowledge changes: because the old knowledge is reinterpreted in the light of new discoveries. Scientific facts can change.** |
| **6.7** | **C. Scientific knowledge appears to change because the interpretation or the application of the old facts can change. Correctly done experiments yield unchangeable facts.** |
| **5.0** | **D. Scientific knowledge appears to change because new knowledge is added on to old knowledge, the old knowledge doesn't change.** |
| **Naïve: 11,7%** | **Realistic: 86,6%** |

### Hypotheses, Theories and Laws (Item 6, 7 and 8)

Do students view hypotheses, theories, and laws as different types of statements? Unfortunately, only 2,5% of the students in the sample had contemporary views about the hypotheses, theories, and laws (alternative E). Almost all students in the sample (89,9%) expressed a simplistic hierarchical relationship in which hypotheses become theories and theories become laws, depending on the amount of proof behind the idea. However, theories and laws are different types of statements, and both are distinguished from hypotheses by virtue of the degree to which they have been accepted by the scientific community (Table 5.27).

**Table 5.27** Percentage of students' responses to item 6

| Scientific ideas develop from hypotheses to theories, and finally, if they are good enough to being scientific laws. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **66.4** | **A. Hypotheses can lead to theories which can lead to laws: because a hypothesis is tested by experiments, if it proves correct, it becomes a theory. After a theory has been proven true many times by different people and has been around for a long time, it becomes a law.** |
| **21.8** | **B. Hypotheses can lead to theories which can lead to laws: because a hypothesis is tested by experiments if there is supporting evidence, it is a theory. After a theory has been tested many times and seems to be essentially correct, it's good enough to become a law.** |
| **1.7** | **C. Hypotheses can lead to theories which can lead to laws: because it is logical way for scientific ideas to develop.** |
| **3.4** | **D. Theories can't become laws because they both are different types of ideas. Theories are based on scientific ideas which are less than %100 certain, and so theories can't be proven true. Laws, however, are based on facts only and are %100 sure.** |
| **2.5** | **E. Theories can't become laws because they both are different types of ideas. Laws describe things in general. Theories explain these laws. However, with supporting evidence, hypotheses may become theories (explanations) or laws (descriptions).** |
| **Naïve: % 93.3** | **Realistic: 2,5%** |

Item 7 investigated students' views on the scientific assumptions. It indicated that when developing new theories or laws, scientists needed to make certain assumptions about the nature. The item questioned whether these assumptions must be true or not in order for science to progress properly. In response to this item, 16,8 % (alternative E) of the students gave the realistic answer, which stated that scientists must make some true or false assumptions in order to start an investigation (Table 5.28). Other students (about 79,9 % of the whole sample) selected A, B, C, D and F alternatives, which were inconsistent with the contemporary views.

**Table 5.28** Percentage of students' responses to item 7

| **When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions *must* be *true* in order for science to progress properly.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **20.2** | **A. Assumptions MUST be true in order for science to progress: because correct assumptions are need for correct theories and laws. Otherwise scientists would waste a lot of time and effort using wrong theories and laws.** |
| **5.9** | **B. Assumptions MUST be true in order for science to progress: otherwise society would have serious problems, such as inadequate technology and dangerous chemicals.** |
| **21.0** | **C. Assumptions MUST be true in order for science to progress: because scientists do research to prove their assumptions true before going on with their work.** |
| **25.2** | **D. It depends. Sometimes science needs true assumptions in order to progress. But sometimes history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.** |
| **16.8** | **E. It doesn't matter. Scientists have to make assumptions, true or not, in order to get started on a project. History has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.** |
| **7.6** | **F. Scientists do not make assumptions. They research an idea to find out if the idea is true. They don't assume it is true.** |
| **Naïve: 79,9%** | **Realistic: 16,8%** |

The last item was about the students' views on simplicity (or complexity) of language used in science and to question their views on the nature of theories. About 72,3% of the students (alternatives A, B, and D) held realistic views about this topic and they took part in the favor of simplicity of scientific knowledge. On the other hand, the most realistic answer (alternative A) to that item was selected about 24,4% of the whole sample. Also, only about 20,9% (selecting alternatives C, E, and F) of whole students believed that complexity was the prerequisite for the quality of a theory. The percentages of the students' selection of alternatives are given below:

**Table 5.29** Percentage of students' responses to item 8

| Good scientific theories explain observations well. But good theories are also *simple* rather than complex. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **24.4** | **A. Good theories are simple. The best language to use in science is simple, short, direct language.** |
| **23.5** | **B. It depends on how deeply you want to get into the explanation. A good theory can explain something either in a simple way or in a complex way.** |
| **13.4** | **C. It depends on the theory. Some good theories are simple, some are complex.** |
| **24.4** | **D. Good theories can be complex, but they must be able to translate into simple language if they are going to be used.** |
| **2.5** | **E. Theories are usually complex. Some things cannot be simplified if a lot of details are involved.** |
| **5.0** | **F. Most good theories are complex. If the world was simpler, theories could be simpler.** |
| **Naïve: 20,9%** **Has Merit: 47,9%** **Realistic: 24,4%** | |

**Scientific Approach to Investigations (Item 9, 10, 11, 12 and 13)**

When participants were asked about the definition of the scientific method, their responses varied. The scientific method was seen by many students as: "questioning, hypothesizing, collecting data and concluding" (44,5%), "testing and retesting- proving something true or false in a valid way" (11,8%), and "getting facts, theories or hypotheses efficiently" (10,1%). The remaining respondents spread their choices over the other seven positions. Unfortunately, the most contemporary view about the scientific method (alternative J) which stated that "there really is no such thing as the scientific method" was selected only 1,7 %.

**Table 5.30** Percentage of students' responses to item 9

| **When scientists investigate, it is said that they follow the scientific method. The scientific method is:** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **4.2** | **A. the lab procedures or techniques; often written in a book or journal, and usually by a scientist.** |
| **5.0** | **B. recording your results carefully.** |
| **7.6** | **C. controlling experimental variables carefully, leaving no room for interpretation.** |
| **10.1** | **D. getting facts, theories or hypotheses efficiently.** |
| **11.8** | **E. testing and retesting- proving something true or false in a valid way.** |
| **8.4** | **F. postulating theory then creating an experiment to prove it.** |
| **44.5** | **G. questioning, hypothesizing, collecting data and concluding.** |
| **1.7** | **H. a logical and widely accepted approach to problem solving.** |
| **1.7** | **I. an attitude that guides scientists in their work** |
| **1.7** | **J. Considering what scientists actually do, there is no such thing as the scientific method.** |
| **Naïve: 48,8%** **Has Merit: 46,2%** **Realistic: 1,7%** | |

As evidenced by Table 5.31, when students were asked whether the best scientists "follow the steps of the scientific method", they tended to favor those positions which suggest that there is a definite pattern to doing science (74%, alternatives A, B and C). Moreover, about 37% of the students selected alternative C in which creativity, imagination and originality had important places in carrying out scientific investigations. Also, 6,7% of the whole sample selected alternative E that many scientific discoveries were made by accident, a view supported by media. Unfortunately only 12,6% of the students chose the contemporary view of most epistemologists which stated that "use any method that might get favorable results" (alternative D). The idea of using any method corresponds in most participants' minds to the idea that there is no such thing as the scientific method.

**Table 5.31** Percentage of students' responses to item 10

| The best scientists are those who follow the steps of the scientific method. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **33.6** | **A. The scientific method ensures valid, clear, logical, and accurate results. Thus, most scientists will follow the steps of the scientific method.** |
| **3.4** | **B. The scientific method should work well for most scientists; based on what we learned in school.** |
| **37.0** | **C. The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.** |
| **12.6** | **D. The best scientists are those who use any method that might get favorable results (including the method of imagination and creativity).** |
| **6.7** | **E. Many scientific discoveries were made by accident, and not by sticking to the scientific method.** |
| **Naïve: 43,7%** | **Has Merit: 37,0%** **Realistic: 12,6%** |

Item 11 was asked to indicate whether the students believed scientific discoveries result from a logical series of investigations or not. To that item, 63% (alternative A and B) of the participants agreed that scientific discoveries result from a logical series of investigation, which is a view consistent with contemporary views. On the other hand, about 22,7% of the all sample agreed that scientific discoveries do not occur as a result of series investigations. In Table 5.32, the percentages of the students' selection of alternatives in the T-VOSTS are presented:

**Table 5.32** Percentage of students' responses to item 11

| Scientific discoveries occur as a result of series of investigations, each one building on an earlier one, and each one leading logically to the next one, until the discovery is made. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **31.9** | **A. Scientific discoveries result from a logical series of investigations: because experiments (for example, the experiments that led to the model of the atom, or discoveries about cancer) are like laying bricks onto a wall.** |
| **31.1** | **B. Scientific discoveries result from a logical series of investigations: because research begins by checking the results of an earlier experiment to see if it is true. A new experiment will be checked by the people who come afterwards.** |
| **11.8** | **C. Usually scientific discoveries result from a logical series of investigations. But science is not completely logical. There is an element of trial and error, hit and miss, in the process.** |
| **20.2** | **D. Some scientific discoveries are accidental or they are the unpredicted product of the actual intention of the scientists. However, more discoveries result from a series of investigations building logically one upon the other.** |
| **0.8** | **E. Most scientific discoveries are accidental or they are unpredicted product of the actual intention of the scientist. Some discoveries result from a series of investigations building logically one upon the other.** |
| **-** | **F. Scientific discoveries do not occur as a result of a logical series of investigations: because discoveries often result from the piecing together of previously unrelated bits of information.** |
| **1.7** | **G. Scientific discoveries do not occur as a result of a logical series of investigations: because discoveries often occur as a result of a wide variety of studies which originally had nothing to do with each other, but which turned out to relate to each other in unpredictable ways.** |
| **Naïve: 22,7%    Has Merit: 11,8%    Realistic: 63%** | |

Item 12 stated that when scientists write an article, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way. The item questioned whether these assumptions must be true or not. When students were asked to the scientists' way while writing articles, the largest group (46,3%) gave the realistic answer (alternatives A and B). Also, the next large student group (22,7%) chose the alternative C which was very close to the contemporary views but still sitting on the fence. On the other hand, about 21% of the all respondents selected alternatives D, E, F, and G which were inconsistent with the contemporary views (Table 5.33).

**Table 5.33** Percentage of students' responses to item 12

| **Scientists publish the result of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **34.5** | **A. Articles are written in a more logical way than the actual work: because scientists can think and work without following a set plan. Consequently, if you read the actual order of their thoughts and procedures, it would be confusing. Therefore, scientists write logically so other scientists will understand the results.** |
| **11.8** | **B. Articles are written in a more logical way than the actual work: because scientific hypotheses are personal views or guesses and thus are not logical. Scientists, therefore, write logically so other scientists will understand the results.** |
| **22.7** | **C. Scientists usually don't want to give away "the recipe" but they do want to tell the world about their results. So they write it up logically but in a way that does not reveal how it was actually done.** |
| **5.9** | **D. It depends. Sometimes scientific discoveries happen by accident. But other times discoveries happen in a logical orderly way, just like the articles are written.** |
| **10.1** | **E. Articles are written in a logical way showing how the actual work was done: because a scientist's work is conducted logically; otherwise, it would not be useful to science and technology.** |
| **2.5** | **F. Articles are written in a logical way showing how the actual work was done: because scientists do work in a logical way so that their published report will be easier to write in a logical way.** |
| **2.5** | **G. Articles are not necessarily written in a logical way. They're written the work was done. This can be complicated or straightforward.** |
| **Naïve: 21%** **Has Merit: 22,7%** **Realistic: 46,3%** | |

Item 13 was about scientists' errors in their work. To that item, about 57,2% (alternatives D and E) of the students gave the realistic answer. As it may be seen in Table 5.34, many students held realistic views about inevitable characteristics of errors. On the other hand, students selecting alternatives A and B (about 26,9%) disregarded the fact that scientists are human beings. Humans make mistakes and learn from them, many things are learned with the method of trial and error.

**Table 5.34** Percentage of students' responses to item 13

| **Scientists should NOT make errors in their work because these errors slow the advance of science.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **21.0** | **A. Errors slow the advance of science. Misleading information can lead to false conclusions. If scientists don't immediately correct the errors in their results, then science is not advancing.** |
| **5.9** | **B. Errors slow the advance of science. New technology and equipment reduce errors by improving accuracy and so science will advance faster.** |
| **12.6** | **C. Errors CANNOT be avoided: so scientists reduce errors by checking each others' results until agreement is reached.** |
| **53.8** | **D. Errors CANNOT be avoided: some errors can slow the advance of science, but other errors can lead to a new discovery or breakthrough. If scientists learn from their errors and correct them, science will advance.** |
| **3.4** | **E. Errors most often help the advance of science. Science advances by detecting and correcting the errors of the past.** |
| **Naïve: 26,9%** **Has Merit: 12,6%** **Realistic: 57,2%** | |

## Precision and Uncertainty in Scientific/Technological Knowledge (Item 14)

Item 14 was related with the views about precision and uncertainty in scientific/technological knowledge. About half of the students (about 57,1% selected A and B alternatives) were aware of the uncertainty of scientific knowledge and predictions made by scientists and engineers and so it may be concluded that they had realistic views. Only about 4,2% of the students (alternative E) held naive views about predictions, they believed that if there was accurate knowledge and enough information then predictions had to be certain. About 31,9 % of the respondents were between two viewpoints. The percentages of respondents' selection of alternatives are given below:

**Table 5.35** Percentage of students' responses to item 14

| **Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what *probably* might happen. They cannot tell what will happen for certain.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **33.6** | **A. Predictions are NEVER certain: because there is always room for error and unforeseen events which will affect a result. No one can predict the future for certain.** |
| **23.5** | **B. Predictions are NEVER certain: because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.** |
| **22.7** | **C. Predictions are NEVER certain: because a prediction is not a statement of fact. It is an educated guess.** |
| **9.2** | **D. Predictions are NEVER certain: because scientists never have all the facts. Some data are always missing.** |
| **4.2** | **E. It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.** |
| **Naïve: 4,2%** **Has Merit: 31,9%** **Realistic: 57,1%** | |

### Logical reasoning (Item 15)

Item 15 investigated the knowledge of students about cause and effect (logical reasoning) relationships. As it may be seen in Table 5.36, the majority of the students (70,6%) knew cause-and effect relationships (alternatives B and C). On the other hand, about 22,7% of the students were unaware of these relationships.

**Table 5.36** Percentage of students' responses to item 15

| If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **11.8** | **A. The facts obviously prove that asbestos causes lung cancer. If asbestos workers have a greater chance of getting lung cancer, then asbestos is the cause.** |
| **27.7** | **B. The facts do NOT necessarily mean that asbestos causes lung cancer: because more research is needed to find out whether it is asbestos or some other substance that causes the lung cancer.** |
| **42.9** | **C. The facts do NOT necessarily mean that asbestos causes lung cancer: because asbestos might work in combination with other things, or may work indirectly (for example, weakening your resistance to other things which cause you to get lung cancer).** |
| **10.1** | **D. The facts do NOT necessarily mean that asbestos causes lung cancer: because if it did, all asbestos workers would have developed lung cancer.** |
| **0.8** | **E. Asbestos cannot be the cause of lung cancer because many people who don't work with asbestos also get lung cancer.** |
| **Naïve: 22,7%** | **Realistic: 70,6%** |

**Fundamental Assumptions for All Science (Item 16)**

Item 16 was related with the topic of science and supernatural being or deity. The results in Table 5.37 provide insights into students' responses. To that item, 47,9 % (alternative A and B) of the participants gave the realistic answer. On the other hand, about 40,3% of the whole sample had a view, which conflict with the tenets of the epistemology of science, that a supernatural being could alter the natural world (alternatives C and D). Further, an small number of students (about 1,7%) thought that science was not limited and that scientists could investigate the supernatural (alternative E).

**Table 5.37** Percentage of students' responses to item 16

| **Science rests on the assumption that the natural world *cannot* be altered by a supernatural being (for example, a deity).** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **26.1** | **A. Scientists assume that a supernatural being will NOT alter the natural world: because the supernatural is beyond scientific proof. Other views, outside the realm of science, may assume that a supernatural being can alter the natural world.** |
| **21.8** | **B. Scientists assume that a supernatural being will NOT alter the natural world: because if a supernatural being did exist, scientific facts could change in the wink of an eye. BUT scientists repeatedly get consistent results.** |
| **8.4** | **C. It depends. What scientists assume about a supernatural being is up to individual scientists.** |
| **31.9** | **D. Anything is possible. Science does not everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world.** |
| **1.7** | **E. Science can investigate the supernatural and can possibly explain it. Therefore, science can assume the existence of supernatural beings.** |
| **Naïve: 42%** | **Realistic: 47,9%** |

## Epistemological Status of Scientific Knowledge (Item 17, 18 and 19)

Item 17 investigated whether students viewed laws as discoveries or inventions while investigating their views on characteristics of laws. According to Table 5.38, it might be said that the majority of the sample (about 71,4%) viewed laws as discoveries by selecting alternatives A, B, and C. In addition to that, alternative D is an erroneous view that media uses, selected by 5,9% of the whole respondents. Moreover, 16,8% of the students gave a realistic answer to that question by selecting alternative E which was stated that scientists invent laws.

**Table 5.38** Percentage of students' responses to item 17

| | |
|---|---|
| **For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific LAWS. Others think that scientists invent them. What do you think?** | |
| **%** | ***Your Position, Basically:*** |
| **31.9** | **A. Scientists discover laws: because the laws are out there in nature and scientists just have to find them.** |
| **8.4** | **B. Scientists discover laws: because the laws are based on experimental facts.** |
| **31.1** | **C. Scientists discover laws: but scientists invent the methods to find those laws.** |
| **5.9** | **D. Some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know.** |
| **16.8** | **E. Scientists invent laws, because scientists interpret the experimental facts which they discover. Scientists don't invent what nature does, but they do invent the laws which describe what nature does.** |
| **Naïve: 77,3%** | **Realistic: 16,8%** |

When in item 17, the term law was replaced by the terms "hypothesis" (item 18) and "theory" (item 19), students expressed very similar to their views on scientific theories and hypothesis. Because the next two items were similar, responses given to them were also similar, and so they were analyzed together.

Item 18 were asked whether hypotheses were discoveries or inventions and item 19 was asked whether theories were discoveries or inventions. About 65,5 percent of the whole respondents for item 18 (Table 5.39) and about 68 percent of the whole respondents for item 19 (Table 5.40) had views which were inconsistent with contemporary views by selecting A, B, C, and D alternatives. On the other hand, 26,9% (alternatives E and F) of the respondents in item 18 and 24,4% (alternatives E and F) of the respondents in item 19 held contemporary views about nature of theories and hypotheses.

**Table 5.39** Percentage of students' responses to item 18

| For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists invent them. What do you think? | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **26.9** | **A. Scientists discover a hypothesis: because the idea was there all the time to be uncovered.** |
| **13.4** | **B. Scientists discover a hypothesis: because it is based on experimental facts.** |
| **20.2** | **C. Scientists discover a hypothesis: but scientists invent the methods to find the hypotheses.** |
| **5.0** | **D. Some scientists may stumble onto a hypothesis by chance, thus discovering it. But other scientists may invent hypothesis from facts they already know.** |
| **16.0** | **E. Scientists invent a hypothesis: because a hypothesis is an interpretation of experimental facts which scientists have discovered.** |
| **10.9** | **F. Scientists invent a hypothesis: because inventions (hypothesis) come from the mind-we create them.** |
| **Naïve: 65,5%** **Has Merit: 16,0%** **Realistic: 10,9%** | |

**Table 5.40** Percentage of students' responses to item 19

| For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists invent them. What do you think? | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **13.4** | **A. Scientists discover a theory: because the idea was there all the time to be uncovered.** |
| **23.5** | **B. Scientists discover a theory: because it is based on experimental facts.** |
| **26.1** | **C. Scientists discover a theory: but scientists invent the methods to find the theories.** |
| **5.0** | **D. Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent theory from facts they already know.** |
| **18.5** | **E. Scientists invent a theory: because a theory is an interpretation of experimental facts which scientists have discovered.** |
| **5.9** | **F. Scientists invent a theory: because inventions (theories) come from the mind-we create them.** |
| **Naïve: 68%** **Has Merit: 18,5%** **Realistic: 5,9%** | |

**Paradigms versus Coherence of Concepts across Disciplines (Item 20 and 21)**

In response to item 20, about 33,6% of participants had a contemporary view on the nature of scientific ideas. Also, alternative B selected by about 23,5% of the students, which was very close to contemporary views. On the other hand, views of students selecting alternatives C, D, and E (30,2%) were inconsistent with contemporary views about scientific ideas. Table 5.41 presents the percentages of participant's selection of alternatives in the T-VOSTS:

**Table 5.41** Percentage of students' responses to item 20

| Scientists in different fields look at the same thing from very different points of view (for example, $H^+$ causes chemists to think of acidity and physicists to think of protons). This makes it difficult for scientists in different fields to understand each others' work. | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **33.6** | **A. It is difficult for scientists in different field to understand each other: because scientific ideas depend on the scientists' viewpoint or on what the scientist is used to.** |
| **23.5** | **B. It is difficult for scientists in different field to understand each other: because scientists must make an effort to understand the language of other fields which overlap with their own fields.** |
| **10.9** | **C. It is fairly easy for scientists in different fields to understand each other: because scientists are intelligent and so they can find ways to learn the different languages and points of view of another field.** |
| **5.9** | **D. It is fairly easy for scientists in different fields to understand each other: Because they have likely studied the various at one time.** |
| **13.4** | **E. It is fairly easy for scientists in different fields to understand each other: Because scientific ideas overlap from field to field. Facts are facts no matter what the scientific field is.** |
| **Naïve: 30.2%  Has Merit: 23.5%  Realistic: 33.6%** | |

In item 21, the meanings of the scientific ideas were asked. The alternative A selected by about 38,7% of the students was the most contemporary view. Also, alternative B selected by about 22,7% of the whole respondents was very close realistic view. On the other hand, students who selected alternatives C, D, and E (about 27,8%) were not consistent with contemporary views about the nature of scientific ideas. In Table 5.42, the percentages of the students' selection of alternatives are presented:

**Table 5.42** Percentage of students' responses to item 21

| **Scientists in different fields look at the same thing from very different points of view (for example, $H^+$ causes chemists to think of acidity and physicists to think of protons). This means that one scientific idea has different meanings, depending on the field a scientist works in.** | |
|---|---|
| **%** | ***Your Position, Basically:*** |
| **38.7** | **A. A scientific idea will have the different meaning in various fields: because scientific ideas can be interpreted differently in one field than in another.** |
| **22.7** | **B. A scientific idea will have the different meaning in various fields: because scientific ideas can be interpreted differently, depending on the individual scientist's point of view or on what the scientist already knows.** |
| **11.8** | **C. A scientific idea will have the same meaning in all fields: because the idea still refers to the same real thing in nature, no matter what point of view the scientist takes.** |
| **12.6** | **D. A scientific idea will have the same meaning in all fields: because all sciences are closely related to each other.** |
| **3.4** | **E. A scientific idea will have the same meaning in all fields: in order to allow people in different fields to communicate with each other. Scientists must agree to use the same meanings.** |
| **Naïve: 27,8%** **Has Merit: 22,7%** **Realistic: 38,7%** | |

## 5.4 Conclusions

The following conclusions can be drawn from the results:

1. The 5E model caused a significantly better acquisition of scientific conceptions related to acids and bases and elimination of misconceptions than TDCI.

2. The 5E model and TDCI developed the similar attitude toward science as a school subject.

3. Science process skill had a significant contribution to the students' understanding of chemical bonding concepts.

4. There was no significant difference between female and male with respect to understanding of acid-base concepts and attitude towards chemistry as a school subject.

5. There was no significant effect of interaction between the gender and treatment on students' understanding of acid-base concepts.

6. Students held some inconsistent views on nature of science issue.

# CHAPTER 6

# DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

## 6.1 Discussion

The major purpose of this study was to compare the effects of instruction based on 5E learning cycle model over traditionally designed chemistry instruction on eleventh grade students' understanding of acid-base concepts.

In the light of the results obtained from the analyses, it can be concluded that the instruction based on 5E learning cycle model caused a significantly better acquisition of the scientific conceptions related to acid-base concepts. In other words, students in the experimental groups instructed by 5E learning showed higher performance than students in the control groups instructed by traditionally designed chemistry instruction with respect to acid-base concepts. In addition, analysis of the interview, which is implemented at the end of the study to learn the reasons of students' misconceptions even after the treatments, indicated that 5E model was more successful in eliminating students' misconceptions than traditionally designed chemistry instruction. These aforementioned results of this study are in agreement with the other studies reported in the literature (i.e., Colburn and Clough, 1997; Bevenino, Dengel and Adams, 1999; Lord, 1999; Coulson, 2002).

Moreover, this study provides the evidence that students have considerable degree of misconceptions related to acid-base concepts, and some of these misconceptions are very resistant to change even after implementation of the treatments. These results also have consisted with the results of the previous studies (i.e., Ross, 1989; Zoller, 1990). If these misconceptions are not corrected, they affect further learning negatively. Therefore, teacher must identify students' misconceptions and find out to prevent them from occurring.

The 5E learning cycle model used in this study was designed to incorporate all aspects of constructivist learning environments by engaging and allowing students to explore the concepts being introduced, discover explanations for the concepts they are learning, and elaborate on what they have learned by applying their knowledge to new situations (MaryKay, and Megan, 2007). In addition, teachers used 5E learning cycle model in the study to activate students' prior knowledge and misconceptions and to help them to understand and apply the acid-base concepts through the use of explanations, demonstrations, experiments and examples.

On the other hand, in the control group, teachers used traditional strategies, which were dependent on teacher exploration without consideration of students' previous experiences and misconceptions. That is, students in the control group were passive listeners and they are not allowed to construct their knowledge.

Traditionally designed methods are not so effective in developing conceptual understanding of the subject matter and removing misconceptions. On the contrary, 5E model are the effective teaching strategies to dispel students' misconceptions and enhance understanding of acid-base concepts. The significant difference in experimental group students' performances could be attributed to the 5E model experiences that gave students the opportunity to question and formulate problems, manipulate materials, observe and record data, and reflect on and construct knowledge from the data. This procedure helped students to learn meaningfully by making connections among concepts and by developing reasoning skills. In the experiment group, students were encouraged to coordinate their experiences and bring them into a logical system. According to Einstein, the object of all science should be to coordinate our experiences and bring them into a logical system (Marek, and Cavallo, 1997). Moreover, in the experimental group, laboratory activities are viewed as an integral part of the lessons, and these laboratory activities provide the experiences, the interpretation of which leads to the logical system (Marek and Cavallo, 1997). That is, the important characteristic of 5E model-laboratory activities used in the experimental groups was that these activities provide students with not only hands-on experiences to learn the concepts but also the opportunity for knowledge construction from their personal experience and for application to new situations.

On the contrary, in the control groups, information was orally delivered to students about the science concepts to be learned. According to this teaching procedure, students in the control groups were informed about what they are to know so they have no experiences to coordinate. That is, the experiences someone else has had are coordinated into a logical system and presented to them (Marek, and Cavallo, 1997). Then, students are shown proof that what they have been told or shown is true by making activities in the laboratory. That is, for this group, laboratory experience is considered a supplemental part of the lesson, not viewed as an integral part of the lesson. These activities were called as experiments in the control groups, but actually they are not true experiments because the outcome is known before the activity is performed. These activities were simply verification or cookbook activities. As cited in Marek and Cavallo (1997), Einstein stated that students simply reenact with materials (apparatus, chemicals, and living things) in verification laboratory, and this laboratory is further disqualified as a science experience because students know the outcome all of the time the “laboratory” is in session. If Einstein is correct, science cannot be taught with utilizing verification laboratory. Marek and Cavallo (1997) also agreed with Einstein, and stated that teaching what is called science without involving the students in a quest or search is not teaching science.

Moreover, traditionally designed chemistry instruction did not facilitate conceptual change because teacher strategies were dependent on teacher exploration without consideration of students’ misconceptions and she/he used a lecture method in instruction. She/he wrote important notes to the board and distributed worksheets to the students to complete. That is, students in the control group were taught with traditionally designed chemistry instruction were passive listeners and they are not construct their knowledge whereas students in the experimental group were allowed to constructed their knowledge by using conceptual change approach. In the experimental groups, the emphasis was given to students' misconceptions. Students were involved in activities that helped them activate their prior knowledge and struggle with their misconceptions. These activities also provide evidence that students' initial conceptions are insufficient and support only partial understanding of the concepts. For example, experiment group students were involved in hands-on activities that helped them to examine the adequacy of their prior conceptions and forced them to argue about and test those conceptions. This led to disequilibrium when predictions based on their prior beliefs are contradicted and provided the opportunity to construct more appropriate concepts.

To summarize, promoting science learning is a painful process. Thus, simply presenting a new concept or telling the learners that their views are inaccurate does not result in improving the students' understanding of the science concepts as traditional methods did. Instead, meaningful learning requires constructivist approach like 5E learning cycle model which allows students to take an active role in reorganizing their knowledge.

In this study, science process skills were found as a strong predictor in understanding the concepts related to acid-base. This result is congruent with the idea that the degree of science process skills was a significant factor in science achievement because it reflects one's intellectual ability to identify variables, identify and state the hypotheses, design investigations and graph and interpret data.

Also, the effect of treatment (instruction based on 5E learning cycle model vs. traditionally designed chemistry instruction) on students' attitudes towards chemistry as a school subject was investigated in this study. However, there was no difference between the experiment and the control groups. Both treatments developed the similar attitude toward science as a school subject. The reason of this might be results from the teachers' characteristics. Both experiment and control groups were instructed by the same teacher for the same school.

Moreover, this study provides the evidence that there are no differences between female and male students with respect to understanding related to acid-base concepts. This means that, there was no significant difference between male and female students who were instructed by instruction based on the 5E learning cycle model and those who were instructed through traditionally designed chemistry instruction. The reason why no significant difference was found in this study might be due to the fact that since the students had similar backgrounds or experience and they are generally familiar with learning subjects from texts or textbook

Like scientific knowledge, helping students develop adequate understanding of the nature of science is another desired outcome of science teaching. Understanding the nature of science is important because the significant misunderstandings that both students and teachers hold regarding the nature of science are particularly affect students' attitudes toward science and science classes, and that clearly has an impact on student learning and the selection of further science classes (Clough, 2000). In addition, understanding science prepares people to lead personally fulfilling and responsible lives (Smith and Scharmann, 1999). Therefore, in this study, students' views about the nature of science were investigated descriptively.

The nature of science has been defined in numerous ways. By the nature of science we mean the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge, as consisted with the definition of Abd-el-Khalick, Bell and Lederman (1998).

In this study, Turkish 11th grade students' understanding of nature of science was investigated. In Turkey, understanding of the nature of science as one of the most important aspect of science teaching, have not been investigated enough yet (Erdogan, 2004). According to Third International Mathematics and Science Study (1999, cited in Erdoğan 2004), the emphasis given on to nature of science in Turkey evaluated as moderate. Moreover, although a large research tradition has developed around the conceptions of nature of science in other countries, less has been done in Turkey (Erdoğan, 2004).

Results of this study revealed that students' held traditional views (naive) regarding the definition of science; the nature of scientific models; the relationships between hypotheses, theories, and laws; the scientific method; and epistemological status of scientific knowledge. On the other hand, they have contemporary views (realistic) on the nature of observation; the nature of classification schemes; the tentativeness of scientific knowledge; uncertainty in scientific knowledge; fundamental assumptions for all science; coherence of concepts across disciplines; cause and effect relationship.

### 6.2 Implications

Results of the present study had some implications for science teachers, educators and the researchers. The findings of this study have the following implications:

1. Most of the students have difficulty in understanding acids and bases topics and hold several misconceptions because they include abstract and theoretical concept. And the existence of these misconceptions among students leads a serious obstacle to learning in chemistry. So, teachers must be aware of these misconceptions and try to prevent them from occurring.

2. Most of the misconceptions arise from the students' inability to use their prior knowledge in learning situations because students construct their knowledge by making links between their idea and new concepts. When teachers link new information to the student's prior knowledge, they activate the student's interest and curiosity, and infuse instruction with a sense of purpose. Therefore, teachers should take time to assess what their students have learned from prior experiences.

3. Teachers should ask questions that activates students' relevant prior knowledge and promotes meaningful learning. Also, they should be allowing to the students to discuss these questions. By this way, students may be realizing that their current ideas were not effective in explaining the situation take the new knowledge into account seriously.

4. Teachers must prepare their lesson while giving importance to students' prior knowledge to make a necessary conceptual change on students' minds.

5. Students should build connections between daily life and their scientific conceptions

6. School administrators should encourage teachers to use 5E Learning Cycle Model in their lesson.

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

8. Teachers should be informed about the usage and importance of constructivist approaches.

9. Science process skill is a strong predictor of science achievement. Teacher should adjust their teaching strategies to develop students' science process skills.

10. Trained teachers on constructivists approach should be model for other teachers.

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

12. Well-designed 5E Learning Cycle Model instruction can be used to remove misconceptions and facilitate understanding of the science concepts. 5E Model activities create conceptual conflict with the existing knowledge and facilitate conceptual change.

13. Students held some inconsistent views on nature of science issue. For this reason, some interventions must be made in order to improve the situation.

14. During the students'education, students should be prepared to give decisions on socio-scientific issues. Therefore, students should understand the nature and importance of science for societies. A conscious society on science brings conscious individuals to the education.

15. One aim of the science educators should be able to teach science, and reduce the possible dogmatic assumptions and myths of science that students may construct while they are learning science from textbooks and in classrooms. Teaching the nature of science is essential to reducing the myths on science that students may construct while they are learning science. Thus teacher training program should be revised to improve the

way that how the nature of science issue can be introduced to the students from any levels of education.

16. The Ministry of Education should include a goal emphasizing the importance of nature of science.

## 6.3 Recommendations

On the basis of the findings from this study, the researcher recommends that:

- A study can be carried out for different grade levels and different science courses.

- This study can be conducted with a larger sample size from different schools to get more accurate results and to search a generalization for Turkish student population.

- Effectiveness of 5E Model can be compared with the other instructional methods such as conceptual change text, problem solving or computer assisted instruction.

- Similar research studies can be conducted to evaluate the effect of constructivist approach on the other learning outcomes such as logical thinking.

- Further studies can be conducted to test the direct effects of the 5E Learning Model separately on science achievement.

- Computers can be used to teach the scientific concepts since they provide dynamic displays and visualizations, simulations and models.

- This study was conducted with descriptive technique to investigate the views of students on nature of science. An inferential study can be conducted with a larger sample to support the findings of this study.

- Researchers may attempt to assess the different grade level of students, and their science teachers' views on nature of science.

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# APPENDIX A

## INSTRUCTIONAL OBJECTIVES

1. To identify acid and base.
2. To explain the properties of an acid and base.
3. To give daily life examples for acids and bases.
4. To state the relationship between acids and bases.
5. To define indicator.
6. To show that acids change blue litmus paper to red.
7. To show that bases change red litmus paper to blue.
8. To show that acids do not change phenolphthalein color.
9. To show that bases change phenolphthalein to pink.
10. To identify pH and pOH terms.
11. To identify the relationship between pH/pOH and $[OH^-]/[H^+]$
12. To explain neutralization.
13. To clarify the strength of an acid and a base.
14. To identify the differences between strong acid/base and weak acid/base
15. To identify the differences between the reactions of active metals with strong acids and weak acids
16. To identify the differences between concentration, pH/pOH and strength of acids/base
17. To state the properties of salts formed at the end of the neutralization reactions.
18. To explain hydrolysis.
19. To state the buffer solutions

# APPENDIX B

## ACID BASE CONCEPT TEST

Bu testte asitler ve bazlar konusundaki anlama düzeyinizi ölçmek için hazırlanan sorular bulunmaktadır. Sorular çoktan seçmeli formatında hazırlanmıştır ve her soru için bir doğru cevap vardır. Lütfen her soru için sadece bir şıkkı daire içine alarak işaretleyiniz.

1- Aşağıdakilerden hangisi yada hangileri bazlar için **her zaman doğrudur**?

I. Suda iyonlaşırlar
II. Yapılarında $OH^-$ iyonu bulunur
III. Asitlerle nötrleşip nötr çözelti oluştururlar

a) I b) II c) III
d) I, II e) I, II, III

2- Aşağıda asitler için verilen bilgilerden hangisi **yanlıştır?**

a) Seyreltik çözeltilerinin tadı ekşidir
b) Nötrleşme tepkimesi verirler
c) Karbonat tuzu ile tepkimeye girerek $CO_{2\,(g)}$ açığa çıkarırlar
d) Yapısında H bulunan maddelere asit adı verilir.
e) Aktif metallerle reaksiyona girerler

3- Bir baz çözeltisi için, aşağıdakilerden hangisi **kesinlikle doğrudur**?

a) Renkleri mavidir
b) Elektriği iletir
c) Asit üretiminde kullanılır
d) Zararlı değildir
e) Mavi turnusol kağıdını kırmızıya çevirirler

4- Aşağıdaki ifadelerden hangisi nötrleşme tepkimeleri için **kesinlikle doğrudur**?

I. Asitler ve bazlar arasında meydana gelir.

II. Fiziksel bir değişimdir.

III. Dışarıya gaz çıkışı olur.

a) I b) II c) III
d) I, III e) I, II, III

5- Asitlerle ilgili aşağıdaki bilgiler-den hangisi doğrudur?

a) Üzerinde bitki yetiştirilen toprak, asit özelliği gösteremez.
b) Bütün güçlü kimyasal maddeler asit özellik gösterir.
c) Bazlardan daha zehirlidirler
d) Metallerin paslanmasına sebeb olurlar
e) Çözeltilerinde $[H^+] > [OH^-]$ olur.

6- Aşağıdaki maddelerden hangisi mavi turnusol kağıdını kırmızıya çevirir

I. Limon suyu
II. Çamaşır suyu
III. Mide öz suyu
IV. Amonyak

a) I, II b) II, IV c) III, IV
d) I, III e) Hepsi

7- Aşağıdakilerden hangisi bütün asit ve baz çözeltileri için geçerlidir?

a) pH değeri 7 den az ise baz çözeltisidir
b) pH= 0 ise çözelti nötrdür.
c) pOH değeri sadece baz çözeltileri için geçerlidir.
d) pH ve pOH değeri asit ve bazlar için aynı değerdir.
e) Asit çözetileri için pH < pOH dır.

8- Renksiz bir çözelti test edildiğinde pH değeri 10 bulunuyor. Bu çözelti için aşağıdakilerden hangisi doğrudur?

a) Asittir
b) İçerdiği hidrojen iyonu $[H^+]$ derişi-mi, hidroksit iyonu $[OH^-]$ derişiminin iki buçuk katıdır.
c) Nötr özellik gösterir
d) İçerdiği hidroksit iyonu $[OH^-]$, hidrojen iyonundan $[H^+]$ daha fazladır.
e) $[OH^-] = 10^{-10}$ dur.

9- KOH kuvvetli baz, $NH_3$ ise zayıf bazdır. Eşit hacim ve derişimdeki KOH ve $NH_3$ çözeltileri için aşağıdakilerden hangisi aynı olur?

a) İyonlaşma yüzdesi
b) $OH^-$ iyonu molar derişimi
c) pH değeri
d) Elektrik iletkenliği
e) Nötrleştirmek için gereken $H^+$ nun miktarı

10- Aynı hacim ve derişimdeki zayıf asit çözeltisi ile kuvvetli asit çözeltisi karşılaştırıldığında,aşağıdakilerden hangisi **her zaman doğru** olur?

a) Kuvvetli asitin, Mg metali ile tepkimesinden daha fazla $H_{2(g)}$ açığa çıkar
b) Kuvvetli asidin pH'ı, zayıf asitten daha fazladır.
c) Zayıf asidin elektrik iletkenliği daha azdır.
d) Kuvvetli asidin bir molekülü daha fazla H içerir.
e) Kuvvetli asit metali daha iyi eritir.

11- Farklı iki kapta eşit hacimlerde zayıf baz ve kuvvetli baz çözeltileri vardır. Bu çözeltilerden hangisinin kuvvetli baz çözeltisi olduğunu anlamak için aşağıdakilerden hangisinin verilmesi **tek başına yeterlidir**?

a) Çözeltilerin pOH değerleri
b) Çözeltilerin pH değerleri
c) Çözeltilerin derişimleri
d)Çözeltilerdeki bazların iyonlaşma yüzdeleri
e)Çözeltidelerdeki toplam iyon sayıları

12- Yukarıdaki soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisi olabilir?

a) Çözeltinin pOH değeri artıkça bazın kuvveti de artar
b) Çözeltinin pH değeri artıkça bazın kuvveti de artar
c) Çözeltideki iyon sayısı arttıkça, kuvvette artar
d) Çözeltideki bazın derişimi azaldıkça kuvveti de azalır
e) Bazın iyonlaşma yüzdesi arttıkça kuvveti artar

13- İki beherden birine hidroklorik asit (HCl), diğerine ise eşit hacim ve derişimdeki asetik asit ($CH_3COOH$) çözeltisi konulmuştur. Bu çözeltilere sırayla Magnezyum şeritler atılırsa aşağıdakilerden hangisi gözlemlenir? (HCl: kuvvetli asit; $CH_3COOH$: zayıf asit)

a) Kaplarda aynı hızda gaz çıkışı gözlemlenir
b) HCl asit bulunan kapta gaz çıkışı daha hızlı olur
c) $CH_3COOH$ bulunan kapta gaz çıkışı daha hızlı olur
d) Sadece HCl bulunan kapta gaz çıkışı olur.
e) Dışarıya gaz çıkışı olmaz

14- Yukarıdaki soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisi olabilir?

a) Metaller asitlerin içinde erirler ve dışarıya gaz çıkışı olmaz
b) HCl bulunan kapta daha hızlı gaz çıkışı gözlemlenir çünkü daha çok hidrojen bağı kırılmıştır
c) HCl bulunan kapta gaz çıkışı daha yavaştır çünkü kuvvetli asitler daha yavaş reaksiyon verirler
d) HCl bulunan kapta daha hızlı gaz çıkışı gözlemlenir çünkü HCl kuvvetli asittir.
e) İki çözeltide de asit bulunduğu için, kaplardan eşit hızda $H_{2\,(g)}$ çıkışı olur.

15-

| | |
|---|---|
| KOH | : Kuvvetli Baz |
| HCl | : Kuvvetli Asit |
| $CH_3COOH$ | : Zayıf Asit |
| $NH_3$ | : Zayıf Baz |

Yukarıda verilen maddeler ile bu maddelerin oluşturdukları KCl, $NH_4Cl$, $CH_3COOK$ tuzlarının sulu çözeltileri için aşağıdakilerden hangisi doğrudur?

| | KCl | $NH_4Cl$ | $CH_3COOK$ |
|---|---|---|---|
| a) | Nötr | Nötr | Nötr |
| b) | Nötr | Asidik | Bazik |
| c) | Nötr | Bazik | Asidik |
| d) | Bazik | Bazik | Bazik |
| e) | Asidik | Asidik | Asidik |

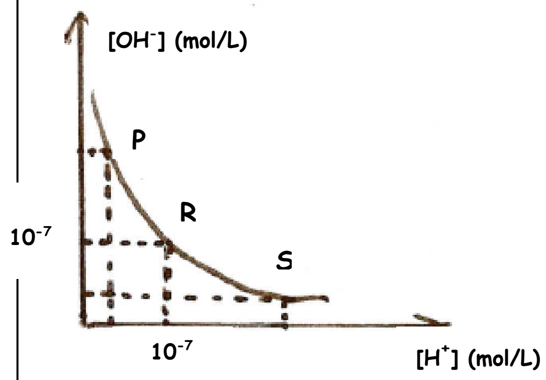
16- Normal şartlarda, eşit hacim ve derişimlerdeki asetik asit ($CH_3COOH$) ile sodyum hidroksiti (NaOH) karıştırılırsa, oluşan çözelti nasıl bir çözeltidir? (Asetik asit: zayıf asit; sodyum hidroksit: kuvvetli bazdır)

a) Nötr b) Bazik c) Asidik
d) Seyreltik e) Derişik

17- Yukarıdaki soruya verdiğiniz cevabın nedeni aşağıdakilerden hangisi olabilir?

a) Asitlerin kuvveti bazlardan daha fazladır, bu yüzden çözelti asidik olur
b) Asitliği temsil eden hidrojen iyonu ile, bazlığı temsil eden hidroksit iyonu tamamen reaksiyona girdiğinden, karışım artık iki iyonu da içermez, ve çözelti nötr olur.
c) Karışımda, nötr su ve nötr tuz oluşur, bu yüzden nötrdür.
d) Su ve sodyum asetat ($CH_3COONa$) oluşur. Asetat iyonun ($CH_3COO^-$) su ile tepkimesinden sonra, hidroksil iyonlarının derişimi hidrojen'inkinden daha fazla olur.
e) Asit yada bazdan biri zayıf olduğu takdirde nötrleşme tamamen gerçekleşemez, bu yüzden asit veya bazdan hangisi daha kuvvetliyse çözelti onun özelliğin gösterir

18-




Sulu çözeltilerdeki $OH^-$ derişiminin, $H^+$ derişimiyle ilişkisi grafikteki gibidir. Bu grafiğe göre, sulu çözeltiler ile ilgili aşağıdaki ifadelerden hangisi **yanlıştır**?

a) S noktasında Mg metali ile tepkimesinde $H_{2\,(g)}$ çıkar.
b) S noktasında kırmızı turnusol kağıdını maviye çevirir.
c) R noktasında nötrdür.
d) P noktasında HCl ile tepkime verir
e) P noktasında elektrik akımını iletir.

(2005-ÖSS)

19-

I. 0,1 M 100 mL HCl çözeltisi

II. 0,1 M 100 mL NaOH çözeltisi

III. 0,1 M 100 mL $NH_3$ çözeltisi

Yukarıdaki çözeltiler için $25^0C$ de aşağıdakilerden hangisi **yanlıştır**?

a) I. ve III. çözeltiler karıştırılırsa nötr çözelti olur

b) II. ve III. deki çözeltiler için pH>7 dir

c) I. ve II. çözeltiler karıştırılırsa nötr çözelti olur

d) Elektrik akımını iletirler

e) Çözeltilere 0,1 M HCl eklenirse, I. çözeltide pH değişmez, diğerlerinde pH azalır.

20- X çözeltisinde $OH^-$ derişimi 1,0. $10^{-3}$ M, Y çözeltisinde ise 1,0. $10^{-11}$ M dır. X ve Y' nin eşit hacimleri karıştırılınca pH değeri 7 olan bir karışım oluşuyor. Bu çözeltiler için,

I- X zayıf, Y ise kuvvetli bazdır

II- X'in pH değeri 11, Y'ninki ise 3 tür.

III- Oluşturdukları karışımda $OH^-$ derişimi 1,0. $10^{-7}$ M dır.

Yargılarından hangileri doğrudur?

a)Yalnız I b)Yalnız II c)Yalnız III

d) I ve II e)II ve III

(1992-ÖYS)

21-

I. $H_2PO_3^- + H_2PO_4^- \leftrightarrow H_3PO_3 + HPO_4^{-2}$

II. $H_2PO_4^- + H_3PO_2 \leftrightarrow H_3PO_4 + H_2PO_2^-$

III. $HPO_4^{-2} + HSO_4^- \leftrightarrow H_2PO_4^- + SO_4^{-2}$

Yukarıdaki tepkimelerden hangisinde ya da hangilerinde $H_2PO_4^-$ iyonu asit olarak etki etmektedir?

a) I b) II c) I ve II

d) I ve III e) I, II ve III

22-

| **Çözelti** | **I** | **II** | **III** | **IV** | **V** |
|---|---|---|---|---|---|
| **pH** | 0 | 1 | 2 | 3 | 4 |

Çizelgede, eşit hacimli farklı çözeltilerin pH değerleri verilmiştir. Bu çözeltileri tamamen nötrleştirmek için harcanan katı NaOH kütlesi hangisinde **en fazladır**?

a) I b) II c) III

d) IV e) V

23-

I. HX için $K_a$= 1. $10^{-10}$

II. $H_2Y$ için $K_a$= 1. $10^{-10}$

III. BOH için $K_b$=1. $10^{-12}$

Yukaradakilere göre, eşit derişimli HX, $H_2Y$ ve BOH sulu çözeltilerinin pH değerleri arasındaki ilişki aşağıdakilerden hangisi gibidir?

a) II > I > III b) I > II > III

c) III > II > I d) III > I > II

e) III > I = II

24-Bromitol mavisi bir boyar maddedir ve asidik ortamda sarı, bazik ortamda mavi, nötr ortamda ise yeşil renk verir.Bir kaptaki bromitol mavisi damlatılmış 10 mL 0,1 M HCl çözeltisine, 0,2 M NaOH çözeltisi azar azar ekleniyor. Bu işlemde çözeltinin rengi ile ilgili aşağıdaki ifadelerden hangisi **yanlıştır**?

a) NaOH eklemeden önce sarı

b) 2 mL NaOH eklendiğinde sarı

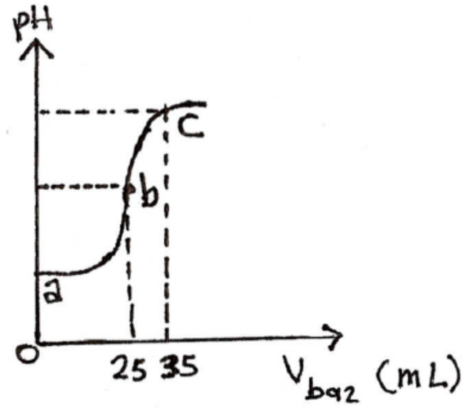
c) 5 mL NaOH eklendiğinde yeşil

d) 10 mL NaOH eklendiğinde yeşil

e) 20 mL NaOH eklendiğinde mavi

(2001-ÖSS)

25- HCl nin (kuvvetli asit) sudaki 0,1 molar çözeltisinin 25 mL si, NaOH in (kuvvetli baz) sudaki 0,1 molar çözeltisiyle titre edilmektedir. Titrasyonda, eklenen baz hacmine (Vbaz) karşı çözeltinin pH sindeki değişim aşağıdaki grafikte verilmiştir.




Bu titrasyon grafiğine göre aşağıdaki ifadelerden hangisi **yanlıştır**?

a) Başlangıç noktası a da çözeltinin (HCl çözeltisi) pH değeri 1 dir.

b) 25 mL baz çözeltisi eklendiğinde eşdeğerlik noktası (dönüm noktası) b ye ulaşılmıştır.

c) c noktasında çözeltinin toplam hacmi 85 mL dir.

d) b noktasında çözeltinin pH değeri 7 dir.

e) Eşdeğerlik noktası (dönüm noktası) b de çözel-tinin toplam hacmi 50 mL dir.

(ÖSS 2007)

26- Bir T sıcaklığında $NH_4Br$ çözeltisinin pH değeri 5 olduğuna göre çözelti derişimi kaç molardır? ($NH_3$ için $K_b$= 1. $10^{-5}$)

a) 1 b) 0,1 c) $10^{-5}$
d) 0.01 e) 10

27- $NH_3$ için $K_b$= 1,8 . $10^{-5}$
$CH_3COOH$ için $K_a$= 1,8 . $10^{-5}$
KOH için $K_b$= çok büyük
HCl için $K_a$= çok büyük

$CH_3COOK$, KCl ve $NH_4Cl$ tuzlarının eşit derişimli sulu çözeltileri için;

I. $CH_3COOK$ çözeltisinin pH ı 7 den büyüktür.
II. KCl çözeltisi elektrik akımını iletmez
III. $NH_4Cl$ çözeltisinin pH ı 7 den küçüktür.
Yargılarından hangileri doğrudur?

a) Yalnız I b) I ve II c) I ve III
d) II ve III e) I, II ve III

28- Bir X maddesi, oda sıcaklığında, su ile

$X_{(suda)} + H_2O_{(sıvı)} \leftrightarrow XH^+_{(suda)} + OH^-_{(suda)}$

tepkimesini veriyor. Dengedeki çözeltide $XH^+$ iyonları derişimi 1,0 . $10^{-4}$ M dır. Bu çözeltinin 100 mL'si ile 0,01 mol HCl ile tamamen nötrleştiğine göre, tepkimenin oda sıcaklığındaki denge sabiti kaçtır?

a) 1,0 . $10^8$ b) 1,0 . $10^7$ c) 1,0 . $10^4$
d) 1,0 . $10^{-4}$ e) 1,0 . $10^{-7}$

(1991-ÖYS)

29- Aşağıda verilen madde çiftlerinden hangisi bir tampon çözelti oluşturur?

a) $H_2O$ ile HCl
b) HCl ile NaOH
c) HCl ile NaCl
d) $NH_3$ ile $NH_4Cl$
e) NaOH ile NaCl

30- Standart koşullarda $NH_3$ için $K_b$= 1,8. $10^{-5}$ olduğuna göre, litresinde 0,1 mol $NH_3$ ve 0,2 mol $NH_4Cl$ bulunduran çözeltide $OH^-$ kaç molar olur?

a)9,0. $10^{-6}$ b)1,8. $10^{-5}$ c)9,0. $10^{-5}$
d) 1,8. $10^{-6}$ e) 2,7. $10^{-7}$

# APPENDIX C

## ATTITUDE SCALE TOWARD CHEMISTRY

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

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

# APPENDIX D

## SCIENCE PROCESS SKILL TEST

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

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

**a.** Her oyuncunun almış olduğu günlük vitamin miktarını.

**b.** Günlük ağırlık kaldırma çalışmalarının miktarını.

**c.** Günlük antreman süresini.

**d.** Yukarıdakilerin hepsini.

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

**a.** Arabaların benzinleri bitinceye kadar geçen süre ile.
**b.** Her arabnın gittiği mesafe ile.
**c.** Kullanılan benzin miktarı ile.
**d.** Kullanılan katkı maddesinin miktarı ile.

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

**a.** Arabanın ağırlığı.
**b.** Motorun hacmi.
**c.** Arabanın rengi
**d.** a ve b.

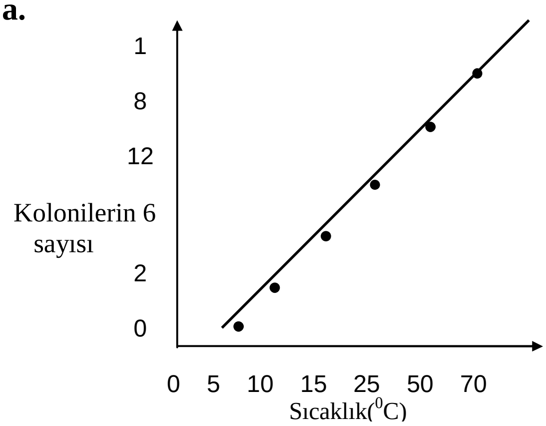
**4.** Ali Bey, evini ısıtmak için komşularından daha çok para ödenmesinin sebeblerini merak etmektedir. Isınma giderlerini etkileyen faktörleri araştırmak için bir hipotez kurar. Aşağıdakilerden hangisi bu araştırmada sınanmaya uygun bir hipotez <u>değildir</u>?
**a.** Evin çevresindeki ağaç sayısı ne kadar az ise ısınma gideri o kadar fazladır.
**b.** Evde ne kadar çok pencere ve kapı varsa, ısınma gideri de o kadar fazla olur.
**c.** Büyük evlerin ısınma giderleri fazladır.
**d.** Isınma giderleri arttıkça ailenin daha ucuza ısınma yolları araması gerekir.

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

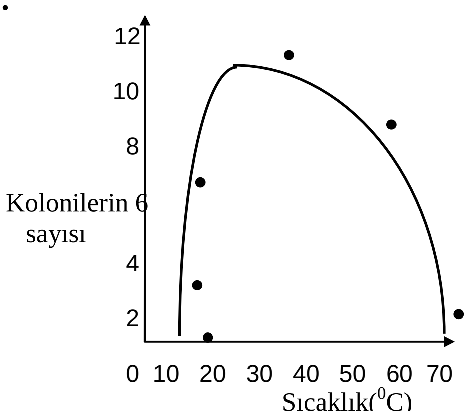
| Deney odasının sıcaklığı ($^0$C) | Bakteri kolonilerinin sayısı |
|---|---|
| 5 | 0 |
| 10 | 2 |
| 15 | 6 |
| 25 | 12 |
| 50 | 8 |

Aşağıdaki grafiklerden hangisi bu verileri doğru olarak göstermektedir?

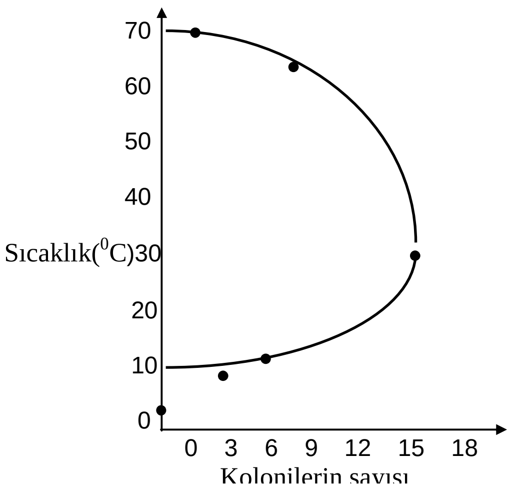
**a.**



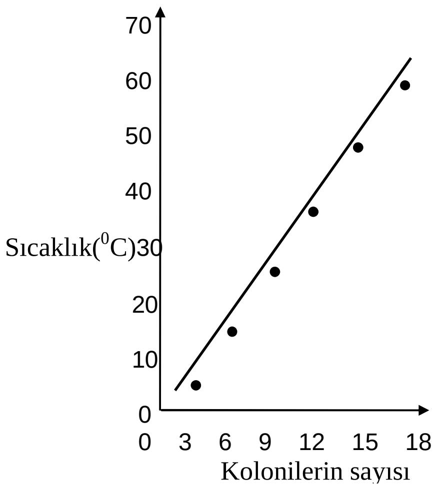

**b.**




**c.**




**d.**



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

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

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

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

**d.** Arabalar eskidikçe kaza yapma olasılıkları artar.

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

**a.** Her deneyde arabanın gittiği toplam mesafe ölçülür.

**b.** Rampanın (eğik düzlem) eğim açısı ölçülür.

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

**d.** Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

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

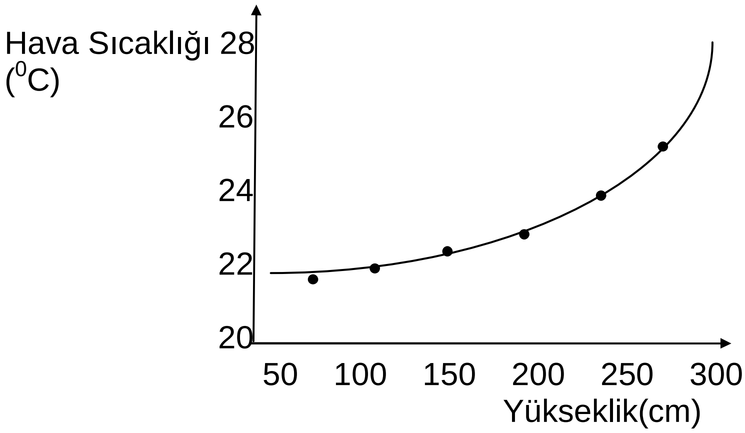
**a.** Tarlaya ne kadar çok gübre atılırsa, o kadar çok mısır elde edilir.

**b.** Ne kadar çok mısır elde edilirse, kar o kadar fazla olur.

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

**d.** Mısır üretimi arttıkça, üretim maliyeti de artar.

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




**a.** Yükseklik arttıkça sıcaklık azalır.

**b.** Yükseklik arttıkça sıcaklık artar.

**c.** Sıcaklık arttıkça yükseklik azalır.

**d.** Yükseklik ile sıcaklık artışı arasında bir ilşki yoktur.

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

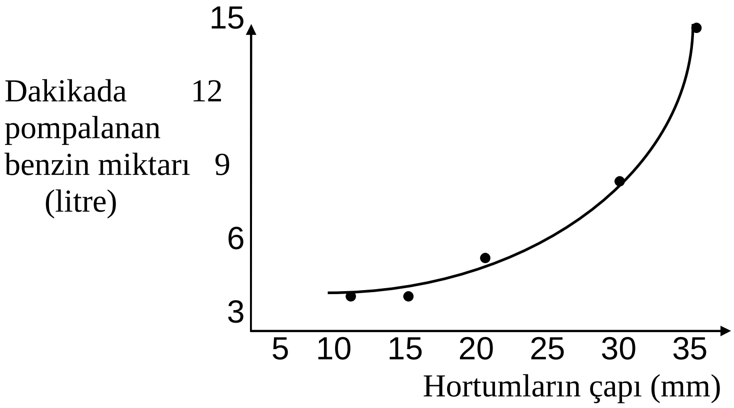
**a.** Topları aynı yükseklikten fakat değişik hızlarla yere vurur.

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

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

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

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




Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

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

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

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

**d.** Pompalanan benzin miktarı azaldıkça, hortumun çapı genişler.

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

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

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

**12.** Araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır?

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

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

**c.** Güneş farklı maddelari farklı derecelerde ısıtır.

**d.** Günün farklı saatlerinde güneşin ısısı da farklı olur.

**13.** Araştırmada aşağıdaki değişkenlerden hangisi kontrol edilmiştir?

**a.** Kovadaki suyun cinsi.

**b.** Toprak ve suyun sıcaklığı.

**c.** Kovalara koyulan maddenin türü.

**d.** Herbir kovanın güneş altında kalma süresi.

**14.** Araştırmada bağımlı değişken hangisidir?

**a.** Kovadaki suyun cinsi.

**b.** Toprak ve suyun sıcaklığı.

**c.** Kovalara koyulan maddenin türü.

**d.** Herbir kovanın güneş altında kalma süresi.

**15.** Araştırmada bağımsız değişken hangisidir?

**a.** Kovadaki suyun cinsi.

**b.** Toprak ve suyun sıcaklığı.

**c.** Kovalara koyulan maddenin türü.

**d.** Herbir kovanın güneş altında kalma süresi.

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

**a.** Hava sıcakken çim biçmek zordur.

**b.** Bahçeye atılan gürenin miktarı önemlidir.

**c.** Daha çok sulanan bahçedeki çimenler daha uzun olur.

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

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

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

**17.** Bu araştırmada sınanan hipotez hangisidir?

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

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

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

**d.** Kullanolan suyun miktarı arttıkça sıcaklığı da artar.

**18.** Bu araştırmada kontrol edilebilen değişken hangisidir?

**a.** Her bardakta çözünen şeker miktarı.

**b.** Her bardağa konulan su miktarı.

**c.** Bardakların sayısı.

**d.** Suyun sıcaklığı.

**19.** Araştımanın bağımlı değişkeni hangisidir?

**a.** Her bardakta çözünen şeker miktarı.

**b.** Her bardağa konulan su miktarı.

**c.** Bardakların sayısı.

**d.** Suyun sıcaklığı.

**20.** Araştırmadaki bağımsız değişken hangisidir?

**a.** Her bardakta çözünen şeker miktarı.

**b.** Her bardağa konulan su miktarı.

**c.** Bardakların sayısı.

**d.** Suyun sıcaklığı.

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

**a.** Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.

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

**c.** Farklı alnlardaki bitkilere verilen su miktarını ölçer.

**d.** Her alana ektiği tohum sayısına bakar.

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

**a.** Kullanılan toz ya da spreyin miktarı ölçülür.

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

**c.** Her fidede oluşan kabağın ağırlığı ölçülür.

**d.** Bitkilerin üzerinde kalan bitler sayılır.

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

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

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

**c.** 10 dakika sonra alevin sıcaklığını ölçer.

**d.** Bir litre suyun kaynaması için geçen zamanı ölçer.

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

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

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

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

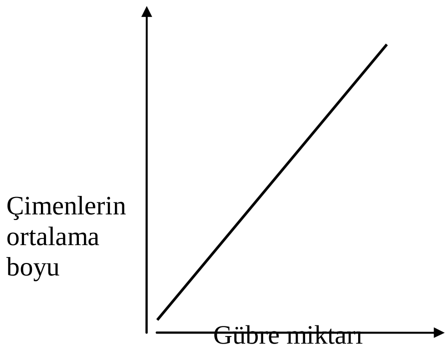
**d.** Herbiri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

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

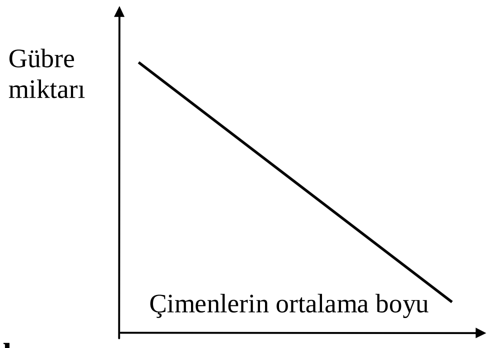
| Gübre miktarı (kg) | Çimenlerin ortalama boyu (cm) |
|---|---|
| 10 | 7 |
| 30 | 10 |
| 50 | 12 |
| 80 | 14 |
| 100 | 12 |

Tablodaki verilerin grafiği aşağıdakilerden hangisidir?

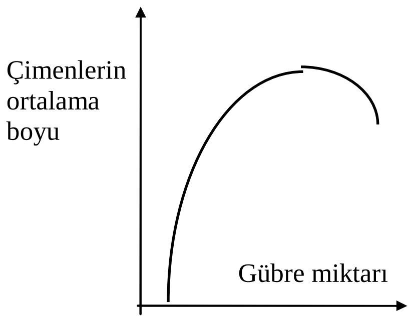
**a.**



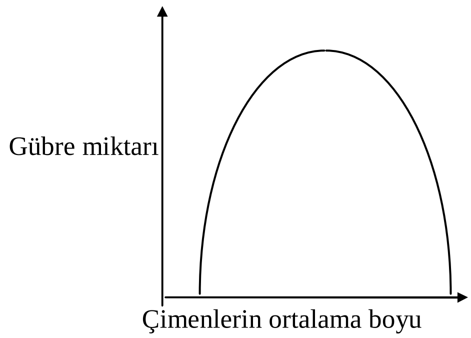

**b.**




**c.**




**d.**




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

**a.** Farelerin hızını ölçer.

**b.** Farelerin, günlük uyumadan durabildikleri süreyi ölçer.

**c.** Hergün fareleri tartar.

**d.** Hergün farelerin yiyeceği vitaminleri tartar.

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

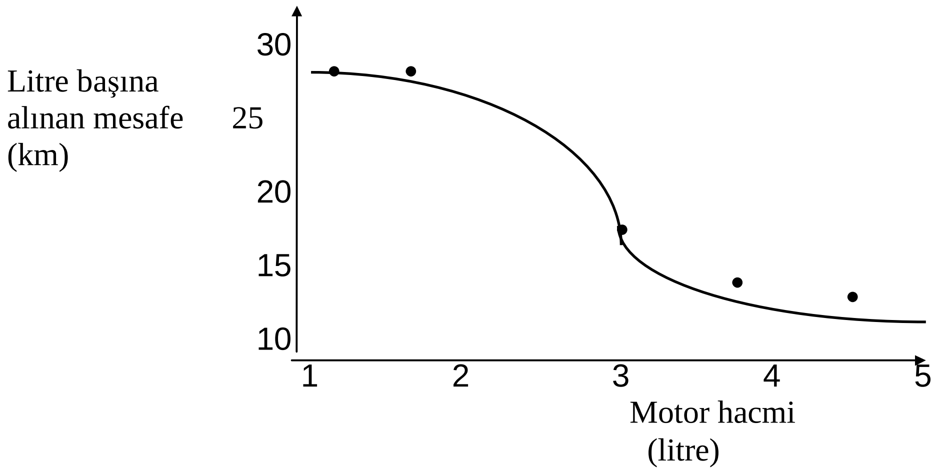
**a.** Daha fazla şekeri çözmek için daha fazla su gereklidir.

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

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

**d.** Su ısındıkça şeker daha uzun sürede çözünür.

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




Aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?

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

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

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

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

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

Toprağa karıtırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki torağa 15 kg., ikinciye 10 kg., üçüncüye ise 5 kg. çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır.

Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan eled edilen domates tartılmış ve kaydedilmiştir.

**29.** Bu araştırmada sınanan hipotez hangisidir?

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

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

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

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

**30.** Bu araştırmada kontrol edilen değişken hangisidir?

**a.** Her saksıdan elde edilen domates miktarı

**b.** Saksılara karıştırılan yaprak miktarı.

**c.** Saksılardaki torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

**31.** Araştırmadaki bağımlı değişken hangisidir?

**a.** Her saksıdan elde edilen domates miktarı

**b.** Saksılara karıştırılan yaprak miktarı.

**c.** Saksılardaki torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

**32.** Araştırmadaki bağımsız değişken hangisidir?

**a.** Her saksıdan elde edilen domates miktarı

**b.** Saksılara karıştırılan yaprak miktarı.

**c.** Saksılardaki torak miktarı.

**d.** Çürümüş yapak karıştırılan saksı sayısı.

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

**a.** Kullanılan mıknatısın büyüklüğü üle.

**b.** Demir tozalrını çeken mıknatısın ağırlığı ile.

**c.** Kullanılan mıknatısın şekli ile.

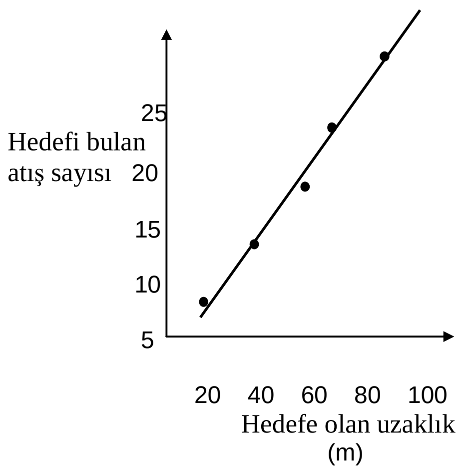
**d.** Çekilen demir tozlarının ağırlığı ile.

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

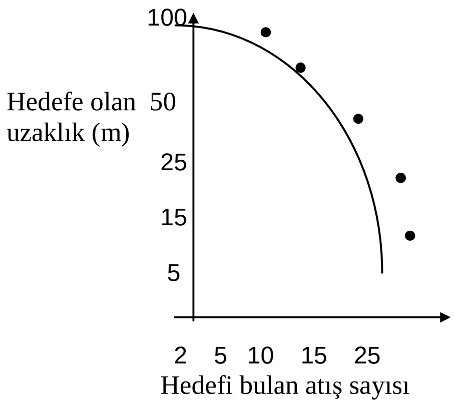
| Mesafe(m) | Hedefe vuran atış sayısı |
|---|---|
| 5 | 25 |
| 15 | 10 |
| 25 | 10 |
| 50 | 5 |
| 100 | 2 |

Aşağıdaki grafiklerden hangisi verilen bu verileri en iyi şekilde yansıtır?

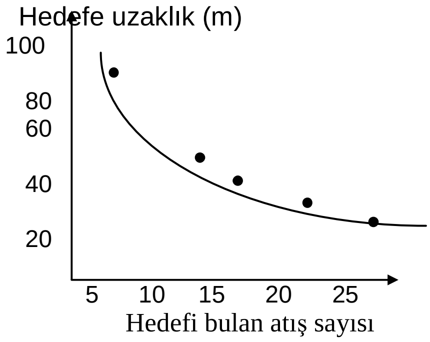
**a.**



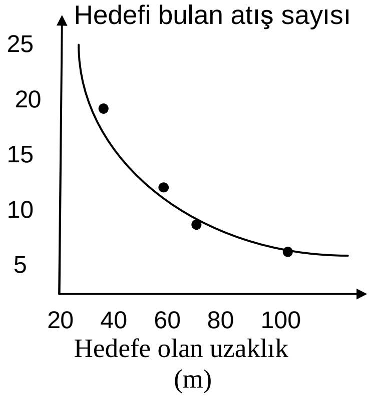

**b.**



c.




d




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

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

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

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

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

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

**a.** TV nin açık kaldığı süre.

**b.** Elektrik sayacının yeri.

**c.** Çamaşır makinesinin kullanma sıklığı.

**d.** a ve c.

## APPENDIX E

## INTERVIEW QUESTIONS

1- Asit denilince aklına ne geliyor? /Asitleri nasıl tanımlarsın?
2- Baz denilince aklına ne geliyor? /Bazları nasıl tanımlarsın?
3- Göstereceğim kartlarda yazılı olan maddelerin çözeltilerini düşünüp, bu çözeltilerin asit ya da baz özelliği gösterip göstermeyeceği hakkında yorum yapar mısın? ($NH_3$; HCl; $Ca(OH)_2$; $CH_3COOH$; $H_2SO_4$).
4- Aşağıdaki tabloda asit ve bazların özellikleri karışık olarak verilmiş. Bu karışıklığı önlemek için asitlerin özelliklerini gösteren şıkları ASİT yazısının altına ve bazların özelliklerini gösteren şıkları da BAZ yazısının altına yazar mısın? Aynı şıkkı birden fazla yerde kullanabilirsin ya da hiç kullanmayabilirsin.

| ASİT | BAZ |
|---|---|
| | |

| | |
|---|---|
| a- Sulu çözeltilerinde $H^+$ iyonu bulunur.<br>b- Sulu çözeltilerinde $OH^-$ iyonu bulunur.<br>c- Suda iyonlaşır.<br>d- Çözeltileri elektriği iletir.<br>e- Seyreltik çözeltilerinin tadı ekşidir. | f- Seyreltik çözeltilerinin tadı acıdır<br>g- Mavi turnusol kâğıdını kırmızıya çevirir.<br>h- Kırmızı turnusol kâğıdını maviye çevirir.<br>i- Aktif metaller ile reaksiyona girer.<br>j- Karbonat tuzları ile reaksiyona girerler ($CaCO_{3\,(k)}$; $NaCO_{3\,(k)}$). |

5- Bir asit çözeltisinin içine Magnezyum metali atarsam ne olur?

- Gaz çıkışı olur mu? Olursa bu gaz nereden geliyor?
- Fiziksel ya da kimyasal bir değişim olur mu?

6- Laboratuarda kuvvetli asitler ve bazlarla ilgili deney yapacaksın. Daha önceden hazırlanıp, cam şişelere konulmuş iki ayrı cam şişeden birinde kuvvetli asit diğerin de ise zayıf asit olduğunu öğrendin. Fakat bu şişelerin etiket kısımları yırtılmış olduğundan asitlerin adlarını bilmiyorsun. Bu asit şişelerinden hangisinde kuvvetli asit olduğunu anlamak için

Asit_1

Asit_2

A) Kartonlarda yazılı olan laboratuar malzemelerinden hangilerini kullanabilirsin? Açıklayarak cevap verin.

- pH metre
- Mg metali
- NaOH ve titrasyon malzemeleri
- HCl ve titrasyon malzemeleri

B) Etiketlerin tamamen bozulmadığını ve alt taraflarında kalan bazı yazıların okunabildiğini düşün. Bu okunan kısımlar için, sana göstereceğim kartonlarda yazılı olan bilgilerden hangisi, içinde kuvvetli asit olan şişeyi tahmin etmende işine yarayabilir? Nasıl?

- pOH değeri
- Elektrik iletkenlikleri
- Çözeltilerinin derişimleri
- Asitlerin molekül formülünde bulunan H sayısı

**7-** Aynı derişimde kuvvetli ve zayıf baz çözeltilerinden 5 er mL beherlere alınıyor.

- Bu çözeltilerdeki $[OH^-]$ aynı mıdır?
- Nötrleştirmek için gerekli $H^+$ miktarları/ Asit miktarları aynı mdır?

Kuvvetli Baz

Zayıf Baz

8- Asit ve bazlar karışınca ne olur?/ Nötrleşme nedir? Çizerek gösterebilir misiniz?

- Nötrleşme sırasında gaz çıkışı gözlemlenir mi?

SAF SU

SAF SU + HCl

SAF SU + HCl + NaOH

Burada HCl (kuvvetli asit) yerine $CH_3COOH$ (zayıf asit) olsaydı çizimin nasıl olurdu? Neden?

SAF SU + $CH_3COOH$

SAF SU + $CH_3COOH$+ NaOH

[SAF SU + HCl + NaOH] çözeltisi ile [SAF SU + $CH_3COOH$+ NaOH] çözeltisi arasında fark var mı**?**

$HCl + NaOH \rightarrow$

$CH_3COOH + NaOH \rightarrow$

Yukarıdaki reaksiyonlarda aynı hacim ve derişimlerde asit ve baz kullanıldığını düşünürsen, her iki reaksiyon hakkında nasıl bir yorum yaparsın? İki reaksiyonda da tamamen nötrleşme gözlemlenir mi? Açıklayınız.

9- Nötr çözelti denilince aklına ne geliyor?

10- $[H^+] < 10^{-7}$ olan bir çözelti için nasıl bir yorum yapabilirsin?

11- pH denilince ne anlıyorsun? Ne amaç ile kullanılıyor? pOH değeri nedir, niçin kullanılır?

## APPENDIX F

## TURKISH VERSION OF VIEWS ON SCIENCE-TECHNOLOGY-SOCIETY (VOSTS-T)

**Sayın Öğrenciler**

Bu anket, **bilimin doğası** konusuna yönelik düşüncelerinizi anlamak amacıyla hazırlanmıştır. Sizlerin görüşleri bizim için çok önemlidir. Yardımlarınız için teşekkür ederiz.

**AÇIKLAMALAR**

**Bilimin Doğası** konusuna yönelik bu anket her sayfaya bir soru gelecek şekilde düzenlenmiştir. Her soru **bilimin doğası** konusunda bir cümle ile başlamaktadır. Bu cümle genellikle temel bir görüş bildirmektedir.

Konu hakkındaki farklı görüş veya durumlar seçeneklerde sıralanmıştır. Her soru için düşüncenize uygun olan **BİR TEK SEÇENEĞİ** işaretleyiniz.

**Bu ankette doğru yanıt yoktur**. Burada amaç sadece sizin bilimin doğası konusundaki görüşlerinizi öğrenmektir.

**KİŞİSEL BİLGİLER**

1. Adınız, Soyadınız :
2. Cinsiyetiniz : ☐ Kız ☐ Erkek
3. Okuduğunuz Lise türü : ☐ Anadolu Lisesi
   ☐ Anadolu Öğretmen Lisesi

1. Bilimi tanımak zordur; çünkü bilim, karmaşıktır ve birçok konuyla ilgilidir. Fakat bilim asıl olarak:

A. Biyoloji, fizik ve kimya gibi konularda çalışmaktadır.
B. Yaşadığımız dünyayı (maddeyi, enerjiyi ve yaşamı) açıklayan prensipler, kanunlar ve teoriler gibi bilgilerdir.
C. Dünyamız ve evren hakkında bilinmeyenleri araştırmak, yeni şeyleri ve nasıl çalıştıklarını keşfetmektir.
D. Yaşadığımız dünya ile ilgili problemleri çözmek için deneyler yapmaktır.
E. Bir şeyler icat etmek ya da tasarlamaktır (yapay kalpler, bilgisayarlar ve uzay araçları gibi)
F. Bu dünyayı yaşam için daha iyi bir yer yapmada gerekli olan bilgiyi bulma ve kullanmadır (hastalıkları tedavi etmek, kirliliği çözmek ve tarımı geliştirmek gibi).
G. Yeni bilgiler keşfetmek için fikir ve tekniklere sahip olan insanların (yani bilim adamlarının) bir arada olduğu organizasyondur.

H. Hiç kimse bilimi tanımlayamaz.

I. Anlamadım.
J. Bir seçim yapmak için yeterli bilgiye sahip değilim.
K. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

2. Eğer yetenekli bilim adamları farklı teorilere inanıyorlarsa yaptıkları gözlemler de farklı olacaktır.

A. Evet, çünkü bilim adamları farklı yöntemler kullanarak deney yapacaklar ve farklı şeylere dikkat edeceklerdir.
B. Evet, çünkü bilim adamları birbirlerinden farklı düşünecekler ve bu da onların gözlemlerini farklılaştıracaktır.

C. Bilim adamları farklı teorilere inansalar da bilimsel gözlemler çok fazla değişmez. Bilim adamları gerçekten yetenekli ise gözlemleri de benzer olacaktır.

D. Hayır, çünkü gözlemler olabildiğince kesindir. Bilim bu şekilde gelişir.
E. Hayır, gözlemler gördüklerimizden başka bir şey değildir ve gerçektir.

F. Anlamadım
G. Bir şeçim yapmak için yeterli bilgiye sahip değilim
H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

3. Araştırma laboratuarlarında kullanılan bir çok bilimsel model (örneğin DNA modeli ve atom modeli) gerçeğin kopyalarıdır.

A. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bilim adamları, bu modellerin doğru olduğunu söyler, öyleyse onların doğru olmaları gerekir.
B. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bir çok bilimsel kanıt onların gerçek olduğunu kanıtlamıştır.
C. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bilimsel modeller hayatın gerçekleridir. Amaçları bize gerçekleri göstermek veya bize bu gerçekler hakkında bir şey öğretmektir.

D. Bilimsel modeller, bilimsel gözlem ve araştırmalara dayandığından hemen hemen gerçeğin kopyalarıdır.

E. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü bilimsel modeller sadece kendi sınırlılıkları içinde öğrenme ve açıklamaya yardım eder.
F. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü teoriler gibi, bilimsel modeller de zamana ve bilgimizin durumuna göre değişir.
G. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü gerçeği göremeyeceğimizden dolayı bu modeller düşünce ya da tahminlerden oluşur.

H. Anlamadım
I. Bir şeçim yapmak için yeterli bilgiye sahip değilim
J. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

4. Bilim adamları sınıflandırma yaparken (örneğin türlerine göre bitkileri, periyodik tabloya göre bir elementi, kaynağına göre bir enerjiyi ya da büyüklüğüne göre bir yıldızı) doğada olduğu gibi sınıflandırırlar. Bundan başka bir yol yanlış olurdu.

A. **Çünkü sınıflandırmalar, doğadaki gerçek şekle birebir uyar.** Bilim adamları yıllar boyunca çalışmaları ile bu sınıflandırmaları kanıtlamışlardır.

B. **Çünkü sınıflandırmalar, doğadaki gerçek şekle birebir uyar.** Bilim adamları, sınıflandırma yaparken gözlenebilir özellikleri kullanırlar.

C. Bilim adamları, doğayı en basit ve mantıklı yolla sınıflandırırlar, ama kullandıkları yol her zaman tek yol değildir.

D. Doğayı sınıflandırmanın birçok yolu vardır, ama bir evrensel sistem üzerinde anlaşmak bilim adamlarının çalışmalarındaki karışıklıkları önler.

E. **Doğayı sınıflandırmanın başka doğru yolları olabilir**. Çünkü bilim, değişikliklere uğrayabileceğinden yeni keşifler farklı sınıflandırma sistemlerine yol açabilir.

F. **Hiç kimse doğanın gerçek şeklini bilemez.** Bilim adamları, doğayı algılamalarına göre veya teorilere göre sınıflandırırlar. Bilim asla kesin değildir ve doğa çok çeşitlidir. Bundan dolayı, bilim adamları birden çok sınıflandırma sistemini doğru olarak kullanabilir.

G. Anlamadım

H. Bir şeçim yapmak için yeterli bilgiye sahip değilim

I. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

5. Bilim adamlarınca yapılan çalışmalar doğru olarak yapılsa bile, araştırma sonunda vardıkları bulgular gelecekte değişebilir.

   A. **Bilimsel bilgi değişir;** çünkü bilim adamları, kendilerinden önceki bilim adamlarının teorilerini ya da buluşlarını çürütür. Bilim adamları bunu yeni teknikleri ve geliştirilmiş araçları kullanarak, daha önce gözden kaçırılmış faktörleri bularak veya ilk araştırmadaki hataları ortaya çıkartarak yaparlar.
   B. **Bilimsel bilgi değişir;** çünkü eski bilgiler yeni buluşalrın ışığında yeniden yorumlanır. Bilimsel gerçekler değişebilir.

   C. **Bilimsel bilgi değişir gibi görünür** çünkü eski gerçeklerin yorumu veya uygulaması değişebilir. Doğru şekilde yapılan deneyler **değişmez** gerçeklere yol açar.
   D. **Bilimsel bilgi değişir gibi görünür** çünkü eski bilgilere yeni bilgiler eklenir; eski bilgiler aslında **değişmez**.

   E. Anlamadım
   F. Bir şeçim yapmak için yeterli bilgiye sahip değilim
   G. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

6. Bilimsel düşünceler, hipotezlerden teorilere doğru gelişir; ve sonuçta yeterince güçlüyseler blimsel kanun olurlar.

A. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bir hipotez deneylerle test edilir, eğer doğruluğu **kanıtlanırsa** teori olur. Teori birçok defa ve uzun zaman boyunca farklı insanlar tarafından test edilip kanıtlanırsa **kanun** olur.
B. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bir hipotez deneyler ile test edilir, eğer **desteklenen kanıtlar** varsa teori olur. Bir teori birçok defalar test edilip **doğru olduğu görülürse** bu teorinin kanun olması için yeterlidir.
C. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bilimsel düşüncenin gelişmesi için bu mantıklı bir yoldur.

D. **Teoriler kanun olmaz;** çünkü bunlar farklı türdeki düşüncelerdir. Teoriler kesinliğinden tam olarak emin olunmayan bilimsel düşüncelere dayanır ve doğrulukları kanıtlanamaz. Ancak kanunlar sadece gerçeklere dayanır ve %100 kesindirler.
E. **Teoriler knaun olamaz;** çünkü bunlar farklı türdeki düşüncelerdir. Kanunlar olguları genel olarak **tanımlar.** Teoriler ise kanunları **açıklar.** Ancak destekleyici kanıtlarla, hipotezler teorliere veya kanunlara dönüşebilir.

F. Anlamadım
G. Bir şeçim yapmak için yeterli bilgiye sahip değilim
H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

7. Bilim adamları yeni teorlieri ya da kanunları geliştirirken, doğa hakkında bazı tahminler yapmaları (bazı şeyleri farzetmeleri) gereklidir (örneğin: maddeler atomlardan oluşur). Bilimin düzenli bir şekilde gelişmesi için bu tahminler doğru olmak zorundadır.

A. **Bilimin gelişmesi için bu tahminler doğru olmalıdır**; çünkü doğru teori ve kanunlar için doğru tahminler gereklidir. Aksi halde bilim adamları, yanlış teori ve kanunları kullanarakçok fazla zamanı ve çabayı boşa harcayacaktır.

B. **Bilimin gelişmesi için bu tahminler doğru olmalıdır;** aksi halde toplum, yetersiz teknoloji ve tehlikeli kimyasal maddeler gibi ciddi problemlerle karşı karşıya kalır.

C. **Bilimin gelişmesi için bu tahminler doğru olmalıdır;** çünkü bilim adamları çalışmalarını ilerletmeden önce, tahminlerinin doğru olduğunu kanıtlamak için araştırma yaparlar

D. **Bilimin gelişmesi için bu tahminler doğru olması gerekir düşüncesi duruma bağlıdır.** Bilim bazen ilerleme içn doğru varsayımlara ihtiyaç duyar. Ama tarih bazen şunu göstermiştir ki, büyük bulular bir teorinin **çürütülmesi** ve onun yanlış tahminlerinin öğrenimesi ile yapılmıştır.

E. **Bilimin gelişmesi için tahminlerin doğru olup olmaması sorun değildir.** Bilim adamları projelerine başlamak için doğru ya da yanlış tahminler yapmak zorundadırlar. Tarih göstermiştir ki, büyük buluşlar bir teorinin **çürütülmesi** ve onun yanlış tahminlerinin öğrenilmesi ile yapılmıştır.

F. Bilim adamları varsayımlarda **bulunmazlar**. Onlar, bir fikrin doğru olup olmadığını öğrenmek için araştırırlar. Onun doğru lduğunu varsaymazlar.

G. Anlamadım

H. Bir şeçim yapmak için yeterli bilgiye sahip değilim

I.Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

8. İyi bilimsel teoriler, gözlemleri iyi bir şekilde açıklar. Aynı zamanda iyi teoriler, karmaşık değil basit olurlar.

A. İyi teoriler basit olurlar. Bilimde kullanılacak en iyi dil basit, kısa ve doğrudan olandır.

B. Bu ne derece **derin** açıklamalar yapmak istediğinize bağlıdır. İyi bir teori, bir şeyi hem basit hem de karmaşık bir yolla açıklayabiir.

C. Bu **teoriye** bağlıdır. Bazı iyi teoriler basit, bazıları ise karmaşıktır.

D. İyi teoriler karmaşık olabilir ama kullanılacaklarsa basit, anlaşılabilir bir dile **çevirilebilmelidir**.

E. Teoriler genellikle **karmaşıktır.** Bazı şeyler, eğr birçok ayrıntı içeriyorsa basitleştirilemez.

F. İyi teorilerin çoğu **karmaşıktır**. Eğer dünya basit olsaydı, teoriler de basit olabilirlerdi.

G. Anlamadım

H. Bir şeçim yapmak için yeterli bilgiye sahip değilim

I. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

9. Bilim adamları araştırma yaptıklarında **bilimsel yöntemi** izledikleri söylenir.

A. **Bilimsel yöntem,** genellikle bilim adamları tarafından dergide ya da kitapta yazılan ve deny yapılırken izlenmesi gereken laboratuar işlemleri ya da teknikleridir.

B. **Bilimsel yöntem** sonuçların dikkatlice kaydedilmesidir.

C. **Bilimsel yöntem** deney değişkenlerinin, yoruma yer bırakmaksızın dikkatlice kontrol edilmesidir.

D. **Bilimsel yöntem** gerçeklerin, teorilerin ve hipotezlerin etkili şekilde elde edilmesidir.

E. **Bilimsel yöntem** test etmek ve tekrar test etmektir. Bir şeyin doğruluğunu ya da yanlışlığını geçerli şekilde kanıtlamaktır.

F. **Bilimsel yöntem teoriyi kanıtlamak için deney oluşturmaktır.**

G. **Bilimsel yöntem** soru sormak, hipotez kurmak, veri toplamak ve sonuca varmaktır.

H. **Bilimsel yöntem** problem çözmede mantıklı ve kabul gören bir yaklaşımdır.

I. **Bilimsel yöntem** bilim adamlarının çalışmalarında yönlendirilen bir tutumdur.

J. Bilim adamlarının aslında ne yaptıkları düşünülürse, gerçekte **bilimsel yöntem** diye bir şey yoktur.

K. Anlamadım

L. Bir şeçim yapmak için yeterli bilgiye sahip değilim

M. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

10. En iyi bilim adamları, bilimsel yöntemin basamaklarını takip edenlerdir.

A. Bilimsel yöntem geçerli, açık, mantıklı ve kesin sonuçları garanti eder. Bu nedenle, birçok bilim adamı bilimsel yöntemin basamaklarını izleyeecktir.

B. Okulda öğrendiklerimize dayanarak, bilimsel yöntem birçok bilim adamının çalışmasında yararlı olması gerekir.

C. Bilimsel yöntem birçok konuda yararlıdır ama bu yöntemin sonuç vereceği garanti değildir. Bundan dolayı başarılı bilim adamları, aynı zamanda orjinalliği ve yaratıcılığı da kullanacaklardır.

D. En iyi bilim adamları, hayal gücü ve yaratıcılık yöntemleri de dahil istenilen sonuçları verebilecek, herhangi bir yöntemi kullanan kişilerdir.

E. Birçok bilimsel keşif, bilimsel yönteme bağlı kalmadan, tesadüfen yapılmıştır.

F. Anlamadım

G. Bir şeçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

11. Bilimsel araştırma sonuçlanana kadar her biri bir sonrakine öncülük eden bir dizi araştırma yapılmıştır.

A. **Bilimsel buluşlar, mantıklı bir dizi araştırmanın sonucudur;** çünkü deneyler (örneğin atom modeline öncülük eden deneyler, ya da kanser ile ilgili buluşlar) bir duvarı oluşturan tuğlalar gibidir.

B. **Bilimsel buluşlar, mantıklı bir dizi araştırmanın sonucudur;** çünkü araştırmalar, önceki deneylerin doğruluğunu görmek için sonuçların test edilmesi ile başlar. Yeni bir deney, daha sonra gelecek bilim adamları tarafından test edilecektir.

C. **Genellikle** bilimsel buluşlar mantıklı bir dizi araştırmadan kaynaklanır. Ama bilim tamamen mantıklı değildir. Bu süreçte deneme-yanılma ve sanş payı vardır.

D. **Bazı** bilimsel bulışlar tesadüfidir veya bilim adamlarının gerçek beklentilerinin önceden tahmin edilemeyen bir ürünüdür. Fakat buluşların **çoğu** birbiri üzerine inşa edilen bir dizi araştırmanın sonucudur.

E. **Çoğu** bilimsel buluşlar tesadüfidir veya bilim adamlarının gerçek beklentilerinin önceden tahmin edilemeyen bir ürünüdür. **Bazı** buluşlar birbirini izleyen mantıklı bir dizi araştırmanın sonucudur.

F. **Bilimsel buluşlar mantıklı bir dizi araştırmanın sonucunda oluşmaz;** çünkü buluşlar sıklıkla, önceden birbirleri ile bağlantılı olmayan bilgi parçalarının bir araya gelmesi iel oluşur.

G. **Bilimsel buluşlar mantıklı bir dizi araştırmanın sonucunda oluşmaz;** çünkü buluşlar temelde birbirleri ile alakasız olan ama beklenmedik bir şekilde birbirleri ile ilişkili hala gelen çok çeşitli çalışmaların sonucunda oluşur.

H. Anlamadım

I. Bir şeçim yapmak için yeterli bilgiye sahip değilim

J. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

12. Bilim adamları, çalışmalarının sonuçlarını bilimsel dergilerde yayınlarlar. Bilim adamları, bir dergi için makale yazdıklarında, raporları çok amntıklı ve düzenli şekilde organize ederler. Fakat bilim adamları aslında çalışmalarını daha az amntıklı bir yolla yaparlar.

A. **Makaleler bilimsel çalışmanın aslından daha mantıklı bir yol ile yazılır**; çünkü bilim adamları düzenlenmiş bir planı izlemeden düşünebilir ve çalışabilirler. Sonuç olarak, eğer onların düşüncelerinin ve methodlarının düzenini okursanız, bu afzla karmaşık olabilir. Bu nedenle bilim adamları diğer bilim adamlarının, sonuçları anlayabilmesi için, makaleleri mantıklı bir yol ile yazarlar.

B. **Makaleler bilimsel çalışmanın aslından daha mantıklı bir yol ile yazılır;** çünkü bilimsel hipotezler, kişisel görüş veya tahmindir ve sonuç olarak mantıklı değildir. Bu nedenle, bilim adamları diğer bilim adamlarının sonuçları anlayabilmesi için mantıklı bir yol ile yazarlar.

C. Bilim adamları genellikle "reçete" vermek istemezler, fakat sonuçlarını dünyaya duyurmak isterler. Bu nedenle çalışmalarını mantıklı bir biçimde yazarlar ama aslında nasıl yaptıklarını açıklamazlar.

D. Bu duruma bağlı. Bazen bilimsel buluşlar tesadüfen oluşur ama bazen de buluşlar makalelerin yazıldığı gibi mantıklı ve düzenli şekilde oluşur.

E. **Makaleler asıl çalışmanın nasıl yapıldığını göstererek mantıklı yolla yazılır;** çünkü bilim adamlarının çalışması mantıkla yürütülür; aksi halde bilim ve teknoloji için yararlı olmayacaktır.

F. **Makaleler asıl çalışmanın nasıl yapıldığını göstererek mantıklı yolla yazılır;** bilim adamları basılan raporlarının mantıklı bir şekilde yazımının kolay olması için, çalışmalarını mantıklı bir yolla yaparlar.

G. **Makalelerin mantıklı bir yolla yazılması gerekli değildir**. Onlar çalışmanın yapıldığı şekilde yazılır. Bu karmaşık veya kolay olabilir.

H. Anlamadım

I. Bir şeçim yapmak için yeterli bilgiye sahip değilim

J. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

13. Bilim adamlarının çalışmalarında hata yapmamaları gerekir; çünkü bu hatalar bilimin ilerlemesini yavaşlatır.

A. **Hatalar bilimin ilerlemesini yavaşlatır**. Yanıltıcı bilgiler yanlış sonuçlara götürebilir. Eğer bilim adamlarının sonuçlarındaki hataları anında düzeltmezlerse bilim ilerlemez.
B. **Hatalar bilimin ilerlemesini yavaşlatır**. Yeni teknoloji ve araçlar, doğruluğu artırarak hataları azaltır ve böylece bilim daha hızlı ilerler.

C. **Hatalardan kaçınılmaz**; bu nedenle bilim adamları, bir fikir birliğine ulaşana dek birbirlerini kontrol ederek hatalarını azaltırlar.
D. **Hatalardan kaçınılmaz**; bazı hatalar bilimin ilerlemesini yavaşlatabilir, ama bazı hatalar yeni veya büyük bir buluşa neden olabilir. Eğer bilim adamları hatalarından bir şeyler **öğrenir** ve düzeltirlerse bilim ilerleyecektir.

E. **Hatalar genellikle bilimin ilerlemesine yardım eder**. Bilim geçmişin hatalarını tespit edip düzelterek ilerler.

F. Anlamadım
G. Bir şeçim yapmak için yeterli bilgiye sahip değilim
H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

14. Kesin bilgilere dayanarak varsayımlar yaparken bile, bilim adamları ve mühendisler bize sadece neyin muhtemelen olabileceğini söyleyebilirler. Kesin olarak ne olacağını söyleyemezler.

A. **Varsayımlar asla kesin değildir;** çünkü daima sonucu etkileyecek önceden tahmin edilemeyen olaylar ve hata olasılığı vardır. Hiçkimse geleceği kesin olarak tahmin edemez.

B. **Varsayımlar asla kesin değildir;** çünkü yeni buluşlar yapıldıkça, kesin bilgi değişir ve bu nedenle de varsayımlar daima değişecektir.

C. **Varsayımlar asla kesin değildir;** çünkü varsayım gerçeğin belirtilmesi değildir. Varsayım iyi yapılmış bir tahmindir.

D. **Varsayımlar asla kesin değildir;** çünkü bilim adamları asla tüm gerçeklere sahip değillerdir. Bazı bilgiler daima eksiktir.

E. **Duruma bağlıdır.** Varsayımlar ancak doğru ve yeterli bilginin olması halinde kesindir.

F. Anlamadım

G. Bir şeçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

15. Eğer bilim adamları, asbestle çalışan insanların akciğer kanserine yakalanma ihtimalinin ortalama bir insanınkinin iki misli olduğunu bulursa, bu asbestin akciğer kanserine sebep olduğu anlamına gelmelidir.

A. **Bu gerçekler açık şekilde asbestin akciğer kanserine sebep olduğunu kanıtlar**. Eğer asbest işçilerinin akciğer kanserine yakalanma olasılığı daha fazlaysa, bu durumda kanserin sebebi asbesttir.

B. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir**; çünkü akciğer kanserine asbestin mi veya başka bir maddenin mi yol açtığını bulmak için daha fazla araştırmaya gerek vardır.

C. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir;** çünkü asbest **başka şeyler ile birlikte** veya dolaylı olarak buna yol açabilir (örneğin akciğer kanserine yakalanmaya sebep olan diğer şeylere karşı direnci zayıflatabilir).

D. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir;** çünkü eğer asbest kanser yapsaydı, tüm asbest işçileri akciğer kanserine yakalanmış olurdu.

E. Asbest akciğer kanserinin nedeni olamaz çünkü asbest ile çalışmayan bir çok insan da akciğer kanserine yakalanmaktadır.

F. Anlamadım

G. Bir şeçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

16. Bilim doğal dünyanın doğaüstü varlıklar tarafından değiştirilemeyeceği (örneğin Tanrı) varsayımına dayanır.

A. **Bilim adamları, doğaüstü bir varlığın doğal dünyayı değiştiremeyeceğini varsayarlar;** çünkü doğaüstü, bilimsel olarak kanıtlanamaz. Bilimin dışındaki diğer bakış açıları, doğaüstü bir varlığın doğal dünyayı değiştirebileceğini varsayar.

B. **Bilim adamları, doğaüstü bir varlığın doğal dünyayı değiştiremeyeceğini varsayarlar;** çünkü şayet doğaüstü bir varlık olsaydı, bilimsel gerçekler bir göz kırpışı ile değişirdi. Ancak bilim adamları sürekli tutarlı sonuçlara ulaşırlar.

C. **Bu duruma bağlıdır**. Bilim adamlarının doğaüstü bir varlık hakkındaki varsayımları kişisel olarak değişmektedir.

D. **Her şey mümkündür**. Bilim doğa hakkındaki her şeyi bilmez. Bundan dolayı, bilim doğaüstü varlıkların doğal dünyayı değiştirebileceği lasılığına karşı açık görüşlü olmalıdır.

E. **Bilim doğaüstünü de araştırabilir ve belki açıklayabilir**. Bundan dolayı, bilim doğaüstü varlıkların olduğunu kabuledebilir.

F. Anlamadım

G. Bir seçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

17. Bir sanatçı bir heykeli “icat ederken” , bir altın madencisinin de altın “keşfettiğini” farzedelim. Bazı insanlar bilim adamlarının bilimsel **KANUNLARI** “keşfettiğini”, bazıları ise “icat ettiklerini” düşünürler. Siz ne dersiniz?

A. **Bilim adamları bilimsel kanunları keşfederler;** çünkü kanunlar doğadadır ve bilim adamları sadece onları bulmak zorundadır.

B. **Bilim adamları bilimsel kanunları keşfederler;** çünkü kanunlar deneysel **gerçeklere** dayanır.

C. **Bilim adamları bilimsel kanunları keşfederler;** fakat bilim adamları bu kanunları bulmak için **yöntemleri** yaratırlar.

D. Bazı bilim adamları, bir kanunu sanş eseri bulur, yani keşfeder. Fakat diğer bilim adamları kanunları önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim adamları bilimsel kanunları icat ederler**; çünkü bilim adamları buldukları deneysel gerçekleri yorumlar. Bilim adamları doğanın yaptıklarını değil, doğanın yaptıklarını **tanımlayan** kanunları icat ederler.

F. Anlamadım

G. Bir seçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

18. Bir sanatçı bir heykeli “icat ederken”, bir altın madencisinin de altın keşfettiğini farzedelim. Bazı insanlar bilim adamlarının bilimsel **HİPOTEZLERİ** keşfetiğini, bazıları ise “icat ettiklerini” düşünürler. Siz ne dersiniz?

A. **Bilim adamları bir hipotezi keşfederler;** çünkü düşünce her zaman doğada, açığa çıkartılmayı bekler.
B. **Bilim adamları bir hipotezi keşfederler;** çünkü hipotez deneysel gerçeklere dayanır.
C. **Bilim adamları bir hipotezi keşfederler;** fakatbilim adamları bir hipotezi bulmak için **yöntemleri** icat ederler.

D. Bazı bilim adamları, bir hipotezi sanş eseri bulur, yani keşfeder. Ancak diğer bilim adamları hipotezi önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim adamları bir hipotezi icat ederler**; çünkü bir hipotez, bilim adamlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır.
F. **Bilim adamları bir hipotezi icat ederler**; çünkü hipotezler zihinden gelir, onları biz oluştururuz.

G. Anlamadım
H. Bir seçim yapmak için yeterli bilgiye sahip değilim
I. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

19. Bir sanatçı bir heykeli “icat ederken”, bir altın madencisinin de altın keşfettiğini farzedelim. Bazı insanlar bilim adamlarının bilimsel **TEORİLERİ** “keşfettiklerini”, bazıları ise “icat ettiklerini” düşünürler. Siz ne dersiniz?

A. **Bilim adamları bir teoriyi keşfederler;** çünkü düşünce her zaman doğada, açığa çıkartılmayı bekler.
B. **Bilim adamları bir teoriyi keşfederler;** çünkü bir teori deneysel gerçeklere dayanır.
C. **Bilim adamları bir teoriyi keşfederler;** fakat bilim adamları bu teorileri bulmak için **yöntemleri** icat ederler.

D. Bazı bilim adamları, bir teoriyi sanş eseri bulur, yani keşfeder. Ancak diğer bilim adamları teoriyi önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim adamları birteoriyi icat ederler**; çünkü bir teori, bilim adamlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır.
F. **Bilim adamları bir teoriyi icat ederler**; çünkü teoriler zihinden gelir, onları biz oluştururuz.

G. Anlamadım
H. Bir seçim yapmak için yeterli bilgiye sahip değilim
I. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

20. Farklı alanlardaki bilim adamları, aynı şeye çok farklı açılardan bakarlar (örneğin, $H^+$ kimyagerlerin asit oranını, fizikçilerin protonları düşünmelerine sebep olur). Bu, farklı alanlarda çalışan bilim adamlarının birbirlerinin çalışmalarını anlamalarını zorlaştırır.

A. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları zordur**; çünkü bilimsel düşünceler bilim adamlarının **bakış açısına** veya onların alışkanlıklarına bağlıdır.

B. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları zordur**; çünkü bilim adamları kendi alanları ile kesişen diğer alanların dilini anlamak için çaba sarfetmelidirler.

C. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır**; çünkü bilim adamları zekidir ve bu nedenle diğer alanların dillerini ve bakış açılarının öğrenmenin yollarını bulabilirler.

D. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır**; çünkü bilim adamlarının aynı anda değişik alanlarda çalışmış olmaları muhtemeldir.

E. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır**; çünkü farklı alanlardaki bilimsel düşünceler kesişir. Gerçekler bilimsel alan ne olursa olsun gerçektir.

F. Anlamadım

G. Bir seçim yapmak için yeterli bilgiye sahip değilim

H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

21. Farklı alanlardaki bilim adamları, aynı şeye çok farklı açılardan bakarlar (örneğin, $H^+$ kimyagerlerin asit oranını, fizikçilerin protonları düşünmelerine sebep olur). Bunun anlamı, bir bilimsel düşüncenin bilim adamının çalıştığı alana bağlı olarak farklı anlamlara sahip olduğudur.

A. **Bilimsel bir düşünce farklı alanlarda farklı anlamlara gelecektir**; çünkü bilimsel düşünceler bir alanda, diğer bir alana göre farklı yorumlanabilir.
B. **Bilimsel bir düşünce farklı alanlarda farklı anlamlara gelecektir**; çünkü bilimsel düşünceler bilim adamının **kişisel** görüşlerine veya önceki bilgilerine bağlı olarak farklı şekilde yorumlanabilir.

C. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** çünkü bilim adamının bakış açısı ne olursa olsun, düşünce yinede doğadaki **aynı gerçekleri ifade eder.**
D. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** çünkü tüm bilimler birbirleri ile **yakın ilişki** içindedir.
E. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** farklı alanlardaki insanların birbirleri ile iletişim kurmaları için bu gereklidir. Bilim adamları aynı anlamları kullanmak için **anlaşmışlardır**.

F. Anlamadım
G. Bir seçim yapmak için yeterli bilgiye sahip değilim
H. Seçeneklerin hiçbiri kişisel görüşümü yansıtmıyor.

## APPENDIX G

## PERCENTAGES OF STUDENTS' RESPONSES ON ACID BASE CONCEPT TEST FOR ALL STUDENTS

**Table G.1** Percentages of students' responses on ABCT for all students

| | | Post- test % | |
|---|---|---|---|
| **Item Number** | **Response** | **Experiment Groups** | **Control Groups** |
| 1 | A* | 69.2 | **35.8** |
| | B | 1.5 | 9.4 |
| | C | 3.1 | 26.4 |
| | D | 3.1 | 17.0 |
| | E | 23.1 | 11.3 |
| 2 | A | 3.1 | 9.4 |
| | B | 1.5 | 3.8 |
| | C | 23.1 | 9.4 |
| | D* | 61.5 | 62.3 |
| | E | 6.2 | 13.2 |
| 3 | A | 3.1 | 9.4 |
| | B* | 84.6 | 77.4 |
| | C | - | 5.7 |
| | D | 4.6 | 5.7 |
| | E | 1.5 | 1.9 |
| 4 | A* | 83.1 | 73.6 |
| | B | - | - |
| | C | - | - |
| | D | 16.9 | 17.0 |
| | E | - | 7.5 |
| 5 | A | - | - |
| | B | - | - |
| | C | - | 3.8 |
| | D | 3.1 | 7.5 |
| | E* | 96.9 | 86.8 |

**Table G.1** (Continued)

| | | | |
|---|---|---|---|
| 6 | A | - | 3.8 |
| | B | 1.5 | 1.9 |
| | C | - | - |
| | D* | 98.5 | 92.5 |
| | E | - | 1.9 |
| 7 | A | 1.5 | - |
| | B | 1.5 | 5.7 |
| | C | 7.7 | 7.5 |
| | D | 1.5 | 7.5 |
| | E* | 87.7 | 75.5 |
| 8 | A | - | 3.8 |
| | B | 4.6 | 9.4 |
| | C | - | - |
| | D* | 95.4 | 84.9 |
| | E | - | 1.9 |
| 9 | A | 1.5 | 5.7 |
| | B | 4.6 | 11.3 |
| | C | 4.6 | 5.7 |
| | D | 7.7 | 15.1 |
| | E* | 80.0 | **52.8** |
| 10 | A | 4.6 | 3.8 |
| | B | 1.5 | 5.7 |
| | C* | **61.5** | **41.5** |
| | D | 13.8 | 13.2 |
| | E | 16.9 | 32.1 |
| 11 | A | 6.2 | 15.1 |
| | B | 3.1 | 18.9 |
| | C | - | 3.8 |
| | D* | 87.7 | **50.9** |
| | E | - | 9.4 |
| 12 | A | 1.5 | 11.3 |
| | B | 4.6 | 11.3 |
| | C | - | 5.7 |
| | D | - | 9.4 |
| | E* | 93.8 | **60.4** |
| 13 | A | - | 7.5 |
| | B* | 92.3 | 69.8 |
| | C | 3.1 | 9.4 |
| | D | 3.1 | 1.9 |
| | E | - | - |

**Table G.1** (Continued)

| | | | |
|---|---|---|---|
| 14 | A | - | 3.8 |
| | B | 20.0 | 34.0 |
| | C | - | 1.9 |
| | D* | 78.5 | **35.8** |
| | E | - | 11.3 |
| 15 | A | - | - |
| | B* | 96.9 | 92.5 |
| | C | - | 3.8 |
| | D | - | - |
| | E | - | - |
| 16 | A | 1.5 | 3.8 |
| | B* | 96.9 | 92.5 |
| | C | - | - |
| | D | - | - |
| | E | - | - |
| 17 | A | 4.6 | - |
| | B | 7.7 | 3.8 |
| | C | 1.5 | 1.9 |
| | D* | **52.3** | **28.3** |
| | E | 33.8 | 58.5 |
| 18 | A | 12.3 | 11.3 |
| | B* | 69.2 | 67.9 |
| | C | - | 1.9 |
| | D | 9.2 | 5.7 |
| | E | 1.5 | - |
| 19 | A* | 78.5 | 62.3 |
| | B | - | 1.9 |
| | C | - | 3.8 |
| | D | - | 1.9 |
| | E | 18.5 | 24.5 |
| 20 | A | - | - |
| | B | 1.5 | 1.9 |
| | C | 3.1 | 5.7 |
| | D | - | 13.2 |
| | E* | 93.8 | 67.9 |

**Table G.1** (Continued)

| | | | |
|---|---|---|---|
| 21 | A | 15.4 | 1.9 |
| | B | 3.1 | 7.5 |
| | C | - | 7.5 |
| | D* | **66.2** | **30.2** |
| | E | 4.6 | 15.1 |
| 22 | A* | 86.2 | 79.2 |
| | B | 6.2 | 5.7 |
| | C | - | - |
| | D | - | - |
| | E | 6.2 | 3.8 |
| 23 | A | 3.1 | 11.3 |
| | B | 4.6 | 7.5 |
| | C | 7.7 | 5.7 |
| | D* | 81.5 | 60.4 |
| | E | - | 9.4 |
| 24 | A | - | - |
| | B | - | 3.8 |
| | C | 7.7 | 13.2 |
| | D* | 86.2 | 75.5 |
| | E | 1.5 | 1.9 |
| 25 | A | - | 5.7 |
| | B | 1.5 | - |
| | C* | 89.2 | 64.2 |
| | D | 1.5 | 3.8 |
| | E | - | - |
| 26 | A | - | 3.8 |
| | B* | 69.2 | **41.5** |
| | C | 6.2 | 20.8 |
| | D | - | 3.8 |
| | E | - | 1.9 |
| 27 | A | - | 1.9 |
| | B | 6.2 | - |
| | C* | 87.7 | 66.0 |
| | D | 1.5 | 9.4 |
| | E | 3.1 | 5.7 |

**Table G.1** (Continued)

| | | | |
|---|---|---|---|
| 28 | A | 4.6 | - |
| | B | 3.1 | - |
| | C | - | 1.9 |
| | D | 20.0 | 3.8 |
| | E* | **46.2** | **22.6** |
| 29 | A | - | - |
| | B | 1.5 | - |
| | C | 3.1 | 5.7 |
| | D* | 92.3 | 88.7 |
| | E | - | - |
| 30 | A* | 78.5 | **49.1** |
| | B | 1.5 | - |
| | C | 3.1 | 5.7 |
| | D | - | 1.9 |
| | E | 1.5 | 1.9 |

# APPENDIX H

## PERCENTAGES OF STUDENTS' RESPONSES ON ACID BASE CONCEPT TEST ACCORDING TO SCHOOL TYPES

**Table H.1** Percentages of students' responses on ABCT according to school types

| | | **Anatolian Teacher High School Posttest %** | | **Anatolian High School Posttest %** | |
|---|---|---|---|---|---|
| **Item No** | **Response** | **Experiment Group** | **Control Group** | **Experiment Groups** | **Control Groups** |
| 1 | A* | 73.9 | 64.3 | 66.7 | 25.6 |
| | B | - | - | 2.4 | 12.8 |
| | C | - | 28.6 | 4.8 | 25.6 |
| | D | - | 7.1 | 4.8 | 20.5 |
| | E | 26.1 | - | 21.4 | 15.4 |
| 2 | A | - | 7.1 | 4.8 | 10.3 |
| | B | - | - | 2.4 | 5.1 |
| | C | 8.7 | 7.1 | 16.0 | 10.3 |
| | D* | 87.0 | 85.7 | 52.6 | 53.8 |
| | E | - | - | 9.5 | 17.9 |
| 3 | A | 4.3 | - | 2.4 | 12.8 |
| | B* | 73.9 | 71.4 | 90.5 | 79.5 |
| | C | - | 21.4 | - | - |
| | D | 4.3 | 7.1 | 4.8 | 5.1 |
| | E | - | - | 2.4 | 2.6 |
| 4 | A* | 69.6 | 85.7 | 90.5 | 69.2 |
| | B | - | - | - | - |
| | C | - | - | - | - |
| | D | 30.4 | 14.3 | 9.5 | 17.9 |
| | E | - | - | - | 10.3 |
| 5 | A | - | - | - | - |
| | B | - | - | - | - |
| | C | - | 7.1 | - | 2.6 |
| | D | 4.3 | - | 2.4 | 10.3 |
| | E* | 95.7 | 92.9 | 97.6 | 84.6 |

**Table H.1** (Continued)

| | | | | | |
|---|---|---|---|---|---|
| 6 | A | - | - | - | 5.1 |
| | B | - | - | 2.4 | 2.6 |
| | C | - | - | - | - |
| | D* | 100 | 92.9 | 97.6 | 92.3 |
| | E | - | 7.1 | - | - |
| 7 | A | - | - | 2.4 | - |
| | B | - | - | 2.4 | 7.7 |
| | C | - | - | 11.9 | 10.3 |
| | D | 4.3 | 7.1 | - | 7.7 |
| | E* | 95.7 | 92.9 | 83.3 | 69.2 |
| 8 | A | - | - | - | 5.1 |
| | B | 4.3 | 7.1 | 4.8 | 10.3 |
| | C | - | - | - | - |
| | D* | 95.7 | 85.7 | 95.2 | 84.6 |
| | E | - | 7.1 | - | - |
| 9 | A | 4.3 | 7.1 | - | 5.1 |
| | B | 4.3 | 21.4 | 4.8 | 7.7 |
| | C | 4.3 | - | 4.8 | 7.7 |
| | D | - | 28.6 | 11.9 | 10.3 |
| | E* | 87.0 | 42.9 | 76.2 | 56.4 |
| 10 | A | - | - | 7.1 | 5.1 |
| | B | 4.3 | - | - | 7.7 |
| | C* | 82.6 | 50.0 | 50.0 | 38.5 |
| | D | 13.0 | 7.1 | 14.3 | 15.4 |
| | E | - | 42.9 | 26.2 | 28.2 |
| 11 | A | 8.7 | 14.3 | 4.8 | 15.4 |
| | B | - | - | 4.8 | 25.6 |
| | C | - | 7.1 | - | 2.6 |
| | D* | 87.0 | 64.3 | 88.1 | 46.2 |
| | E | - | 7.1 | - | 10.3 |
| 12 | A | - | 21.4 | 2.4 | 7.7 |
| | B | - | - | 7.1 | 15.4 |
| | C | - | 21.4 | - | - |
| | D | - | 28.6 | - | 2.6 |
| | E* | 100 | 21.4 | 90.5 | 74.4 |
| 13 | A | - | 7.1 | - | 7.7 |
| | B* | 100 | 50.0 | 88.1 | 76.9 |
| | C | - | 35.7 | 4.8 | - |
| | D | - | 7.1 | 4.8 | - |
| | E | - | - | - | - |

**Table H.1** (Continued)

| | | | | | |
|---|---|---|---|---|---|
| 14 | A | - | - | - | 5.1 |
| | B | 4.3 | 14.3 | 28.6 | 41.0 |
| | C | - | 7.1 | - | - |
| | D* | 95.7 | 50.0 | 69.0 | 30.8 |
| | E | - | 14.3 | - | 10.3 |
| 15 | A | - | - | - | - |
| | B* | 100 | 85.7 | 95.2 | 94.9 |
| | C | - | 14.3 | - | - |
| | D | - | - | - | - |
| | E | - | - | - | - |
| 16 | A | - | - | 2.4 | 5.1 |
| | B* | 100 | 100 | 95.2 | 89.7 |
| | C | - | - | - | - |
| | D | - | - | - | - |
| | E | - | - | - | - |
| 17 | A | - | - | 7.1 | - |
| | B | 4.3 | - | 9.5 | 5.1 |
| | C | - | - | 2.4 | 2.6 |
| | D* | 60.9 | 42.9 | 47.6 | 23.1 |
| | E | 34.8 | 57.1 | 33.3 | 59.0 |
| 18 | A | - | 35.7 | 19.0 | 2.6 |
| | B* | 78.3 | 64.3 | 64.3 | 69.2 |
| | C | - | - | - | 2.6 |
| | D | - | - | 14.3 | 7.7 |
| | E | - | - | 2.4 | - |
| 19 | A* | 73.9 | 85.7 | 81.0 | 53.8 |
| | B | - | - | - | 2.6 |
| | C | - | - | - | 5.1 |
| | D | - | 7.1 | - | - |
| | E | 26.1 | 7.1 | 14.3 | 30.8 |
| 20 | A | - | - | - | - |
| | B | 4.3 | - | - | 2.6 |
| | C | - | - | 4.8 | 7.7 |
| | D | - | 7.1 | - | 15.4 |
| | E* | 95.7 | 85.7 | 92.9 | 61.5 |

**Table H.1** (Continued)

| | | | | | |
|---|---|---|---|---|---|
| 21 | A | 4.3 | - | 21.4 | 2.6 |
| | B | 8.7 | 7.1 | - | 7.7 |
| | C | - | - | - | 10.3 |
| | D* | 87.0 | 64.3 | 54.8 | 17.9 |
| | E | - | 28.6 | 7.1 | 10.3 |
| 22 | A* | 95.7 | 92.9 | 81.0 | 74.4 |
| | B | - | 7.1 | 9.5 | 5.1 |
| | C | - | - | - | - |
| | D | - | - | - | - |
| | E | - | - | 9.5 | 5.1 |
| 23 | A | - | 14.3 | 4.8 | 10.3 |
| | B | 4.3 | 7.1 | 4.8 | 7.7 |
| | C | 8.7 | 7.1 | 7.1 | 5.1 |
| | D* | 87.0 | 50.0 | 78.6 | 64.1 |
| | E | - | 21.4 | - | 5.1 |
| 24 | A | - | - | - | - |
| | B | - | 14.3 | - | - |
| | C | 8.7 | 21.4 | 7.1 | 10.3 |
| | D* | 91.3 | 64.3 | 83.3 | 79.5 |
| | E | - | - | 2.4 | 2.6 |
| 25 | A | - | 7.1 | - | 5.1 |
| | B | - | - | 2.4 | - |
| | C* | 87.0 | 85.7 | 90.5 | 56.4 |
| | D | - | 7.1 | 2.4 | 2.6 |
| | E | - | - | - | - |
| 26 | A | - | 14.3 | - | - |
| | B* | 69.6 | 71.4 | 69.0 | 30.8 |
| | C | 4.3 | 14.3 | 9.5 | 23.1 |
| | D | | - | - | 5.1 |
| | E | 4.3 | - | - | 2.6 |
| 27 | A | - | - | - | 2.6 |
| | B | 13.0 | - | 2.4 | - |
| | C* | 82.6 | 78.6 | 90.5 | 61.5 |
| | D | - | - | 2.4 | 12.8 |
| | E | - | 21.4 | 4.8 | - |

**Table H.1** (Continued)

| | | | | | |
|---|---|---|---|---|---|
| 28 | A | 8.7 | - | 2.4 | - |
| | B | 4.3 | - | 2.4 | - |
| | C | - | - | - | 2.6 |
| | D | 8.7 | - | 26.2 | 5.1 |
| | E* | 56.5 | 50.0 | 40.5 | 12.8 |
| 29 | A | - | - | - | - |
| | B | 4.3 | - | - | - |
| | C | - | - | 4.8 | 7.7 |
| | D* | 91.3 | 100 | 92.9 | 84.6 |
| | E | - | - | - | - |
| 30 | A* | 87.0 | 71.4 | 73.8 | 41.0 |
| | B | 4.3 | - | - | - |
| | C | - | 21.4 | 4.8 | - |
| | D | - | - | - | 2.6 |
| | E | - | 7.1 | 2.4 | - |

## APPENDIX I

## THE EXCERPTS FROM THE STUDENTS' INTERVIEWS

***I: Asit denilince aklına ne geliyor? /Asitleri nasıl tanımlarsın?***

*$S_1$: Asit deyince aklıma pH ı 7 den küçük olan bileşikler geliyor. İyonlaştıkça suya $H^+$ verenler geliyor….Yapısında Hidrojen iyonu olanlar geliyor.*

*$S_2$: pH ı 7 den küçük olan H iyonu OH' hından fazla olan. Tadı ekşi olan*

*$S_6$: Tehlikeli bir şey geliyor veya limon gibi bir şey geliyor.*

*$S_7$: pH ı 7 den küçük olanlar aklıma geliyor.*

*$S_8$: Öğrendiğim kadarı ile pH ı 7 den küçük olanlar.*

*$S_3$: Asit deyince, $H^+$ iyonları, pH ı 0 ile 7 arasında. Başka yakıcı özelliği var. Tatları ekşi. Başka ne diyebilirim? Midenin pH ı 2 düzeyinde olduğu için asidik özellik gösterir. HCl midede bulunan bir asittir. Zayıf asitler vardır, %100 iyonlaşmayan asitler. Bir de %100 iyonlaşan mesela HCl asit kuvvetli asitler vardır.*

*$S_9$: Yakıcı, ekşi. pH ı 7 den küçük olanlar.*

*$S_4$: Yakıcı bir şey, ekşi bir şey.*

*$S_5$:Aklıma H geliyor. Limon geliyor. Turnusol kâğıdını kırmızıya çeviriyor.*

*$S_{10}$: pH ı 7 den küçük olanlar, tatları ekşi, hidrojen iyonu veriyorlar.*

***I: Baz denilince aklına ne geliyor?/Bazları nasıl tanımlarsın?***

*$S_1$: Baz deyince de suda çözündüğünde suya OH iyonu verenler geliyor. pH ı 7 den büyük olanlar geliyor*

*$S_2$: Baz deyince pH ı 7 den büyük olan, OH iyonu H iyonundan fazla olan aklıma geliyor.*

*$S_6$: Sabun.*

*$S_7$: pH ı 7 den büyük*

*$S_8$:  Baz da pH ı 7 den büyük olanlar.*

*$S_3$: $OH^-$ iyonu veren maddeler baz olarak adlandırılabilir. pH ı 7 ile 14 arasındadır. Genellikle temizlik için kullanılan maddelerde de vardır. Mesela deterjan, sabun, şampuan gibi. pH ları 7 ile 14 arasındadır. Bir de pOH denilen bir ölçek vardır bunla da $OH^-$ iyonlarının molaritesi ile hesaplanır.*

*$S_9$: pH ı 7 den büyük, kaygan, acı, o da yakıcı. Elektriği iletiyor sulu çözeltisi.*

*$S_4$: Çamaşır suyu*

*$S_5$: Baz deyince de tam tersi geliyor. Hidroksit iyonu geliyor. Turnusol'u maviye çeviriyor o geliyor. Sabun geliyor.*

*$S_{10}$: pH ı 7 den büyük olanlar. OH veriyor. Elektriği iletiyor.*

***I: Göstereceğim kartlarda yazılı olan maddelerin asit ya da baz özelliği gösterip göstermeyeceği hakkında yorum yapmanı istiyorum.***

- **HCl**

*$S_1$: Hidroklorik asit*

*$S_2$: Hidroklorik asit*

*$S_6$: Hidroklorik asit*

*$S_7$: Asit miydi? Asit.*

*$S_8$: Asit.*

*$S_3$: Asit.*

*$S_9$: Asit.*

*$S_4$: Kuvvetli Asit.*

*$S_5$: Asit.*

*$S_{10}$: Asit.*

- **$NH_3$**

*$S_1$: Bu baz.*

*$S_2$: Baz.*

*$S_6$: Zayıf baz.*

*$S_7$: Baz değil mi?*

*$S_8$: Evet bu tuz olabilir.*

*$S_3$: Baz.*

*$S_9$: Baz.*

*$S_4$: Zayıf Baz.*

*$S_5$: Baz.*

*$S_{10}$: Baz.*

- **$Ca(OH)_2$**

*$S_1$: Kalsiyum hidroksit. Baz, çünkü yapısında OH var.*

*$S_2$: Hımm baz…hımm. baz değil mi?  OH var baz.*

*$S_6$: Baz.*

*$S_7$: Baz.*

*$S_8$: Baz.*

*$S_9$: Baz.*

*$S_5$: Baz.*

*$S_{10}$: Baz çünkü OH iyonu var.*

- **$CH_3COOH$**

*$S_1$: Bu asit.*

*$S_2$: Asit. H iyonu veriyor.*

*$S_6$: Zayıf asit.*

*$S_7$: Organik asit.*

*$S_8$: Asit.*

*$S_3$: Asit.*

*$S_9$: Baz mı? Asit, asit.*

*$S_4$: Zayıf Asit.*

*$S_5$: Asit.*

*$S_{10}$: Asit*

- **$H_2SO_4$**

*$S_1$: Asit olabilir çünkü H var yapısında.*

*$S_2$: Sülfürik asit… Asit.*

*$S_6$: Kuvvetli asit.*

*$S_7$: Baz amaaaa galiba asit..çünkü H iyonu var.*

*$S_8$: Asit.*

*$S_3$: Asit.*

*$S_5$: Asit.*

*$S_{10}$: Asit.*

***I: Aşağıdaki tabloda asitlerin ve bazların özellikleri karışık olarak verilmiştir. Bu karışıklığı önlemek için asitlerin özelliklerini gösteren şıkları ASİT yazısının altına ve bazların özelliklerini gösteren şıkları da BAZ yazısının altına yazar mısınız? Aynı şıkkı birden fazla yerde kullanabilirsininiz ya da hiç kullanmayabilirsiniz.***

| **ASİT** | **BAZ** |
|---|---|
| | |
| a- Sulu çözeltilerinde $H^+$ iyonu bulunur.<br>b- Sulu çözeltilerinde $OH^-$ iyonu bulunur.<br>c- Suda iyonlaşır.<br>d- Çözeltileri elektriği iletir.<br>e- Seyreltik çözeltilerinin tadı ekşidir. | f- Seyreltik çözeltilerinin tadı acıdır<br>g- Mavi turnusol kâğıdını kırmızıya çevirir.<br>h- Kırmızı turnusol kâğıdını maviye çevirir<br>ı- Aktif metaller ile reaksiyona girer<br>j- Karbonat tuzlarına etki ederek $CO_{2(g)}$ açığa çıkarır |

$S_1$:

| ASİT | BAZ |
|---|---|
| a g | c h |
| c i | b |
| d | d |
| e | f |

$S_{10}$:

| ASİT | BAZ |
|---|---|
| a d | b |
| c | h d |
| e | f |
| g | j |

$S_2$:

| ASİT | BAZ |
|---|---|
| a, d, e, g | c, b, d, f, h, i, j |
| c, j | |

$S_8$:

| ASİT | BAZ |
|---|---|
| a c i | b h |
| e g j | |

$S_7$:

| ASİT | BAZ |
|---|---|
| a g | c h |
| c i | d J |
| d | b |
| f | e |

$S_9$:

| ASİT | BAZ |
|---|---|
| e, a, c, d, J, i, g. | b, c, d, f, h, i |

$S_4$:

| ASİT | BAZ |
|---|---|
| a, c, e, g, i, d, j | b, d, f, h, c |

$S_5$:

| ASİT | BAZ |
|---|---|
| a d | b d |
| c | c |
| e | f |
| g | h |

$S_6$:

| ASİT | BAZ |
|---|---|
| a c d e g i | b c d f h |

$S_3$:

| ASİT | BAZ |
|---|---|
| a – e – g – i – c – d – | c – f – h – b – d |

***I: Bir asit çözeltisinin içine Magnezyum metali atılırsa ne olur?***

*$S_1$: Asitte erir. Hidrojen gazı açığa çıkar yani reaksiyona girer.*

*$S_2$: Hımmm… Tepkimeye girer. Eee şey Hidrojen gazı açığa çıkar.*

*$S_6$: $H_2$ gazı açığa çıkar*

*$S_7$: Hidrojen açığa çıkar, asit ile birleştiği için.*

*$S_9$: Değişiklik olabilir yani magnezyum tepkimeye girer hidrojen çıkar.*

*$S_8$: Tepkimeye girer. Kimyasal tepkime olur. $H_2$ gazı açığa çıkar.*

*$S_4$: Tepkime olur amfoter metal olduğu için $H_2$ gazı çıkartır.*

*$S_5$: Tepkime olur, kimyasal bir tepkime olur. Bir gaz çıkışı gözlemlenir.*

*$S_{10}$: Bilmiyorum.*

***I: Bu olayı fiziksel ya da kimyasal bir değişiklik olarak tanımlayabilir misin?***

*$S_1$: Fiziksel olarak oluyor, yapısı da değişiyor. $H_2$ gazı açığa çıkıyor.*

*$S_2$: Aktif metal kaybolur yani.*

*$S_6$: Asitlerin içinden hidrojenler çıkıyor ve o an kimyasal bir tepkimeye giriyor.*

*$S_3$: Metal dağılır suyun içerisinde. Kimyasal bir değişme olur.*

***I: Laboratuarda kuvvetli asit ve bazlarla ilgili deney yapacaksınız. Daha önceden hazırlanıp, cam şişelere konulmuş iki ayrı cam şişeden birinde kuvvetli asit diğerin de ise zayıf asit olduğunu öğrendiniz. Fakat bu şişelerin etiket kısımları tahriş olduğundan asitlerin adlarını okuyamıyorsunuz. Bu asit şişelerinden hangisinde kuvvetli asit olduğunu anlamak için size göstereceğim kartonlarda yazılı olan laboratuar malzemelerinden hangilerini nasıl kullanabileceğiniz hakkında yorum yapacaksınız.***

- **pH metre**

***I: pH ne demekti hatırlıyor musun?***

*$S_2$: pH, asit ya da baz ya da nötr olup olmadığını anlamak için kullanılıyordu.*

*$S_6$: pH ortamın asidik ya da bazik olduğunu belirtiyor.*

*$S_7$: Asitlik sabiti. Asidin derecesini göstermek için kullanılıyordu.*

*$S_5$: H iyonu derişimi.*

*$S_{10}$: pH, asitlik bazlık derecesini gösteriyor.*

***I: pH metrenin ne olduğunu hatırlıyor musun?***

*$S_1$: pH ını ölçüyor. Eksi logaritma $H^+$ iyonları*

*$S_2$: H iyonlarının eksi logaritmasını alıyorduk.*

*$S_7$: pH ı ölçer.*

*$S_8$: Bununla bulabilirim. Asidin kuvvetli mi baz mı asit mi olduğunu anlamak için kullanılır. pH 7 ise nötrdür. pH ı 7 den küçük ise zayıf, pH ı 7 den büyük ise kuvvetli demektir.*

*$S_3$: Eğer molariteleri eşit ise pH metre işe yarar. Derişimler eşit değil ise yaramaz. Çünkü derişimleri eşit olmadığı için sadece $H^+$ lar da eşit olmayabilir. Mesela bir tanesi 1 mol çözününce 2 mol $H^+$ veriyor olabilir. Öbüründen 2 mol çözmüşündür ama1 mol $H^+$ veriyordur.*

*$S_9$: H iyonlarının molaritesini bulmak için kullanılır.*

*$S_4$: H iyonlarını ölçer.*

***I: Sadece pH metre kullanarak bu iki şişeden hangisinin kuvvetli asit olduğunu bulabilir misin?***

*$S_1$: Ölçebilirim pH değerlerinden kuvvetli olanı anlayabilirim.*

*$S_2$: Anlayabiliriz. Kuvvetli olanın pH ı daha küçük olur, zayıf olanın ki daha yüksek olur.*

*$S_6$: Evet. Daha düşük olanlar daha kuvvetli asit, 7 ye daha yakın olanlar zayıf*

*$S_7$: pH ı küçük olanın kuvveti büyük olur. Büyük olanın da küçük olur.*

*$S_9$: Evet bulabiliriz. pH değeri küçük olan daha kuvvetli olur.*

*$S_4$: Onu kullanabiliriz. pH ı küçük olan kuvvetli bazdır.*

*$S_5$: Evet*

*$S_{10}$: İşe yarar, evet.*

***I: Bu çözeltilerin derişimleri verilmemiş ama sana.***

*$S_1$: Hımm o zaman pH metre ilk derişimlerini bilseydim $H^+$ iyonlarından bulabilirdim ama şimdi bulamam.*

*$S_2$: Hımm Fark etmez.*

*$S_6$: Fark etmez yine işime yarar.*

*$S_7$: Derişimlerini bilmiyorsak…bunları da bilemeyiz. Ama pH değerleri belliyse hangisinin kuvvetli olduğunu anlamak için kullanabiliriz.*

*$S_8$: Farketmez.*

*$S_9$: Evet yine bulabiliriz*

*$S_4$: Derişimlerini bilmiyorsam, pH ı 0 olan kuvvetlidir. pH ı sıfırdan farklı olan zayıftır.*

*$S_5$: O zaman olmaz. Çünkü %100 iyonlaşıp iyonlaşmadığını bilmiyoruz.*

*$S_{10}$: İşe yaramaz.. Yo yarar, çünkü farklı pH değerleri olduğunda büyük olan daha kuvvetli olmuyor mu?*

- ***Mg metali***

***I: Mg metali verilirse kullanabilir misin?***

*$S_1$: Mg asitlerle tepkime verir bence kullanamayız bunu çünkü ikisi ile de tepkime verir. Bir fark olmaz.*

*$S_2$: Anlayamam çünkü Magnezyum ikisi ile de tepkime verir.*

*$S_6$: İşime yaramaz. Tepkime sonucu çıkan değerleri bulamayız*

*$S_7$: Yarar çünkü işte magnezyum ile tepkime veren kuvvetli asitler miydi? Bir tanesi daha çok reaksiyon verir.*

*$S_8$: Hayır bulamam, bilmiyorum çünkü ikisi ile de tepkimeye girebilir.*

*$S_3$: Ayıramam çünkü ikisinin de tepkimeye girmesi için aynı mol sayısında metal harcarım.*

*$S_9$: Evet zayıf olan tepkime vermez magnezyumla. Kuvvetli olan verir.*

*$S_4$: Yarar kuvvetli asit ile tepkime verir. Zayıfla vermez.*

*$S_5$: Ayıramam. Sanırım ikisi ile de reaksiyon olur.*

*$S_{10}$: Yaramaz. Kuvvetli asitler ile daha fazla reaksiyon veriyor yüzde iyonlaşması ama Mg etkisi olmaz.*

- **NaOH ve titrasyon malzemeleri**

***I: Titrasyon nedir biliyor musun?/hatırlıyor musun?***

*$S_1$: Titrasyon. İşte mesela Asidin üzerine yavaş yavaş baz ekliyorduk ne kadar eklersek hani orada bırakıyorduk..molünü, molaritesini alıyorduk bulmak için…yani derişimlerini bulmak için kullanıyorduk. Kullanamayız yani.*

*$S_2$: Hatırlıyorum.. Bir asit alıyorduk mesela içine bazla rengi değişen ama asitle değişmeyen bir madde koyuyorduk. Daha sonra asit bazın bir titrasyon aleti…Neydi adı? titrasyon aleti.. büretin içine baz koyuyorduk ve asidin molaritesini ölçüyorduk… ve o şeyi …musluğu açıyorduk o maddenin rengi ne zaman değişirse o zaman titreşmiş oluyordu.Ona göre de Asitle bazın nötrleşme molaritelerini buluyorduk.*

*$S_6$: Evet biliyorum. Şey, tam beyaz oluyordu..renk değişiyordu.*

*$S_7$: İşlemiştik ama hatırlamıyorum.*

*$S_8$: Titrasyon? Hayır hatırlamıyorum.*

*$S_9$:Evet titrasyon nötrleme, nötrleşme.*

*$S_3$: Hatırlıyorum. Asit ile ….Yani molaritesini bilmediğimiz bir tanesi öbürünün molaritesini biliyoruz, yani molaritesini bildiğimizin hacmini kullanarak diğerinin molaritesini buluruz.*

*$S_5$: Evet, titrasyon mesela asit ise baz ekliyorduk ya da su koyuyorduk. pH ını değiştiriyorduk. Nötrleşme oluyor.*

*$S_{10}$: Bilmiyorum.*

***I: Kuvvetli asit ile zayıf asidi ayırmak için NaOH (kuvvetli bir baz) ile titrasyon yapsan işine yarar mı/ kullanabilir misin?***

*$S_1$: İkisi için de gereken baz aynı olacağı için bununla da ayıramam.*

*$S_2$: Şimdi NaOH kuvvetli bir baz tam nötrleşmesi için kuvvetli bir asit olması gerekiyor bu yüzden bulabiliriz.*

*$S_6$: Bilmiyorum…*

*$S_9$: Evet titrasyon ile hangisinin kuvvetli, hangisinin zayıf olduğu anlaşılabilir. Katılan bazın derişimine göre anlayabiliriz.*

*$S_4$: İkisi de titrasyon verebilir. Ama biri %100…molariteleri eşit ise biri tamamen nötrleşir diğeri tamamı ile nötrleşmez. Çünkü verdiği zayıf asit verdiği $H^+$ iyonları yani iyonları daha az olduğu için baz çözelti olur. Evet bulabilirim.*

*$S_5$: Tam değerler olsa aslında fikir yürütebilirdim. Mesela kuvvetli asitler %100 iyonlaştığı için bunlar da %100 iyonlaşmadığı için sanırım bir fark çıkar.*

***I: Peki titrasyonu hatırlamıyorsan, NaOH gibi bir baz kullanarak, kuvvetli asit ile zayıf asidin ayrım yapabilir misin, burada?***

*$S_7$: Yapılamaz*

*$S_8$: O zaman bazla tepkimeye girer. İkisi de tepkimeye girer ama kuvvetli asit daha çok tepkimeye girer.*

*$S_{10}$: Renk değişir kırmızı maviye döner, kuvvetlide.*

- **HCl ve titrasyon malzemeleri**

***I: Aynı şekilde NaOH yerine, HCl gibi bir asit kullansak (titrasyonda) hangisinin kuvvetli olduğunu anlamak için işimize yarar mı?***

*$S_1$: Asit kullanamayız çünkü asit zaten ikisi de.*

*$S_2$: İkisi de asit olduğu için titrasyon olmaz.*

*$S_6$: Evet çünkü asit %100 iyonlaşır, derişimi artarsa, derişimlere bakarak bulabiliriz.*

*$S_7$: Evet yapılabilir. Hımm bilmiyorum.*

*$S_8$:Buradan bulamayabilirim. Çünkü sonuçta bunlar da asit olduğu için tepkime vermeyeceği için.*

*$S_3$: Yine aynı şekilde zaten bu da asit nötrleşme de vermez.*

*$S_9$: Hayır.*

*$S_4$: Hayır çünkü asit ve asit tepkime vermez.*

*$S_5$: Hayır, işe yaramaz. Asit olduğu için.*

*$S_{10}$: Olmazdı çünkü zaten asit olduğu için.*

***I: Etiketlerin tamamen bozulmadığını ve alt taraflarında bazı yazıların okunabildiğini düşünün. Bu okunan kısımlar için göstereceğim kartlarda verilen bilgilerden hangisi içinde kuvvetli asit olan şişeyi tahmin etmenizde işinize yarayabilir? Nasıl?***

- **pOH değeri**

***I: pOH nedir biliyor musun?***

*$S_1$: OH iyonlarının eksi logaritması. Yani, pOH ını bulmak için, ikisini toplayınca, pH ile pOH ı toplayınca 14 e eşit oluyordu.*

*$S_2$: pOH değeri, OH ların eksi logaritmasını alarak elde ediliyor. Yani H iyonları ile doğru orantılı, bu yüzden kuvvetli olanın H iyonları fazla olduğu için pOH ı da fazla olur, zayıfında düşük olur.*

*$S_6$: Bazlık*

*$S_8$: Şimdi pH ile pOH ın toplamları 14 yapmak zorunda. Yani her asidin her bazın içinde de pH ve pOH değeri var. İkisi de vardır onun için azda olsa çokta olsa pOH vardır.*

*$S_9$: pH dan farkı hidroksit iyonlarının derişimlerini ölçer.*

*$S_4$: H iyonlarından 14 eksi H olunca*

*$S_{10}$:14 eksi pH tır.*

***I: Asit için pOH değeri olur mu?***

*$S_1$: Olur.*

*$S_2$: Olur.*

*$S_6$: Çarparsak onların da vardır.*

*$S_7$: Vardır.*

*$S_8$: Evet vardır.*

*$S_9$: Vardır.*

*$S_4$: Olur.*

***I: Peki pOH değerinden bulabilir misin/kuvvetleri hakkında bir yorum yapabilir misin? (çözeltilerin derişimleri verilmemiş)***

*$S_1$: Yine ilk derişimlerini bilmediğimiz için bulamayız*

*$S_2$: Anlarım*

*$S_6$: Evet. pH ile pOH toplamına bakarız 14 oluyor, oradan çıkartırız hangisinin kuvvetli hangisinin zayıf olduğunu.*

*$S_7$: Yapabiliriz.*

*$S_8$: Evet bulabilirim.*

*$S_3$: Bunda kararsızım ama bulamam çünkü derişimlerini bilmiyorum.*

*$S_9$: Kuvvetli olan daha yüksek değer verecektir.*

*$S_4$: Bulabilirim.*

*$S_5$: Olmaz derişimi bilmediğimiz için.*

*$S_{10}$: Yani buradan asitlik derecesini ölçebilirim. Kuvvetli mi yoksa zayıf mı olduğunu bulurum.*

- **Elektrik iletkenlikleri**

***I: Peki Elektrik iletkenliklerini verse?***

*$S_1$: Bulabiliriz mesela çok kuvvetli olan elektriği daha iyi iletecek az kuvvetli olan daha az iletecek.*

*$S_2$: Eee oradan anlayabiliriz. Kuvvetli olanlar daha çok iletir, daha iyi iyonlaştığı için.*

*$S_6$: İkisi de iletir.*

*$S_7$: İkisi de iletir, farkı olmaz.*

*$S_8$: Evet onu da bulabilirsin.*

*$S_3$: O zaman ayırırım. Çünkü kuvvetli olan daha çok iyonlaşacağı için, elektrolarda iyonlar ile taşındığı için daha çok iyonlaşan daha kuvvetlidir.*

*$S_9$: İkisi de elektriği iletir o yüzden bulamam.*

*$S_4$: Evet daha kuvvetli olan daha iyi iletir. Çünkü daha çok iyonlaşır.*

*$S_5$: Evet. Kuvvetli olan daha çok iletir.*

*$S_{10}$: Hayır çünkü fikrim yok.*

***I: Nasıl bir yorum yaparsın elektrik iletkenliklerini bilsen?/ Neden?***

*$S_1$: Kuvvetli olan tabi %100 iyonlaşacak daha çok iyonu var suda ondan daha iyi iletir.*

*$S_8$:Kuvvetli asitlerin daha çok elektrik iletkenlikleri olur. Çünkü pH ı daha küçük olduğu için olabilir.*

*$S_5$:Bir fikrim yok.*

- **Çözeltilerinin derişimleri**

***I: İki asit çözeltisinin de derişimlerini okuyabilirsen bulabilir misin (anlayabilir misin) kuvvetli/zayıf olanı?***

*$S_1$: Yok yine bulamayız.*

*$S_2$: Hayır anlayamam.*

*$S_6$: Tepkime sonunda neyin çıktığını bilemezsek bulamayız.*

*$S_7$: Evet. Derişimlerinden pH ı buluruz. Oradan da zayıf veya kuvvetli olduğunu anlarız.*

*$S_8$: Bilemem çünkü derişimlerine bağlı olarak kuvvetli ya da zayıf olduğunu anlayamam*

*$S_3$: Ama çözünen asidin mol sayılarını bilmem lazım. Bilmiyorsam bulamam.*

*$S_9$: Evet anlayabiliriz. Derişimi yüksek olan herhalde daha kuvvetli olur.*

*$S_4$: Hayır çünkü verdikleri iyonu bilmiyorum.*

*$S_5$: Anlayamayız çünkü 100% iyonlaşır.*

*$S_{10}$: Yaramaz. Çünkü onların hiçbir anlamı yok. Asitlik ve bazlığını anlatmıyor bize.*

- **Asitlerin molekül formülünde bulunan H sayısı**

***I: Asitlerin molekül formüllerinde bulunan H iyonu sayısını verse. Mesela $H_2SO_4$ te 2 tane H var HCl de bir tane bunları verse?***

*$S_1$: Yok bulamayız çünkü etkilemez sonuçta kuvvetli yada zayıf olması iyonlaşmasına bağlı*

*$S_2$: Anlayamayız. Çünkü yüzde iyonlaşmalarını bilmiyoruz, başlangıç molleritelerini bilmiyoruz.*

*$S_6$: Hayır oradan bakarak başlangıç derişimini bilmediğimiz halde nasıl tepkime çıktığını bulamayız.*

*$S_7$: O zaman yapılamaz sadece çünkü çözeltide olmadığı için.*

*$S_8$: Bilemem çünkü derişimlerine bağlı olarak kuvvetli ya da zayıf olduğunu anlayamam.*

*$S_3$: Bulamam.*

*$S_9$: Hayır ama değerlerini bulabiliriz.*

*$S_4$: O da işe yaramaz çünkü verdikleri iyonlar farklıdır.*

*$S_5$: Galiba yarar ama emin değilim.*

*$S_{10}$: İşe yarar. Çünkü onla doğru orantılı olarak asidik kuvvet artıyordu. O zaman kuvvetlide daha fazla Hidrojen iyonu olur.*

***I: Aynı derişimde kuvvetli ve zayıf baz çözeltilerinden 5 er mL beherlere alınıyor.***

- ***Bu çözeltilerde bulunan [OH$^-$]  aynı mıdır? Nasıl olur?***

*$S_1$: Aynı olmaz. Kuvvetli bazda daha çok OH iyonu olur. Çünkü o %100 iyonlaşacak.*

*$S_2$: Farklıdır çünkü iyonlaşmaları farklıdır. Kuvvetli bazda daha fazla olur.*

*$S_6$: Hayır. Biri kuvvetli biri zayıftır. Kuvvetli olanda daha fazladır.*

*$S_7$: Kuvvetli bazda hidroksit fazladır.*

*$S_8$: Kuvvetlide daha fazla*

*$S_3$: İyon miktarı aynı değildir sadece mol sayısı aynıdır. Mol sayıları aynı ama molariteler farklıdır. Kuvvetli bazda daha fazladır OH$^-$ nin molaritesi.*

*$S_9$: Bilmem…eşittir sanırım.*

*$S_4$: Hayır kuvvetli bazda daha çok OH vardır. Çünkü daha çok iyonlaşır.*

*$S_5$: Farklıdır. Kuvvetli olanda daha çoktur.*

*$S_{10}$: Ters orantılıdır. Şimdi kuvvetli bazda daha az OH oluyordu. Kuvvetli asitte daha az H olmuştu.*

- ***Bu çözeltileri nötrleştirmek için gerekli H$^+$ miktarları/ asit miktarları aynı mıdır? Neden?***

*$S_1$: Aynıdır. Çünkü nötrleşecek olan bunun başlangıçtaki iyonları yani ne kadar eklersek yine eşit miktarda olur yani molariteleri eşit olduğu için, molleri de eşit olduğu için*

*$S_2$: Gereken asit miktarları aynıdır. Çünkü başlangıçtaki molariteleri aynıdır…hımm Nötrleşiyordu ama bir tanesinde mesela baz özelliği gösterebiliyordu biri asit özelliği gösteriyordu ya da tamamen nötrleşebiliyordu o yüzden başlangıçta aynı olur evet.*

*$S_6$: Aynıdır. Başlangıç derişimleri aynıysa aynıdır.*

*$S_7$: Farklıdır çünkü biri kuvvetli biri zayıf.*

*$S_8$: Hayır aynı değildir. Kuvvetli bazda OH değeri daha fazladır. Çünkü daha çok bazik özelliği gösterdiği için olabilir. pH ile pOH ın toplamını 14 e eşitlediğimiz için bunları nötrleştirmek için gerekli olan miktar aynı olmaz. Örneğin bu kuvvetli için daha az hidrojene ihtiyaç vardır öbüründe daha çok.. Imm 1 dakika..tam tersi. Kuvvetli için daha az hidrojen iyonu,  zayıf için daha fazla gerekir*

*$S_3$: Evet aynıdır çünkü mol sayıları eşit ise aynı olmalıdır.*

*$S_9$: Hayır. Kuvvetli baz daha çok hidrojen ister çünkü daha kuvvetlidir. Yani hidroksit iyonu daha fazladır, o yüzden daha çok hidrojen iyonu gerektirir.*

*$S_4$: Aynıdır. Çünkü başlangıçtaki molü alıyoruz.*

*$S_5$: Değerlikleri de aynı ise asit miktarı aynıdır. Çünkü molünü bulacağız. Molünden yaptığımız zaman aynı olması gerekiyor.*

*$S_{10}$: Farklıdır. Kuvvetli bazı nötrleştirmek için daha fazla H gerekir. Çünkü daha fazla OH vardır.*

***I: Asit ve bazlar karışınca ne olur?/ Nötrleşme denilince aklına ne geliyor?***

*$S_1$: : Nötürleşiyor. Tuz oluşuyor, su oluşuyor.*

*$S_2$: Nötürleşiyor. Asit ile baz karıştığında tuz oluşuyor, su oluşuyor.*

*$S_6$: Eee ortamın eşit şekilde asidik ya da bazik olması. pH'ın 7 olması. Asit ile baz eşit mollerde tam olarak tepkimeye giriyor. Nötr çözelti oluşuyor.*

*$S_7$: Çökelme mi oluyordu? $H_2O$ mu çıkıyor?*

*$S_8$: pH' ı 7 olması lazım. Yakıcı özellik olmaması lazım. Örneğin sabun gibi olabilir. Tuz olabilir. Tuz zaten nötrdür. Yani pH ile pOH ı birbirine eşit.*

*$S_3$: Tuz ve su oluşur.*

*$S_9$: Asit ve baz tepkimeye giriyor tuz oluşur. Su oluşur.*

*$S_4$: Tuz + su*

*$S_5$: H iyonları ile OH iyonları derişimleri aynı olduğu zaman nötrleşme oluyor.*

*$S_{10}$: pH ı 7 olması geliyor.*

***I: Peki mesela burada saf suyu çizsen nasıl çizersin? Mesela hidrojeni H olarak gösterebilirsin, Oksijeni O olarak ya da bunları farklı geometrik şekiller kullanarak gösterebilirsin. / Saf suyun içinde neler vardır?***

*$S_1$: Mesela şöyle olabilir. $H_2O$ lar var.*

*$S_6$: $H_2O$ vardır. Bir de Oksijen vardır.*

*$S_{10}$: $H_2O$ vardır.*

*$S_2$: Hidrojenler ve Oksijenler vardır.*

*$S_7$: $H_2O$ var, H vardır. O vardır.*

*$S_8$: O ve H lar ayrık olur ve $H_2O$ olarak dolaşır.*

*$S_3$: İyonlar vardır, $H_2O$ vardır.*

*$S_9$: H, $H_2O$, OH vardır.*

*$S_4$: Hidrojen ve hidroksit iyonları vardır. Bir de su vardır.*

*$S_5$: Sadece $H_2O$ vardır.*

***I: Oksijen ile hidrojen birlikte mi dolaşırlar peki saf suda? / H ve O bağlı mı?***

*$S_6$: Evet, molekül halinde.*

*$S_{10}$: Evet.*

*$S_2$: Ayrı ayrı dolaşıyorlar.*

*$S_5$: Evet.*

***I: Peki bunun içine Hidrojen Klorür (HCl) eklersem, bunu çizerek gösterebilir misin?***

*$S_1$: $H^+$ ve $Cl^-$ olur. Bir de su olur yine.*

*$S_6$: Yani derişimi azalacak. Bunlar tepkimeye girer. $H^+$ ve $Cl^-$ böyle ayrı ayrı dolaşır.*

*$S_{10}$: Burada H iyonları ayrı dolaşır. Suda iyonlarına ayrışacak, HCl de olarak ortamda bulunur.*

*$S_2$: Yine asit özelliği gösterir.*

*$S_7$: H ve Cl ayrışır, ayrı ayrı dolaşır.*

*$S_8$: O zaman Hidrojen daha fazla olur. İçlerinde oksijenler de olur ama daha seyrek olur. Cl ayrı dolaşır. Bir kısmı ayrı dolaşır bir kısmı da HCl şeklinde dolaşır.*

*$S_3$: %100 iyonlaştığı için HCl yoktur.*

*$S_9$: Daha çok H olur, Cl olur.*

*$S_4$: Ek olarak H iyonu ve Cl iyonu olur.*

*$S_5$: H ve Cl birbirlerinden ayrılmazlar.*

***I: HCl suda nasıl bulunur molekül halinde ayrılmadan/iyonlaşmadan mı?/ Ayrılırsa hepsi mi ayrılır yoksa ayrılmadan molekül halinde (HCl olarak) kalan da olur mu?***

*$S_1$: Çünkü suda çözülünce ayrılıyor iyonlarına. Kalmıyor. Hepsi ayrılıyor*

*$S_2$: Aslında ayrı ayrı dolaşırlar. Çünkü suda çözülünce ayrılıyor iyonlarına. Hepsi ayrılıyor.*

*$S_9$: Sanırım çünkü ayrılıyorlar ya. Imm emin değilim ama hepsi ayrı olabilir.*

*$S_4$: HCl olmaz. %100 iyonlaştığı için olmaz.*

***I: Peki içine bir de NaOH bazını koysam?***

*$S_1$: Şimdi NaOH koyunca H ve OH birleşecek yani nötrleşecekler, tekrar $H_2O$ olacak ve NaCl tuzu oluşacak.*

*$S_6$: Baz ile HCl tepkime verir. Sonra bir kısmı nötrleşir. Ortamda su ve tuz oluşur, bir de sodyum klorür oluşur.*

*$S_{10}$: Fikrim yok.*

*$S_2$: Şimdi NaOH koyunca, H ve OH birleşecekler nötrleşecekler, su olacak ve NaCl olacak bir de saf su vardı.*

*$S_7$: Reaksiyona girer, nötrleşir işte.*

*$S_8$: O zaman H ve Cl ayrı olur. Na ayrı gezer. Tepkime olmaz.*

*$S_3$: Tepkime olur ama bire bir olmayabilir. Yine su ve tuz oluşur.*

*$S_9$: O zaman yine aynı şeyleri olur. Nötrleşme olur.*

*$S_4$: H ve OH nötrleşme tepkimesi verir. Na+, Cl-, bir de su*

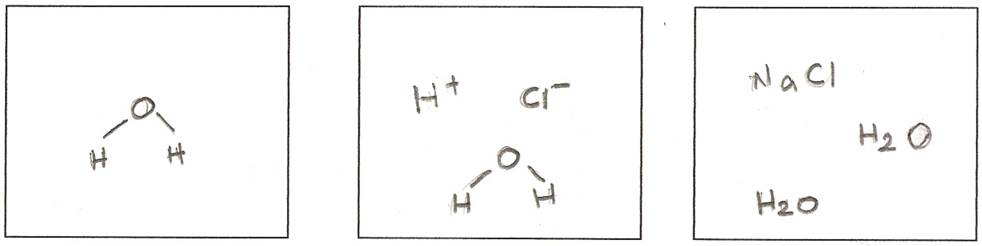
*$S_5$: HCl, NaOH, $H_2O$ olur*

***I: Katı halinde mi olacak? NaCl(k) mı olacak? Ya da sodyum ile klor ayrı ayrı mı olacak?***

*$S_1$: Katı halde olmaz. $Na^+$ ve $Cl^-$ ayrı ayrı ama şey diye düşündüm bunlar nötrleşecek ya $H_2O$ ve NaCl oluşacak ondan.*

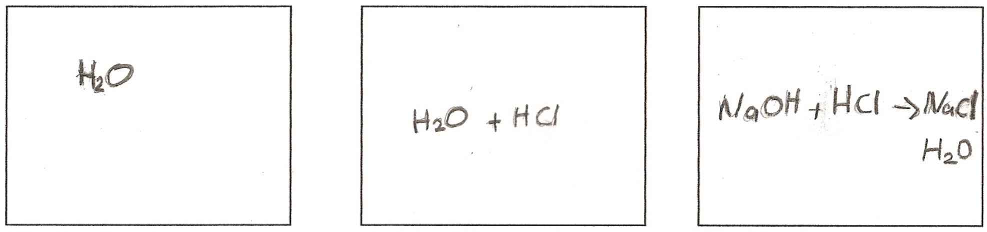
*<u>ÖĞRENCİ ÇİZİMLERİNDEN ÖRNEKLER:</u>*

*$S_1$:*



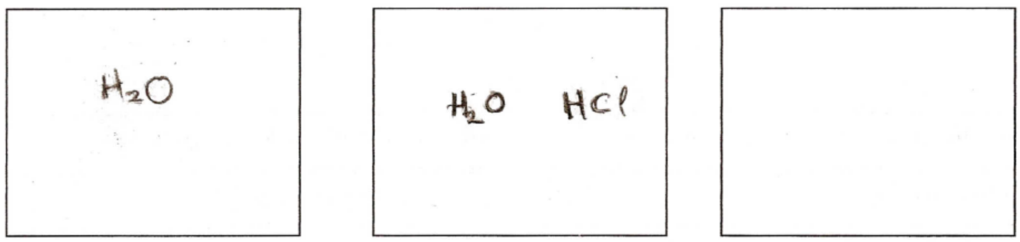

**SAF SU** **SAF SU + HCl** **SAF SU + HCl + NaOH**

*$S_6$:*



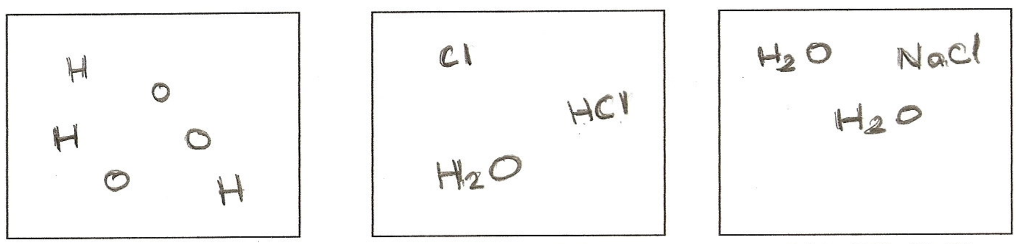

**SAF SU** **SAF SU + HCl** **SAF SU + HCl + NaOH**

*$S_{10}$:*



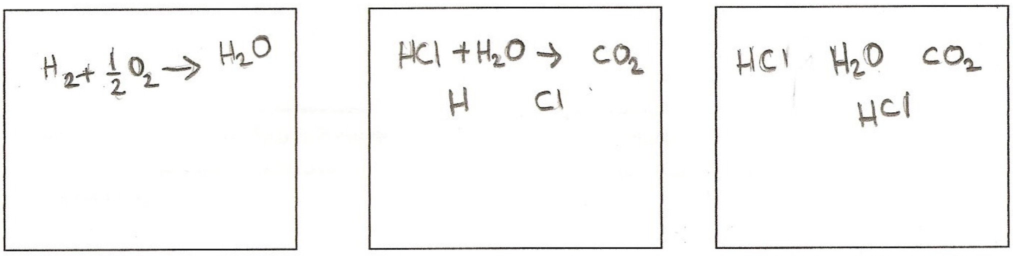

**SAF SU** **SAF SU + HCl** **SAF SU + HCl + NaOH**

*$S_2$:*



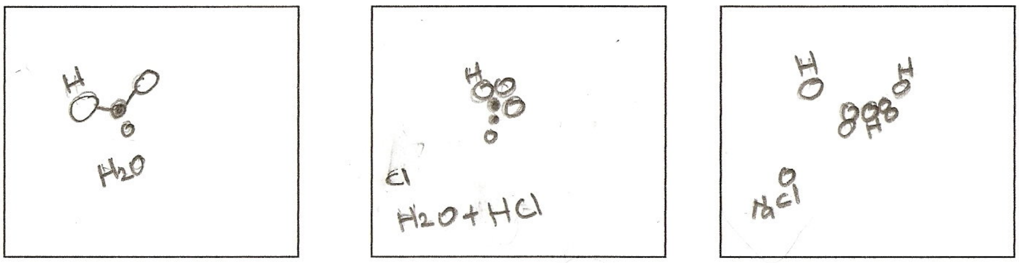

**SAF SU** **SAF SU + HCl** **SAF SU + HCl + NaOH**

*$S_7$:*



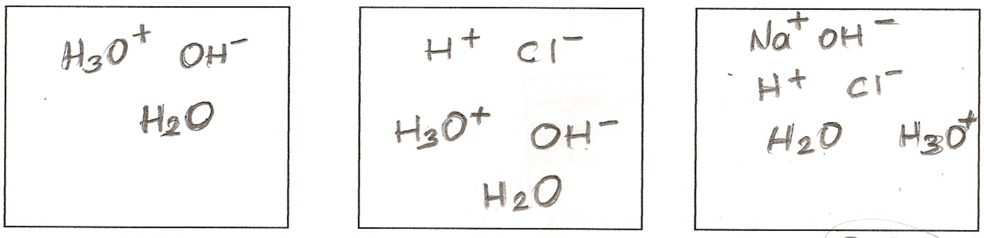

SAF SU | SAF SU + HCl | SAF SU + HCl + NaOH

*$S_8$:*



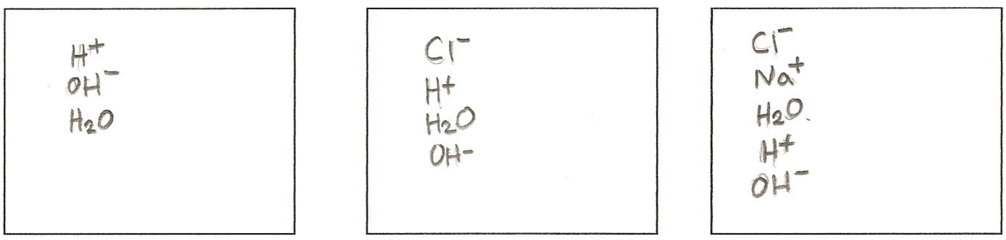

SAF SU | SAF SU + HCl | SAF SU + HCl + NaOH

*$S_3$:*



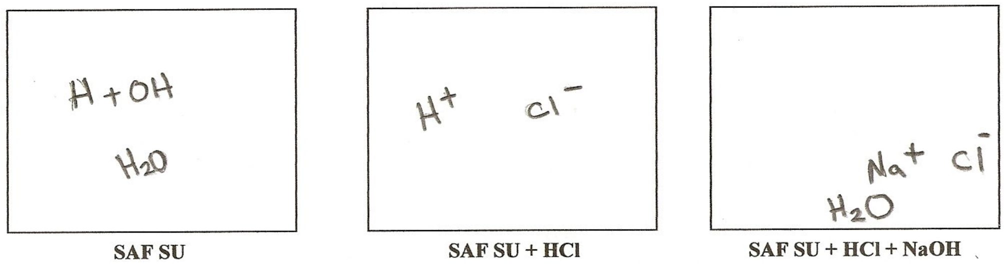

SAF SU | SAF SU + HCl | SAF SU + HCl + NaOH

*$S_9$:*

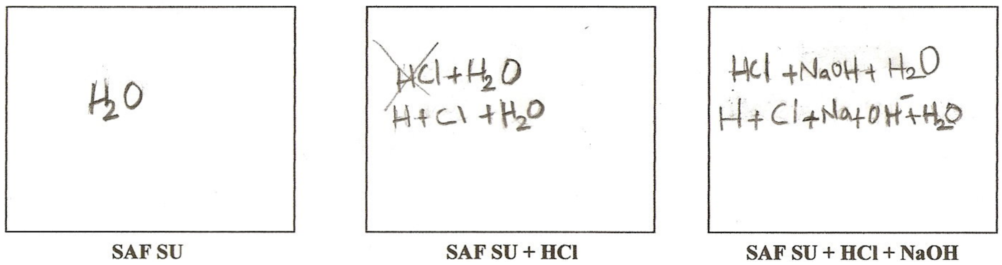



SAF SU | SAF SU + HCl | SAF SU + HCl + NaOH

$S_4$:




$S_5$:




***I: Peki burada HCl gibi kuvvetli bir asit yerine zayıf bir asit olan $CH_3COOH$ olsaydı bir fark olur muydu? Nasıl?***

*$S_1$: Yine iyonlarına ayrılır.*

*$S_2$: Eee yine bunlar böyle yine ortamda su var bir de şu asitten olur. O da iyonlarına suda ayrışır.*

*$S_6$: Olmaz.*

*$S_8$: Farklı olurdu. Bağlar biraz daha ayrık olurdu. Ayrı olarak H olabilir.*

*$S_3$: Bir kısmı moleküller halinde kalır, bir kısmı dağılır, bir de su olur.*

*$S_9$: O zaman asidik çözelti olur. Hepsi iyonlarına ayrışmaz zayıf olduğu için.*

*$S_{10}$: H iyonu ayrı gezer.$H_2O$ ayrıdır. $CH_3COOH$ da ayrıdır.*

*$S_4$: %100 iyonlaşmayacağı için asetat iyonu olur, H iyonu ve kendisi olur.*

*$S_5$: Yani %100 iyonlaşmaz.*

***I:* Gösterir misin nasıl olduğunu? İyonlarına ayrılacak mı? /Hepsi mi ayrılacak iyonlarına?/ Peki burada $H_2O$ ve asetik asitten başka bir şey olacak mı çözeltide?**

*$S_1$:Yok hepsi ayrılmaz zayıftır çünkü %100 iyonlaşmayacak o yüzden daha burada $CH_3COOH$ ta olacak.*

*$S_2$: H iyonları bir de $CH_3COO$ olacak.*

*$S_6$: İyonlarına ayrışmaz.*

***I: Peki buna NaOH eklenirse?***

*$S_2$:Zayıf asit kuvvetli baz. OH iyonları artacak ve yine tuz oluşacak.*

*$S_6$: Yine nötrleşme tepkimesi olacak.*

*$S_8$: Aynı şekilde olur. Fark olmaz.*

*$S_3$: Yine bunlar olur. $H^+$, $Na^+$, $OH^-$ olur ve bunların bir kısmı yine tepkimeye girebilir.*

*$S_9$: Bazik çözelti olur.*

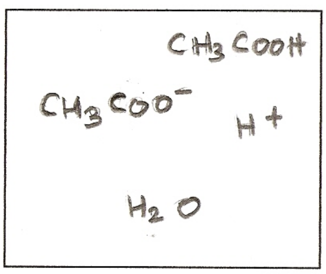
*$S_{10}$: Tepkime olmaz…ımm bilmiyorum.*

*$S_4$: Tepkime verirdi, tuz oluşurdu ama tam olarak nötrleşmediği için. CH3COOH iyonu kalır ortamda.*

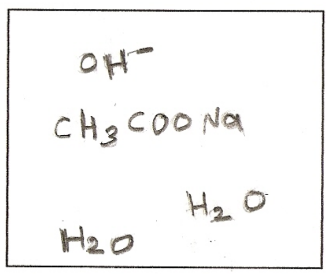
*$S_5$: Bazik olur.*

<u>*ÖĞRENCİ ÇİZİMLERİNDEN ÖRNEKLER:*</u>

*$S_1$:*




**SAF SU + $CH_3COOH$**




**SAF SU + $CH_3COOH$+ NaOH**

*$S_6$:*

| SAF SU + $CH_3COOH$ | SAF SU + $CH_3COOH$+ NaOH |
|---|---|
| $H_2O + CH_3COOH$ | $CH_3COONa + H_2O$ |

*$S_{10}$:*

| SAF SU + $CH_3COOH$ | SAF SU + $CH_3COOH$+ NaOH |
|---|---|
| H $H_2O$<br>$CH_3COO$ | |

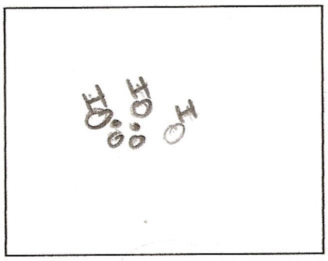
*$S_2$:*

| SAF SU + $CH_3COOH$ | SAF SU + $CH_3COOH$+ NaOH |
|---|---|
| $CH_3COO$ H<br>$H_2O$<br>$CH_3COOH$ | $CH_3COONa$<br>$H_2O$<br>OH |

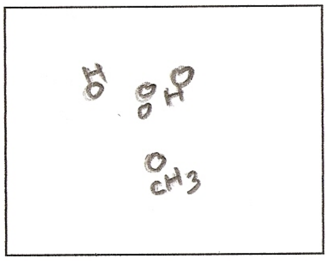
*$S_7$:*

| SAF SU + $CH_3COOH$ | SAF SU + $CH_3COOH$+ NaOH |
|---|---|
| $H_2O$ $CH_3$ COO H | $H_2O$ $CH_3$ COO H<br>Na $CH_3$ |

*$S_8$:*

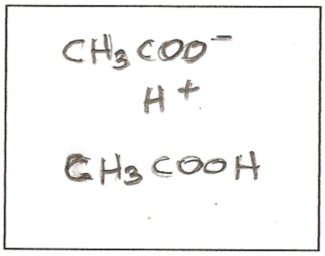


SAF SU + $CH_3COOH$

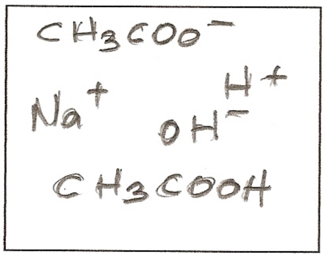



SAF SU + $CH_3COOH$+ NaOH

*$S_3$:*

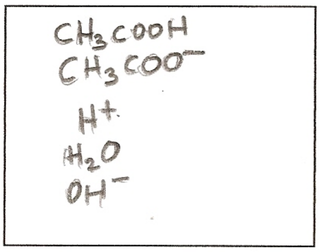



SAF SU + $CH_3COOH$

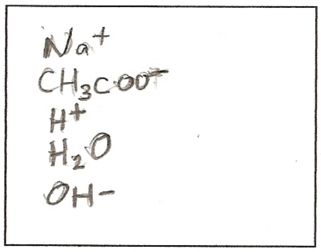



SAF SU + $CH_3COOH$+ NaOH

*$S_9$:*

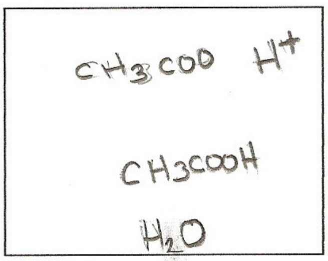



SAF SU + $CH_3COOH$

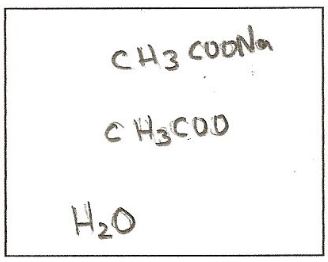



SAF SU + $CH_3COOH$+ NaOH

*$S_4$:*

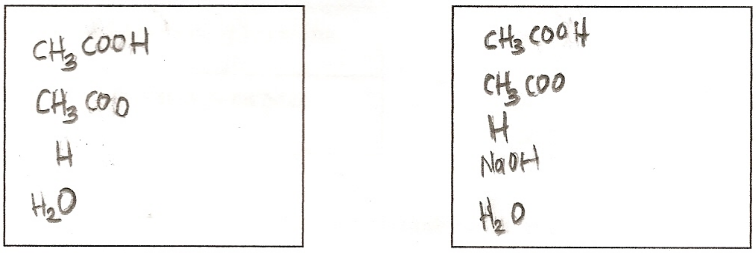



SAF SU + $CH_3COOH$




SAF SU + $CH_3COOH$+ NaOH

*$S_5$:*




**SAF SU + $CH_3COOH$** **SAF SU + $CH_3COOH$+ NaOH**

***I: Yukarıdaki çözeltilerin ilkinde HCl (kuvvetli asit) ile NaOH (kuvvetli baz), ikincisinde ise $CH_3COOH$ (zayıf asit) ile NaOH (kuvvetli baz) tepkimeye giriyor. İki tepkimede de (eşit miktarlarda asit ve baz alındığında) tamamen nötrleşme olabilir mi? / Bu tepkimeler arasında bir fark olur mu?***

*$S_1$:Tamamen olur ikisinde de.*

*$S_2$: Hayır. Kuvvetli olanlar bir birbirini nötrleştirir ama zayıf asit ile kuvvetli baz tepkimeye girince baz özelliği gösterir.*

*$S_3$: HCl ve NaOH…tamamen nötrleşir. ($CH_3COOH$ ve NaOH) ….tamamen nötrleşir ama bunun moleküller halinde kalan kısmı da olur.*

***I: Peki birinci çözelti ile ikinci çözelti nasıl çözeltiler olur? Aralarında fark var mı? Nötr/asidik/bazik?***

*$S_1$: Birincisi nötr tuz olur ama ikinci çözelti de tuz olur ama bazik bir çözelti olur. Çünkü NaOH daha kuvvetli.*

*$S_8$: 1. si nötr. 2.si asidik, çünkü zayıf asit içerdiği için asidik özelliği gösterir. Örneğin NaOH baz,..asidik özelliği çünkü suda da H iyonları vardır.*

*$S_3$: ($CH_3COOH$ ve NaOH) Çözeltisi bazik olur. Çünkü $H^+$ iyonu daha az.*

***I: Çözeltinin bazik olmasını ne etkiliyor?/NaOH mi? Neden baz özelliği gösteriyor dedin çözelti?***

*$S_1$: Çünkü OH iyonları olacak yine daha yani çünkü bazik tuz olacak ya. O %100 iyonlaşacak daha kuvvetli olduğu için ortak onun türünden olacak bazik tuz olacak*

*$S_2$: Çünkü iyonlaşan H iyonları daha az oluyor, OH iyonları daha fazla iyonlaşıyor ..yani OH iyonları daha fazla kaldığı için baz özelliği gösteriyor. Mesela HCl %100 iyonlaşıyor, asetik asit daha az iyonlaşıyor, molariteleri aynı olduğu için $CH_3COOH$ den gelen H iyonları NaOH dan gelen OH iyonlarından daha az oluyor.*

*$S_3$: %100 nötrleşmiyor çünkü bazik olması lazım. OH molaritesi $H^+$ den daha fazla olduğu için.*

***I: Eşit miktarlarda HCl (kuvvetli asit) ve NaOH (kuvvetli baz) tamamen nötrleşme tepkimesi verir mi?***

*$S_6$: Evet, nötr çözelti olur.*

*$S_9$: Evet.*

*$S_{10}$: Nötrleştirir.*

*$S_4$: Evet.*

*$S_5$: Evet.*

***I: Eşit miktarlarda $CH_3COOH$ (zayıf asit) ile NaOH (kuvvetli baz) tamamen nötrleştirilebilir mi?***

*$S_6$: Hayır, ortam bazik olur. Bazın etkisi daha çok olduğu için.*

*$S_9$: %100 olmaz. Daha çok tuz ve baz oluşur. Çünkü biri kuvvetli biri zayıf. Çözelti bazik olur. Derişimleri fazla olduğu için..ama derişim aynı.. O zaman nötr olur bilmem. Nötr olur.*

*$S_{10}$: Nötrleşmezdi bazik olurdu. Çünkü zayıf asit. Çünkü daha fazla baz çözünüyor.*

*$S_4$: Hayır çünkü zayıftır.*

*$S_5$: Hayır çünkü biri zayıf diğeri kuvvetli.*

***I: Nötr çözelti deyince aklına ne geliyor?***

*$S_1$: Asit yada baz özelliği göstermeyen, pH ı 7 olacak.*

*$S_2$: Nötr çözelti asit ile bazın tepkimeye girmesi ile oluşan pH ı 7 olan.*

*$S_6$: pH ı 7 olan.*

*$S_7$: pH ı 7 olan çözelti.*

*$S_8$: pH ı 7 olan, asit ile bazın tepkimesi sonucu ortaya çıkan çözeltidir.*

*$S_3$: Hidrojen ile hidroksit iyonlarının eşit olması.*

*$S_9$: Hidrojen ve hidroksit iyonları derişimi eşit olur.*

*$S_4$: pH ı 7 olan.*

*$S_5$: H ve OH iyonları derişimleri eşit olan çözelti*

*$S_{10}$: pH' ı 7 olan çözeltiler.*

***I: $[H^+] < 10^{-7}$ olan bir çözelti için neler söyleyebilirsin?***

*$S_1$: Baz özelliği gösterir.*

*$S_2$:Baz olduğu aklıma geliyor..çünkü H iyonları $10^{-7}$ den küçükmüş, demek ki OH iyonları $10^{-7}$ den daha büyükmüş, çünkü ikisinin çarpımı $10^{-14}$ olur. Bu küçüldükçe diğeri büyüyeceği için baz özelliği gösterir.*

*$S_6$: Ortam bazik olur. Çünkü $OH^-$ iyonları daha fazla, pH ı 7 den büyüktür.*

*$S_7$: Bazik olduğunu anlarım. Ve pH ı 7 den küçük olur, çözelti asidik olur.*

*$S_8$: pH ı 7 den küçüktür, o zaman bu asittir. Yani zayıf asitte olabilir kuvvetli asitte olabilir.*

*$S_3$: Baziktir çünkü $OH^-$ daha büyük olur.*

*$S_9$: Asittir. pH ı 7 den küçüktür.*

*$S_4$: Baziktir. pH ı 7 den büyüktür.*

*$S_5$: Bu çözelti asidiktir. pH ı 7 den küçüktür.*

*$S_{10}$: Hımm $10^{-8}$ olsa pH ı 8 olurdu. Asidik olur galiba.*

**I: Neden?**

*$S_1$: Çünkü OH iyonları daha fazla, H yediden küçükse, $10^{-7}$ den küçük ise.*

**I: peki pH ı?**

*$S_1$: pH ı da 7 den büyük olacak*

*$S_2$: pH ı da 7 den büyük olur çünkü eksi logaritmasını alıyorduk, o yüzden de büyük olur.*

*$S_3$: 7 ile 14 arasında olur.*

***I: Çok teşekkür ederim bu kadar.***

# APPENDIX J

## PERCENTAGES OF STUDENTS' RESPONSES ON VOSTS-T ACCORDING TO EXPERIMENT AND CONTROL GROUPS

**Table J.1** Percentage of students' responses on VOSTS_T according to all groups

| No | Response | Experiment Groups (%) | Control Groups (%) |
|---|---|---|---|
| 1 | A | 1.7 | 1.7 |
| | B | 15.3 | 21.7 |
| | C | 37.3 | 21.7 |
| | D | 1.7 | 5.0 |
| | E | 1.7 | - |
| | F | 30.5 | 40.0 |
| | G | 1.7 | 5.0 |
| | H | 3.4 | 5.0 |
| | Naïve | 52.6 | 68.4 |
| | Has Merit | 39.0 | 26.7 |
| | Realistic | 1.7 | 5.0 |
| 2 | A | 15.3 | 33.3 |
| | B | 52.5 | 38.3 |
| | C | 22.0 | 16.7 |
| | D | 3.4 | 10.0 |
| | E | 1.7 | 1.7 |
| | Naïve | 27,1 | 28,4 |
| | Realistic | 67,8 | 71,6 |
| 3 | A | - | - |
| | B | 15.3 | 28.3 |
| | C | 20.3 | 30.0 |
| | D | 28.8 | 13.3 |
| | E | 8.5 | 3.3 |
| | F | 15.3 | 13.3 |
| | G | 6.8 | 8.3 |
| | Naïve | 64,4 | 71,6 |
| | Has Merit | 22,1 | 21,6 |
| | Realistic | 8,5 | 3,3 |

**Table J.1** (Continued)

| | | | |
|---|---|---|---|
| 4 | A | 8.5 | 5.0 |
| | B | 11.9 | 20.0 |
| | C | 22.0 | 20.0 |
| | D | 20.3 | 16.7 |
| | E | 16.9 | 18.3 |
| | F | 18.6 | 16.7 |
| | Naïve | 20,4 | 25,0 |
| | Has Merit | 22,0 | 20,0 |
| | Realistic | 55,8 | 51,7 |
| 5 | A | 61.0 | 55.0 |
| | B | 23.7 | 33.3 |
| | C | 5.1 | 8.3 |
| | D | 6.8 | 3.3 |
| | Naïve | 11,9 | 11,6 |
| | Realistic | 84,7 | 88,3 |
| 6 | A | 61.0 | 71.7 |
| | B | 23.7 | 20.0 |
| | C | - | 3.3 |
| | D | 5.1 | 1.7 |
| | E | 3.4 | 1.7 |
| | Naïve | 89,8 | 96,7 |
| | Realistic | 3,4 | 1,7 |
| 7 | A | 22.0 | 18.3 |
| | B | 1.7 | 10.0 |
| | C | 18.6 | 23.3 |
| | D | 27.1 | 23.3 |
| | E | 20.3 | 13.3 |
| | F | 6.8 | 8.3 |
| | Naïve | 76,2 | 83,3 |
| | Realistic | 20.3 | 13.3 |
| 8 | A | 32.2 | 16.7 |
| | B | 30.5 | 16.7 |
| | C | 3.4 | 23.3 |
| | D | 18.6 | 30.0 |
| | E | 1.7 | 3.3 |
| | F | 6.8 | 3.3 |
| | Naïve | 11,9 | 29,9 |
| | Has Merit | 49,1 | 46,7 |
| | Realistic | 32.2 | 16.7 |

**Table J.1** (Continued)

| | | | |
|---|---|---|---|
| 9 | A | 5.1 | 3.3 |
| | B | 6.8 | 3.3 |
| | C | 5.1 | 10.0 |
| | D | 15.3 | 5.0 |
| | E | 1.7 | 21.7 |
| | F | 8.5 | 8.3 |
| | G | 47.5 | 41.7 |
| | H | - | 3.3 |
| | I | 3.4 | - |
| | J | 3.4 | - |
| | Naïve | 42,5 | 54,9 |
| | Has Merit | 50,9 | 41,7 |
| | Realistic | 3.4 | - |
| 10 | A | 33.9 | 33.3 |
| | B | 3.4 | 3.3 |
| | C | 42.4 | 31.7 |
| | D | 10.2 | 15.0 |
| | E | 3.4 | 10.0 |
| | Naïve | 40,7 | 46,6 |
| | Has Merit | 42.4 | 31.7 |
| | Realistic | 10.2 | 15.0 |
| 11 | A | 27.1 | 36.7 |
| | B | 32.2 | 30.0 |
| | C | 11.9 | 11.7 |
| | D | 22.0 | 18.3 |
| | E | - | 1.7 |
| | F | - | - |
| | G | 1.7 | 1.7 |
| | Naïve | 23,7 | 21,7 |
| | Has Merit | 11.9 | 11.7 |
| | Realistic | 59,3 | 66,7 |
| 12 | A | 37.3 | 31.7 |
| | B | 11.9 | 11.7 |
| | C | 16.9 | 28.3 |
| | D | 5.1 | 6.7 |
| | E | 11.9 | 8.3 |
| | F | 3.4 | 1.7 |
| | G | 3.4 | 1.7 |
| | Naïve | 23,8 | 18,4 |
| | Has Merit | 16.9 | 28.3 |
| | Realistic | 49,2 | 43,4 |

**Table J.1** (Continued)

| | | | |
|---|---|---|---|
| **13** | **A** | **16.9** | **25.0** |
| | **B** | **8.5** | **3.3** |
| | **C** | **11.9** | **13.3** |
| | **D** | **55.9** | **51.7** |
| | **E** | **3.4** | **3.3** |
| | **Naïve** | **25,4** | **28,3** |
| | **Has Merit** | **11.9** | **13.3** |
| | **Realistic** | **59,3** | **55,0** |
| **14** | **A** | **37.3** | **30.0** |
| | **B** | **20.3** | **26.7** |
| | **C** | **20.3** | **25.0** |
| | **D** | **10.2** | **8.3** |
| | **E** | **3.4** | **5.0** |
| | **Naïve** | **3.4** | **5.0** |
| | **Has Merit** | **30,5** | **33,3** |
| | **Realistic** | **57,6** | **56,7** |
| **15** | **A** | **15.3** | **8.3** |
| | **B** | **28.8** | **26.7** |
| | **C** | **47.5** | **38.3** |
| | **D** | **3.4** | **16.7** |
| | **E** | **-** | **1.7** |
| | **Naïve** | **18,7** | **26,7** |
| | **Realistic** | **76,3** | **65,0** |
| **16** | **A** | **28.8** | **23.3** |
| | **B** | **18.6** | **25.0** |
| | **C** | **8.5** | **8.3** |
| | **D** | **33.9** | **30.0** |
| | **E** | **-** | **3.3** |
| | **Naïve** | **42,4** | **41,6** |
| | **Realistic** | **42,7** | **48,3** |
| **17** | **A** | **32.2** | **31.7** |
| | **B** | **10.2** | **6.7** |
| | **C** | **32.2** | **30.0** |
| | **D** | **8.5** | **3.3** |
| | **E** | **8.5** | **25.0** |
| | **Naïve** | **83,1** | **71,7** |
| | **Realistic** | **8.5** | **25.0** |

**Table J.1** (Continued)

| | | | |
|---|---|---|---|
| 18 | A | 20.3 | 33.3 |
| | B | 15.3 | 11.7 |
| | C | 16.9 | 23.3 |
| | D | 8.5 | 1.7 |
| | E | 16.9 | 15.0 |
| | F | 10.2 | 11.7 |
| | Naïve | 61,0 | 70,0 |
| | Has Merit | 16.9 | 15.0 |
| | Realistic | 10.2 | 11.7 |
| 19 | A | 16.9 | 10.0 |
| | B | 20.3 | 26.7 |
| | C | 25.4 | 26.7 |
| | D | 6.8 | 3.3 |
| | E | 16.9 | 20.0 |
| | F | 5.1 | 6.7 |
| | Naïve | 69,4 | 66,7 |
| | Has Merit | 16.9 | 20.0 |
| | Realistic | 5.1 | 6.7 |
| 20 | A | 32.2 | 35.0 |
| | B | 22.0 | 25.0 |
| | C | 8.5 | 13.3 |
| | D | 5.1 | 6.7 |
| | E | 16.9 | 10.0 |
| | Naïve | 30,5 | 30,0 |
| | Has Merit | 22.0 | 25.0 |
| | Realistic | 32.2 | 35.0 |
| 21 | A | 49.2 | 28.3 |
| | B | 20.3 | 25.0 |
| | C | 10.2 | 13.3 |
| | D | 5.1 | 20.0 |
| | E | 5.1 | 1.7 |
| | Naïve | 20,4 | 35,0 |
| | Has Merit | 20.3 | 25.0 |
| | Realistic | 49.2 | 28.3 |

# APPENDIX K

## SAMPLE EXPERIMENT SHEET FOR TRADITIONAL GROUPS

### LABORATUVAR RAPORU

Grup Üyeleri: Tarih:
Grup No: Sınıf:

**Deneyin Adı:** Asitler, Bazlar ve Genel Özellikleri

**Deneyin Amacı:** Günlük hayatta kullanılan bazı maddeleri asit ya da baz olarak sınıflandırmak.

**Hazırlık Soruları**:

1. Günlük hayatta kullanılan asitlere ve bazlara örnekler verebilir misiniz?
2. Asitler ve bazların genel özellikleri nelerdir?

**Not:** Asit ve bazların özelliklerini deneyden önce okuyup hatırlayınız.

**Malzemeler:** Limon suyu, sirke, çamaşır suyu, mide özsuyu, amonyak, kola, formik asit, karbonat, kırmızı ve mavi turnusol kâğıdı, Magnezyum parçaları, $Na_2CO_3$ veya $CaCO_3$, lahana suyu, fenolftalein, damlalık, saat camı, beher.

**Deneyin yapılışı ve Gözlemler**

Bu bölüme öğretmeniniz tarafından size verilen iki malzemeden hangisinin asit, hangisinin baz oldunu bulacaksınız.

Malzeme Adı: …………………..

| Mavi turnusol renk? | Pembe turnusol renk? | Mg gaz çıkışı? | $CaCO_3$/ $Na_2CO_3$ gaz çıkışı? | Lahana Suyu renk? | Fenolftalein Renk? |
|---|---|---|---|---|---|
| | | | | | |

Malzeme Adı: ………………….

| Mavi turnusol renk? | Pembe turnusol renk? | Mg gaz çıkışı? | $CaCO_3$/ $Na_2CO_3$ gaz çıkışı? | Lahana Suyu renk? | Fenolftalein Renk? |
|---|---|---|---|---|---|
| | | | | | |

**Deney Sonu Soruları:**

**1.** Size verilen malzemelerden hangisi asit özelliği gösterdi? Neden?

**2.** Size verilen malzemelerden hangisi baz özelliği gösterdi? Neden?

**Cevaplar:**

1.

2.

**Deneyin Sonucu: (**Deney sonunda gözlemlerinizi ve cevaplarınızı diğer gruplar ile sınıfta paylaşınız.)

## APPENDIX L

## SAMPLE 5E EXPERIMENT SHEET

| **LABORATUVAR RAPORU** | |
|---|---|
| Grup Üyeleri:<br>Grup No: | Tarih:<br>Sınıf: |

**1. İlgi çekme:**

<u>Lütfen bu bölümdeki cevaplarınızı Tükenmez Kalem ile yazınız!!!</u>

- Limonun tadı nasıldır? Neden?

- Yüzünüzü yıkarken ağzınıza sabun kaçsa nasıl bir tat bırakır? Neden?

- Sabun ele alındığında nasıl bir his verir? Neden?

- Karınca ısırığı neden can acıtır? Acıyı azaltmak için sizce ne yapılabilir?

Aşağıdaki malzemelerden benzer özellik gösterenleri 2 ayrı sınıfa ayırıp verilen tabloyu doldurunuz.

| Limon suyu, sirke, çamaşır suyu, mide özsuyu, amonyak, kola, formik asit, karbonat. | |
|---|---|
| I | II |
| | |

**2. Araştırma-keşif yapma:**

Yukarıdaki malzemelerden iki tanesini seçin ve bu malzemelerin özelliklerini laboratuardaki araç-gereçleri kullanarak gözlemleyin.

**Araç-Gereçler**: Kırmızı ve mavi turnusol kâğıdı, Magnezyum parçaları, $Na_2CO_3$ veya $CaCO_3$, lahana suyu, Fenolftalein, damlalık, saat camı, beher.

Bu bölüme deneyle ilgili notlarınızı kaydetmeniz önerilir

Malzeme Adı: …………………………

| Mavi turnusol | Pembe turnusol | Mg parçaları | $CaCO_3$/ $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| | | | | | |

Malzeme Adı: …………………………

| Mavi turnusol | Pembe turnusol | Mg parçaları | $CaCO_3$/ $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| | | | | | |

### 3. Kavram Aktarımı

Bu aşamada sizden ilk olarak, araştırma-keşif yapma sırasında edindiğiniz deneyimleri yorumlayıp arkadaşlarınız ile tartışmanız isteniyor. Bunun için, grubunuzdan bir kişi (grubun yazıcısı) sonuçları tahtada çizili olan tabloya yazmalı, bir arkadaşınız da (grubun sözcüsü) sınıfa grup olarak yaptığınız araştırmaları/keşifleri açıklamalı. Daha sonra, diğer gruplarında açıklamalarını dinlemelisiniz. Tartışma sırasında, siz deneyimleriniz hakkında konuşurken, öğretmeniniz de size soruları ile yol gösterici olacaktır. Ayrıca kullandığınız anahtar kelimeleri ve konuda öğretilmesi hedeflenen yeni kavramları sizin deneyimlerinizden de yararlanarak açıklayacaktır. Aşağıda tartışmalar sırasında cevaplanabilecek sorulara bazı örnekler verilmiştir.

- Deney sonunda bulunan sonuçlar, grup olarak yaptığınız önceki tahminlerinizden farklı mıydı? Hangilerinde farklılık var? Neden?
- Günlük hayatta kullanılan malzemelerin birbirinden farklı özellik göstermesinin sebepleri neler olabilir?
- Grup olarak seçtiğiniz malzemeler hakkında nasıl bir yorum yapabilirsiniz?
- Fenolftalein, turnusol kâğıdı ve lahana suyunun ortak özellikleri ne olabilir?
- Çözeltilerin içine Magnezyum (Mg) metali attığınızda ne oldu? Bunun sebebi ne olabilir?
- İçine lahana suyu damlatılmış formik asidin üzerine amonyak damlattığınızda neden rengi değişti?
- Karbonat ile sirkeyi karıştırınca neden köpürme oldu?
- Arı soktuğunda canınız acır. Bunun sebebi arısının iğnesinde bulunan salgının bal arısında asidik, eşek arısında ise bazik özellik göstermesidir. Eşek arısı sokan birine yapılacak ilk müdahale için neler önerirsiniz? Neden?

**4. Kavram Uygulaması:**

Final zamanında, ODTÜ' deki 3. yurdun çalışma salonunda arkadaşınız Deniz ile sabahlamaya karar verdiğinizi düşünün. Deniz Sun Shine'dan aldığı bol sirkeli ve limonlu salatasını yedikten sonra, siz de uykunuz gelmesin diye eşsiz bir karışım olarak duyduğunuz kola-kahve karışımını hazırladınız. Ama işler umduğunuz gibi gitmedi ve Deniz bir müddet sonra midesinin ekşidiğini, bu halde daha fazla çalışamayacağını söyledi. Beraber okuldaki Sağlık Merkezine gittiğinizde oradaki görevli Deniz'in mide yanması olduğunu söyleyip, Deniz'e bir ilaç verdi. Ayrıca böyle gereksiz karışımlardan uzak durmanızı da ekledi.

Aşağıdaki soruları grup arkadaşlarınız ile tartışıp cevaplandırınız.
Bu soruları cevaplarken öğrendiğiniz yeni kavramları kullanmayı UNUTMAYIN!!!!

1- Sizce görevli mide yanması derken ne demek istedi?
2- Deniz'e nasıl bir ilaç verilmiş olabilir?
3-Eğer ilaç bulamasaydınız, arkadaşınıza bunun yerine ne yapmasını tavsiye edebilirdiniz? Neden?

**NOT:** Bu sorulara ek olarak sınıfta besinlerin sindirimi; midedeki asitlik oranı; sirke, limon ve kolanın asit özellikleri; mide yanmasına sebep olabilecek başka yiyecek ve içecekler ya da konuyla ilgili ilginizi çeken şeyleri de araştırıp sınıfta tartışabilirsiniz.

## APPENDIX M

## THE EXCERPTS FROM THE STUDENTS' RESPONSES ON 5E EXPERIMENT SHEETS

### 1. İlgi Çekme (Engage):

- Limonun tadı nasıldır? Neden?

*Grup-1*

Ekşidir. Çünkü asidik özellik gösterir

*Grup-2*

Ekşidir. Çünkü asitli bir maddedir.

*Grup-3*

Ekşidir çünkü asit özelliği gösterir.

*Grup-4*

Ekşidir, çünkü asittir. pH<7

- Yüzünüzü yıkarken ağzınıza sabun kaçsa nasıl bir tat bırakır? Neden?

*Grup-1*

Acı. Bazik bir özellik gösterir

*Grup-2*

Sabun baz olduğu için ağzımızda acı bir tat bırakır.

*Grup-3*

Acı çünkü baziktir

*Grup-4*

Acı bir tat bırakır, çünkü bazdır. pH>7

- Sabun ele alındığında nasıl bir his verir? Neden?

*Grup-1*

Kaygandır Baz olduğu için

*Grup-2*

Kaygandır. Baz olduğu için

*Grup-4*

Kayganlık hissi verir. Çünkü bazdır.

- Karınca ısırığı neden can acıtır? Acıyı azaltmak için sizce ne yapılabilir?

*Grup-1*

Salgıladığı asitten dolayı. Sabun gibi bazik özellikteki bir madde sürülebilir.

*Grup-2*

Karınca vücudunda asit bulundurduğu için can acıtır. Isırdığı yere sabun süreriz.

*Grup-4*

Karınca ısırdığı zaman asit bırakır. Bu yüzden canımız acır.
Acıyı azaltmak için bir baz kullanabiliriz. Mesela, orayı sabunla yıkayabiliriz.

- Size verilen malzemelerden benzer özellik gösterenleri 2 ayrı sınıfa ayırıp aşağıdaki tabloyu doldurun.

*Grup1:*

| I | II |
|---|---|
| Limon suyu<br>Sirke<br>Kola<br>Formik asit<br>Mide özsuyu | Amonyak<br>Çamaşır suyu<br>Karbonat |

*Grup2:*

| I | II |
|---|---|
| Limon suyu<br>Formik asit<br>Mide özsuyu<br>Kola<br>Sirke<br>Asit | Amonyak<br>Karbonat<br>Çamaşır suyu<br>Baz |

## 2. Araştırma-keşif yapma (Explore)

*Grup-1:*

Malzeme Adı: Formik asit

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Pembe renge dönüştü | Değişiklik olmadı | Magnezyumu çözdü. Reaksiyon verdi. | $CaCO_3$ ilavesiyle ilk önce köpürme meydana geldi. Sonra içinde çözündü | Rengi kırmızıya çevirdi | Değişiklik olmadı |

Malzeme Adı: Karbonat

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Değişiklik olmadı | Maviye çevirdi | Çözünme gerçekleşmedi. magnezyum dibe çöktü. Reaksiyon vermedi. | $CaCO_3$ dibe çöktü. | mavi renge dönüştürdü. | Kırmızı renge dönüştürdü. |

*Grup-2:*

Malzeme Adı: Sirke

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Kırmızıya çevirdi | Etki yapmadı | Rengi beyazladı Erimeye başladı | Bir etki yapmadı Biraz gaz çıkımı gözlendi | Bir etki yapmadı | Bir etki yapmadı |

Malzeme Adı: Formik asit

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Kırmızıya çevirdi | Etki yapmadı | Rengi beyazladı Erimeye başladı | Kabarcıklar göründü, karbonat eridi. | Rengi kırmızı oldu | Bir etki yapmadı |

*Grup-4:*

Malzeme Adı: Çamaşır suyu

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Rengi değişmedi. | Maviye döndü. | İlk dakikalarda tepkime vermedi, değişim gözlenmedi. | — | Rengi sarıya döndü. | Önce pembe oldu sonra eski haline döndü. ? |

Malzeme Adı: Sirke

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Kırmızı oldu. | Değişmedi. | Tepkime verdi, gaz çıkışı oldu. | Gaz çıkışı gözlendi, rengi açıldı. | Pembe oldu. | Değişim gözlenlenmedi. |

*Grup-5:*

Malzeme Adı: Amonyak

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Renk değişmedi | Maviye dönüştü | Birşey olmuyor | Homojen olarak karıştı Ayrana benzedi | Yeşil sarı karışımı bir renk oluştu | Kırmızı renk oluştu |

Malzeme Adı: Mide öz suyu

| Mavi turnusol | Pembe turnusol | Magnezyum ekleme | $CaCO_3$ / $Na_2CO_3$ ilavesi | Lahana suyu | Fenolftalein |
|---|---|---|---|---|---|
| Kırmızıya dönüştü | Renk değişimi olmadı | Bitti bir anda çözünme hızlı | Köpürdü çözünme hızlı | Kırmızı oluştu | ~~Yeşil renk oluştu~~ Renk değişimi oluşmadı |

### 3. Kavram Aktarımı (Explain)

- Deney sonunda bulunan sonuçlar, grup olarak daha önceki tahminlerinizden farklı mı? Hangilerinde farklılık var?

*Grup-2:*

farklı değil.

*Grup-4:*

Tahminlerimize benzer sonuçlar çıktı, farklılık yok.

- Size verilen (limon suyu, sirke, amonyak gibi) malzemelerin birbirinden farklı özellik göstermelerinin sebebi ne olabilir?

*Grup-2*

Asitlik - Bazlık derecesi

*Grup-4:*

Asidik ve bazik özellik göstermesine ve asit ve bazların kuvvetine göre değişir.

- Seçtiğiniz malzemeler hakkında nasıl bir yorum yapabilirsiniz?

*Group-1:*

Karbonatın bir baz olduğundan emin değildik. Fakat yaptığımız deneyler sonucunda bi baz olduğunu anladık.

*Grup-2:*

İkiside asit

- İçine lahana suyu damlatılmış formik asidin üzerine amonyak damlattığınızda renk neden açıldı?

*Group-2:*

nötrleşme tepkimesi gerçekleştiği için

*Group-4:*

Amonyak damlatınca, amonyak baz olduğu için, formik asidin asitlik derecesi azaldı.

- Fenolftalein, turnusol kâğıdı ve lahana suyunun ortak özelliği ne olabilir?

*Group-2:*

İndikatör maddelerdir.

*Group-4:*

Asit ve bazları ayırmada kullanılan maddeler.

- Çözeltilerin içine Magnezyum (Mg) metali attığınızda ne oldu? Bunun sebebi ne olabilir?

*Group-2:*

Kuvvetli asite attığımızda daha hızlı eridi. Zayıf asite attığım erime daha yavaş oldu.

*Group-4:*

Gaz çıkışı gözlemledik. Reaksiyona girdi ve $H_2$ gazı ortaya çıktı

- Arı soktuğu zaman canınız acır. Bunun sebebi sokma sırasında salgılanan bal arısının asidik, eşek arısın ise bazik salgılarıdır. Eşek arısı sokan birine yapılacak ilk müdahale için ne önerirsiniz? Neden?

*Group-2:*

asitli bir madde sürmeniz gerekir. yani sirke sürebilirsiniz. Bal arısı sokduğunda ise bazik bir madde sürmeniz gerekir yani sabun sürebilirsiniz.

*Group-4:*

Zayıf bir asit olarak sirke kullanılabilir.

**4. Kavram Uygulaması (Elaborate)**

- Sizce görevli mide yanması derken ne demek istedi?

*Grup-2:*

Midenin pH değerinin çok düştüğünü anlatmak istemiştir

*Grup-4:*

Asit dengesinin bozulması

- Deniz'e nasıl bir ilaç verilmiş olabilir? Verilen ilacın özelliği olabilir?

*Grup-2:*

Midenin düşen pH değerini yükseltmek için düşük baz özelliğine sahip ilaç verilmiştir.

*Grup-4:*

Zayıf bir bazdır.

- İlaç bulamasaydınız, bunun yerine arkadaşınıza yardım için ne yapmasını tavsiye ederdiniz? Neden?

*Grup-2:*

Soda, karbonat gibi düşük (zayıf) baz özelliği gösteren baz maddeler önerirdik

*Grup-4:*

Karbonat, çünkü zayıf bazdır.

## APPENDIX N

## SAMPLE ACID-BASE LESSON IMPLEMENTATION BASED ON 5E LEARNING CYCLE MODEL

### $E_1$: İlgi çekme (Engage)

Öğrencilerin asitler ve bazlar konusuna olan ilgilerini arttırmak ve genel olarak bu konu hakkındaki ön deneyimlerini öğrenmek amacı ile derse öğrenciye günlük hayatla bağlantılı gösteriler yaparak ve sorular sorularak başlanılır. Gösteri olarak öğretmen; ilk olarak sirke ile karbonatı karıştırır, ikinci olarak ise seffaf bir çözeltinin içine lahana suyu koyup rengini ilk önce pembe yapar, daha sonra başka bir şeffaf çözeltiden ekleyerek rengini mora dönüştürür bir müddet sonra ise renk mavi-yeşil olur. Öğrencilerden bu gösteriler ve gözlemleri hakkında yorumlar yapmaları istenir. Daha sonra, sınıfta konu ile ilgili şu sorular sorulur; Limonun tadı nasıldır? Yüzünüzü yıkarken ağzınıza sabun kaçsa nasıl bir tat bırakır? Sabun ele alındığında nasıl bir his verir? Karınca ısırığı neden can acıtır, bu acıyı azaltmak için ne yapılabilir? Size limon suyu, sirke, çamaşır suyu, mide özsuyu, amonyak, kola, formik asit ve karbonat verilip bu malzemeleri iki sınıfa ayırmanız istenilse nasıl bir sınıflama yapardınız? Bu sınıflamayı yaparken malzemelerin hangi özelliklerine bakılabilir? Her soruyu düşünüp, yorumları için öğrencilere süre verilir. Öğrenciler soruları dersin başında oluşturdukları 4-5 kişilik grupların içinde tartışır ve yorumlarını tükenmez kalem ile kendilerine verilen deney föylerine kaydederler. Bu esnada öğretmen, öğrencilere yaptıkları bu ilk yorumların kesinlikle not ile değerlendirilmeyeceğini, burada amacın onların ilk fikirlerini anlamak ve bu fikirlerin zamanla ne kadar değiştiğini gözlemlemek olduğunu hatırlatır.

**$E_2$: Araştırma-keşif yapma (Explore)**

Bu aşamada öğrencilerden asitler ve bazlar konusu ile ilgili ön bilgilerini/fikirlerini laboratuar ortamında çeşitli malzemeler kullanarak, deneyler yaparak sınamaları istenmektedir. Bunun için öğretmen farklı deney malzemelerinin bulunduğu farklı istasyonlar hazırlar ve öğrencilerden gruplar halinde çalışarak ilgi çekme aşamasında sorulan sorulara verdikleri cevapların doğruluğunu bu malzemeleri kullanarak kontrol etmelerini ister. Öğrencilere, anlatıldığı gibi gruplar halinde araştırma yapacakları ve gözlemlerini deney föylerine kaydedecekleri söylenir. Gruplara ilk aşamada verilen, 5E modeline göre hazırlanmış deney föylerinin kullanılm amacı, öğrencilere araştırmalarını yaparken izleyecekleri yol hakkında fikir vermek ve öğrencilerin deneyimlerini düzgün bir şekilde not etmelerine yardımcı olmaktır. Öğrenciler araştırmak istedikleri malzemeleri kendileri seçerler. Öğrencilerin her istasyona uğraması veya bütün malzemeleri kullanmaları amaç değildir. Amaç öğrencilerin kavramlar ile ilgili ilk fikirlerini/bilgilerini sınamalarını sağlamakır. Bu sırada, öğretmen sürekli olarak bütün grupları dolaşıp öğrencilere malzemelerin kullanımında ve karşılaştıkları zorluklarda yardımcı olur.

**$E_3$: Kavram Aktarımı (Explain)**

Burada, öğrencilerin araştırma-keşif aşamasını nasıl değerlendirdikleri ile deney föylerine aldıkları notlar üzerinde durulur. Diğer bir deyişle, sınıf ortamında gruplar tarafından yapılan çalışmalar ve sonuçları tartışılıp değerlendirilir. Tartışma aşamasında, grupların buldukları sonuçları birbirleri ile karşılaştırmalarına olanak sağlamak için, her gruptan bir kişi (grubun yazıcısı) bulgularını, sınıfın tahtasına, önceden öğretmen tarafından çizilmiş tabloya yazar. Böylece bütün gruplar birbirlerinin çalışmaları hakkında fikir sahibi olmuş olur. Öğrenciler gözlemlerini ve yorumlarını paylaşırken, öğretmen de yol gösterici olmalıdır. Öğrencilere sorular sorarak tartışmalarından, bilim tarafından kabul edilen sonuçlara ulaşmaları için yardım etmelidir. Ayrıca, tartışmalarda geçen önemli kelimeleri ve öğrenilmesi gereken terimleri de tahtaya yazmalı ve bunların açıklamalarını öğrencilerin fikirlerini de dikkate alarak yapmalıdır. Bu etkinlikte kavram aktarılması sırasında, asit ve bazıların tanımları, genel özellikleri, indikatör ve nötrleşme kavramları anlatılmıştır.

### $E_4$: Kavram Uygulaması (Elaborate)

Burada, öğrencilere öğrendiklerini benzer ama yeni durumlarda uygulama, pratik yapma ve bilgilerini sınama fırsatı verilmeldir. Öğretmen ve öğrencilerin rolleri araştırma-keşif aşamasındaki gibidir. Bu aşamanın, araştırma-keşif aşamasından en önemli farkı ise yeni öğrenilen terimlerin kullanılmasının öğretmen tarafından teşvik edilmesidir. Aşağıdaki etkinlik asitler, bazlar ve bunların özellikleri ile ilgili bir kavram uygulaması etkinliğidir.

Final zamanında, ODTÜ' deki 3. yurdun çalışma salonunda arkadaşınız Deniz ile sabahlamaya karar verdiğinizi düşünün. Deniz Sun Shine'dan aldığı bol sirkeli ve limonlu salatasını yedikten sonra, siz de uykunuz gelmesin diye eşiz bir karışım olarak duyduğunuz kola-kahve karışımını hazırladınız. Ama işler umduğunuz gibi gitmedi ve Deniz bir müddet sonra midesinin ekşidiğini ve artık bu halde çalışamayacağını söyledi. Beraber okuldaki Sağlık Merkezine gittiğinizde oradaki görevli Deniz'in mide yanması olduğunu söyleyip, bir ilaç verdi. Ayrıca böyle gereksiz karışımlardan uzak durmanızı da ekledi.

Bu durumda

1- Sizce görevli mide yanması derken ne demek istedi?

2- Deniz e nasıl bir ilaç verilmiş olabilir? Verilen ilacın özelliği nedir?

3- İlaç bulamasaydınız, bunun yerine arkadaşınıza yardım için ne içmesini/yemesini tavsiye ederdiniz? Neden?

NOT: Bu sorulara ek olarak sınıfta besinlerin sindirimi; midedeki asitlik oranı; sirke, limon ve kolanın asitlik özellikleri; mide yanmasına sebep olabilecek başka yiyecek ve içecekler de kısaca tartışılabilir.

### $E_5$: Değerlendirme (Evaluate)

Aslında, değerlendirme 5E modelinin her aşamasında öğretmen ve öğrenci tarafından yapılmalıdır. Fakat buna ek olarak, 5E modeline göre hazırlanmış uygulamalarının sonunda, deney föyleri de değerlendirilebilir.

## CURRICULUM VITAE

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### PUBLICATIONS

1. Pabuçcu, Aybüke and Geban, Ömer (Ağustos, 2008). “5E Öğrenme Döngüsü Modeline Dayalı Öğretimin Asitler ve Bazlarla İlgili Kavramları Anlamaya Etkisi” 8. Fen Bilimleri ve Matematik Eğitimi Kongresi, Bolu.

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