EFFECT OF CASE BASED LEARNING ON 10^{TH} GRADE STUDENTS' UNDERSTANDING OF GAS CONCEPTS, THEIR ATTITUDE AND MOTIVATION

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ABSTRACT

EFFECT OF CASE BASED LEARNING ON 10^{TH} GRADE STUDENTS' UNDERSTANDING OF GAS CONCEPTS, THEIR ATTITUDE AND MOTIVATION

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The main purpose of the present study was to investigate the effect of case-based instruction based on conceptual change conditions to overcome 10^{th} grade students' misconceptions related to gas concepts. Moreover, the effect of this method on students' attitudes toward chemistry and their perceived motivation was explored.

The study was carried out during the 2008-2009 academic year at both a state high school and an Anatolian high school. A total of 128 tenth grade students were the participants of the study. One of the classes of the same chemistry teacher was randomly assigned as experimental group and one of them was control group in each school. Students in experimental groups were instructed by case-based learning based on conceptual change conditions while the control group students received traditionally designed chemistry instruction.

Gas Concept Test, Attitude toward Chemistry and Motivated Strategies for Learning Questionnaire were administered to both groups of students as pretest and posttest to determine the students' misconceptions and their understanding of gas concepts, their attitude toward chemistry and perceived motivation.

Two two-way ANOVA based on gain scores were used to assess the effect of case-based learning on students' understanding of gas concepts and attitudes toward chemistry. In addition, the effect of case-based learning on students' perceived motivation was investigated by MANOVA based on gain scores. The results revealed that case-based learning was an effective method for overcoming students' misconceptions about the gas concepts and promoting their attitudes and motivation towards chemistry in Anatolian high school.

Keywords: Case-Based Learning, Misconception, Gas, Motivation, Attitude toward Chemistry.

ÖZ

ÖRNEK OLAYA DAYALI ÖĞRENME YÖNTEMİNİN ONUNCU SINIF ÖĞRENCİLERİNİN GAZLAR KONUSU İLE İLGİLİ KAVRAMLARI ANLAMALARINA, TUTUMUNA VE MOTİVASYONUNA ETKİSİ

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Bu çalışmanın başlıca amacı, kavramsal değişim koşulları göz önünde bulundurulmuş örnek olaya dayalı öğrenme yönteminin, 10.sınıf lise öğrencilerinin gaz kavramlarıyla ilgili kavram yanılgılarını gidermeye etkisini incelemektir. Ayrıca, bu öğretme metodunun öğrencilerin kimyaya karşı tutumlarına ve motivasyonlarına etkisi araştırılmıştır.

Bu çalışma 2008-2009 öğretim yılında hem düz lisede hem de Anadolu lisesinde gerçekleşmiştir. Çalışmaya toplam olarak 128, 10.sınıf öğrencisi katılmıştır. Her okul için, aynı kimya öğretmeninin sınıflarından biri deneysel grup, diğeri ise kontrol grup olarak rastgele olarak atanmıştır. Deney grubundaki öğrenciler örnek olaya dayalı öğrenme yöntemi doğrultusunda eğitim alırken, kontrol grubundaki öğrenciler geleneksel yönteme dayalı eğitim almışlardır.

Gaz Kavram Testi, Kimyaya Karşı Tutum Ölçeği ve Öğrenmede Güdüsel Stratejiler Anketi öğrencilerin gazlar konusundaki kavram yanılgılarını, gaz kavramlarını anlamalarını, kimyaya karşı tutumlarını ve motivasyonlarını belirlemek için her iki gruba öntest ve sontest olarak uygulanmıştır.

Örnek olaya dayalı öğrenme yönteminin öğrencilerin gaz kavramlarını anlamalarına etkisi ve kimyaya karşı tutumları iki tane kazanım puanlara dayandırılmış varyans analizi (ANOVA) ile değerlendirilmiştir. Ayrıca, örnek olaya dayalı öğrenme yönteminin öğrencilerin motivasyonlarına etkisi kazanım puanlarına dayandırılmış çok yönlü varyans analizi (MANOVA) ile araştırılmıştır. Sonuçlar örnek olaya dayalı öğrenme modelinin geleneksel yönteme kıyasla öğrencilerin gazlarla ilgili kavram yanılgılarını gidermede etkili bir yöntem olduğunu göstermiştir. Buna ek olarak, bu yöntemin Anadolu lisesindeki öğrencilerin kimyaya karşı tutumlarını ve motivasyonlarını geliştirmede etkili olduğu ortaya çıkmıştır.

Anahtar Sözcükler: Örnek Olaya Dayalı Öğrenme, Kavram Yanılgısı, Gazlar, Güdülenme, Tutum.

To My Family,

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GCT: Reaction Rate Concept Test

MSLQ: Motivated Strategies for Learning Questionnaire

ASTC: Attitude Scale toward Chemistry

SPST: Science Process Skill Test

CBCC: Case-Based Learning on Conceptual Change

TDCI: Traditionally Designed Chemistry Instruction

EG: Experimental Group

CG: Control Group

IGO: Intrinsic Goal Orientation

EGO: Extrinsic Goal Orientation

TV: Task Value

CLB: Control of Learning Beliefs

SELP: Self-efficacy for Learning and Performance

TA: Test Anxiety

SD: Standard Deviation

p: Significance level

η^2: Effect Size Measure

F: F statistic

df: Degrees of freedom

N: Sample size

MANOVA: Multivariate Analysis of Variance

ANOVA: Analysis of Variance

CHAPTER 1

INTRODUCTION

In last decade, there is a rapid change in the world and it can be observed that this change has an effect on social, political and economical areas. Global changes in economic, social and cultural fields in the world require the change in the field of education. Scientific developments and innovations with advances in society are reflected in the school as a part of the society. In recent years, most of the developed and developing countries have made many innovations to improve their education systems. These innovations include reforms in the system level, efforts to create modern institutions and teaching tools and provision of supplies and improvement on the teachers' professional knowledge and skill (Karip, 1996). Therefore, the common aim of the curriculum developers is to promote the notions of "learning to learn", "lifelong learning" and improve students' attitude toward science and enhance their motivation.

Research findings indicated that students come to science classes with prior knowledge, and this knowledge might be correct or incorrect. The ideas that are different from the scientifically accepted view are referred in the literature as "*misconceptions*"(Helm, 1980; Fisher, 1985; Griffiths & Grant, 1985); "*preconceptions*" (Novak 1977); "*alternative conceptions*" (Driver & Easley, 1978; Driver & Erickson, 1983; Nakhleh, 1992; Palmer, 2001);"*children's science*" (Gilbert, Watts, & Osborne, 1982), "*children's scientific intuitions*" (Sutton, 1980); "*common sense concepts*" (Halloun & Hestenes, 1985); "*spontaneous knowledge*" (Pines & West, 1986), "*naive beliefs*" (Caramazza, McCloskey, & Green, 1981); "*naive theories*" (Resnik, 1983); "*naive conceptions*" (Champagne, Gunstone, &

Klopfer, 1983); "*conceptual framework*" (Southerland, Abrams, Cummins, & Anzelmo, 2001); "*students' intuitive theories*" (Boujaoude, 1992); or "*prescientific conceptions*" (Good, 1991). In chemistry, the identification of students' misconceptions has great importance to improve teaching and learning in that subject (Garnett, Garnett, & Hackling, 1995). Research results also indicated that students often have misconceptions before or even after science instruction (Wandersee, Mintzes, & Novak, 1994). Sometimes students' misconceptions cannot be exchanged with the scientifically accepted ideas after instruction, or they may still exist in the amalgam versions of the existing ideas (Gilbert, Osborne, & Fensham, 1982). Many of the misconceptions are persistent, stable, and resistant to change and despite years of formal schooling in science, some students persist in giving answers consistent with their misconceptions (Driver & Easley, 1978; Osborne, 1983). Traditional approach to science instruction has been consistently shown to be ineffective in engaging students' interest or promoting their conceptual understanding of the subject matter (Driver & Erickson, 1983; Anderson & Smith, 1987; Haider & Abraham, 1991). Most of current traditional teaching focused on the knowledge transmission. Knowledge transmission is no longer enough for an effective and stimulating learning process because students are not passive learners and cannot learn meaningfully through the knowledge transmission by the teacher. Instead, students construct their own knowledge by making links between their ideas and new concepts through experience they acquire in school or daily life. These observations led 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 & West, 1986). In addition, it allows students to construct knowledge, to think and to learn. Constructivist ideas have had a major impact on science educators over the last decade (Appleton, 1997). Several models of learning in science such as 5E learning cycle approach (Stepans, Dyvhe, & Beiswenger, 1988), inquiry approach (Martin-Hansen, 2002), conceptual change model (Posner, Strike, Hewson, & Gertzog, 1982), problem-based approach (Arambula-Greenfield, 1996) and case-based approach (Herreid, 1994) were based on constructivist approach.

Sometimes students learn something, but they cannot develop meaningful association between the concepts. According to cognitive psychologists, a person's prior knowledge plays a critical role in the process of learning. Learners receive information from the environment and create their own interpretations and meanings. Learners' understandings of concepts are impressed by not only their prior knowledge and experience, but also by the external environment. A person arranges the prior knowledge as memory clusters that are generally called as *schemata*. Meaningful learning can occur when new information is combined with the suitable schemata in the memory. Recent research studies on science learning indicated that students often come to classes with their own misconceptions and experiences with everyday phenomena and everyday language. Therefore, significant changes must be made in students' own schemata so that students can accept the scientifically correct knowledge. This kind of learning was promoted by conceptual change model by Posner et al. (1982). For such learning to take place, students should perceive, (1) that their existing knowledge conflicts with the scientific concepts, (2) that their own conceptions are insufficient, incomplete, or inconsistent with the new coming information, and (3) a scientific conceptualization offers a more persuasive and influential option to their own conceptions (Roth, 1990). In addition, many research studies have showed that misconceptions create significant barriers to learning. Abstract concepts of chemistry make it harder to learn. Students who have current inability to comprehend abstract concepts will not construct a deep understanding about these concepts (Colburn, 2000). Therefore, many studies have tried to identify students' misconceptions and their understanding in recent years. Some of the chemistry topics that research studies have addressed are *mole concept* (Furio, Azcona, Guisasola, & Ratcliffe, 2000), *chemical equilibrium* (Chiu, Chou, & Liu, 2002), *chemical reactions* (Barker & Millar, 1999), *covalent bonding* (Peterson & Treauguest, 1989), *electrochemistry* (Garnett & Treaguest, 1992a; 1992b), *acids and bases* (Ross & Munby, 1991; Sisovic & Bojovic, 2000), *atoms and molecules* (Griffiths & Preston, 1992), *solubility and solutions* (Ebenezer & Fraser, 2001); *the particulate nature of matter* (Valanides, 2000); *chemical bonding* (Coll & Treagust, 2001); *solubility* (Longden, Black, & Solomon, 1991), *element, compound, and mixture* (Papageorgiou & Sakka, 2000). Gas topic is one of those topics including many abstract concepts. Researchers also showed great interest for students' conceptual understanding of gases (Beall & Prescott, 1994; Cornely-Moss, 1995; Lin, Kirsch, & Turner, 1996; Mason, Shell, & Crawley, 1997; Nakhleh & Mitchell, 1993; Niaz, 1998; Niaz & Robinson, 1993; Noh & Scharmann, 1997; Nurrenbern & Pickering, 1987; Pickering, 1990; Sawrey, 1990; Niaz, 2000). Understanding of gas concepts is important not only as a school subject but also as a link to other subjects in chemistry such as particulate nature of matter, mole concept, and chemical reactions. Therefore, elimination of misconceptions on the gas topic is important. While preparing a new method of teaching, students' prior knowledge should be considered. Constructivist learning stressed the role of active engagement of students in the learning process (Mayer, 1999). Honebein (1996) defined that constructivist learning embeds learning in realistic and social experience and provides students practice in the process of knowledge construction. Hence, learners should be encouraged to construct their own learning by engaging in activities which enables them to gain more than one perspective to events and produce solutions. Accordingly, case-based learning environments and real life examples promote constructivist learning (Jonassen, 1994).

Although case method of instruction has been generally used in medicine, law, and business, it has been used in science education in recent years. Several studies showed that case method promotes problem solving, decision-making, critical thinking, self-directed learning, self-evaluation, interpersonal communication, access to the necessary information and use of it (Amos & White, 1998; Dowd & Davidhizar, 1999). In addition, cases have positive impact on students' learning and participation (Yadav, Jundeberg, DeSchryver, Dirkin, Schiller, Maier, & Herreid, 2008). Students instructed with case-based learning demonstrated significantly better learning gains and exhibited higher-order thinking skills with respect to the students instructed traditionally (Rybarczyk, Baines, McVey, Thompson, & Wilkins, 2007). Case method teaching develops students' oral and written communication skills, and professional decision-making skills by providing them practice with real life problems (Jones, 2003). Case study method is also effective for improving students' conceptual understanding and their motivation (Dori & Herscovitz, 1999). This method facilitates social construction of knowledge in a relevant and motivating framework. Moreover, literature indicated that obstacles in learning cannot be solved with traditional methods (Gallucci, 2007). Therefore, case-based learning with small group format as Herreid (2000) specified was followed in this study. Cases were analyzed in small groups and small group and whole class discussions were carried out. Thus, students' attainment, attitude and motivation were tried to be promoted by offering them active learning environment.

Attitude is the one of the important affective variables that has an influence on students' understanding of science concepts and it is often regarded as an indicator of student achievement. In addition, attitudinal constructs are also stated as the moderator of conceptual change (Pintrich, Marx, & Boyle, 1993). In science education, researchers have dealt with different teaching methods to improve students' attitude. There are few empirical studies investigating the effect of case-based learning on students' attitude towards science. Case-based instruction can be considered to be effective in increasing students' attitude because students actively engage in learning as a group, and case based learning promotes critical thinking, and provides opportunities for students to experience or practice real life situations. In general, students find this learning strategy realistic, challenging, interesting, enjoyable, and encouraging for learning (Brickman et al., 2008; Heid, Biglan, & Ritson, 2008; Herreid, 2006; Hoskin, 1998; Jackson, 1998; Mayo, 2002; Parilla, 2007; Ribbens, 2006; Walters, 1999).

Motivational beliefs are also important in science education. Students engage in tasks due to some reasons such as intrinsic interest or enjoyment, task value or utility and these might enhance students' perceived motivation. When students, who are intrinsically motivated, are involved in a presented task, they work harder to overcome the difficulties that they encounter. Enhancement in motivation leads to increase in attainment of students so achievement can be thought as an indirect index of motivation (Pintrich & Schunk, 2002). Case-based learning provides an environment to enhance students' interest and enjoyment toward learning (Mayo, 2002, 2004; Naumes & Naumes, 2006; Wassermann, 1994). Although there is little empirical research on the effectiveness of case-based learning on students' perceived motivation, case-method of instruction can be a useful teaching strategy improving students' perceived motivation. Recent research findings indicate that case-based instruction promotes intrinsic and extrinsic goal orientation and students exposed to this teaching strategy find the assignments more valuable than students instructed with traditionally designed instruction (Saral, 2008).

Chemistry is one of the most important branches of science and it is a difficult subject for students for several reasons. One of the reasons for difficulty of understanding chemistry concepts is the abstract nature of the subjects (Ben-Zvi, Eylon, & Silberstein, 1988), and the other is the use of words in chemistry that have different meanings in everyday life (Bergquist & Heikkinen, 1990). However, overcoming misconceptions and promoting conceptual change about the concepts of chemistry is important for meaningful learning. Though there are some studies investigating students' understanding of gas concepts, there is no reported research investigating the effectiveness of case-based learning based on conceptual change conditions for overcoming the misconceptions about the gas concepts.

1.1 Purpose of the Study

The aim of this study was to: (1) identify and examine the students' misconceptions about gas concepts; (2) compare the effectiveness of case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to students' understanding of the gas concepts; (3) compare the effectiveness of case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to students' attitudes toward chemistry; (4) compare the effectiveness of case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to students' perceived motivation.

1.2 Significance of the Study

Case-based learning is a widely used teaching method in medical sciences, law and business schools. However, case studies have been rarely used in secondary science teaching. The main purpose of this study was to eliminate the students' misconceptions about gas concepts and teaching materials were prepared in the light of the misconceptions found in the literature. Moreover, it was aimed to increase students' attitudes and motivation toward chemistry by taking the advantage of daily life nature of case-based learning. The activities related to the daily life events attract students' interest and curiosity to the instructional tasks. Students who learnt to solve the problems in a given scenario will be trained to solve the problems in professional life in a more rational way. In addition, students will find chance to share and discuss their ideas with group mates and the whole class. Group work provides students to recognize the inadequacies of their conceptions, and gain different points of view towards the events as well. Therefore, in this study case-based learning with small group discussion was used.

There are some studies concerning the effect of case-based learning compared to traditional instruction on students' understanding, attitude or motivation (Brink, Goodney, Hudak, & Silverstein, 1995; Çakır, 2002; Çam, 2009; Gallucci, 2007; Rybarczyk et al., 2007; Saral, 2008) but the current study is the only one that intended to investigate the effect of case-based learning based on conceptual change conditions to remedy students' misconceptions on the subject of gases as well as the effect of this teaching method on their attitude and motivation. This study is significant because it provides detailed information about case-based learning, and guides chemistry teachers by providing them useful materials. Moreover, the concept of gas is the one unit in chemistry as a school subject but this unit has also many connections with other subjects in chemistry such as subject of matter, mole concept, and chemical reactions. Therefore, understanding of gas concepts is also important in the learning of other concepts. In addition to these, this study will guide researchers in the field of chemistry education and curriculum developers about how to plan an instruction to remove students' misconceptions on the subject of gases and increase their attitude and motivation toward chemistry. And, it was expected to contribute to chemistry instruction at high schools, be helpful for chemistry educators providing detailed information about case-based learning and useful teaching materials prepared on the basis of case-based learning approach.

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter presents the literature review about the effectiveness of case-based learning on remedying students' misconceptions on gas concepts, their attitude and motivation. The misconceptions related to gas concepts were presented firstly. The features of CBL and its effectiveness in science classes were presented in the next part. In addition, the relationship between case-based learning and constructivism and conceptual change theory was discussed. Then, affective domains, motivation and attitude, as well as their relationship with CBL were mentioned briefly. The next part focused on effect of class size and school facilities and their effects on students' learning and achievement.

2.1 Misconceptions of Gases

The concept of gas is the one of the abstract topic that students have misconceptions about it. Scientific understanding of this subject will help students to understand the daily life events and the reasons beyond them. For instance, why the soccer balls or automobile tires deflates in cold weather, how the hot air balloons fly, how we breathe, and how air bags save our lives, etc. can all be explained by the behavior of gases (İpek, 2007). On the other hand, most of the studies in science education indicated that students have difficulty in understanding basic properties and behavior of gases due to their invisibility (Novick & Nussbaum, 1978; Novick & Nussbaum, 1981; Ben-Zvi, Eylon, & Silberstein, 1982; Brook, Briggs, & Driver, 1984; Stavy, 1988; Gabel, Samuel, & Hunn, 1987; Benson, Wittrock, & Baur, 1993; Hwang, 1995; Brook, Briggs, & Driver, 2003).

Gas concept is one of the most important subjects in chemistry. It is an important topic because unlike many of the other topics in chemistry, students learn this topic not only in high school but also in elementary and primary school throughout their educational life. However, students in all levels face with problems in understanding of the behavior of gas because of the invisibility of nature of it (Stavy, 1988). Chemistry educators have demonstrated great interest about the conceptual understanding of gases (Beall & Prescott, 1994; Cornely-Moss, 1995; Lin et al., 1996; Mason et al., 1997; Nakhleh & Mitchell, 1993; Niaz, 1994, 1995, 1998; Niaz & Robinson, 1992, 1993; Noh & Scharmann, 1997; Nurrenbern & Pickering, 1987; Pickering, 1990; Sawrey, 1990; Niaz, 2000).

Novick and Nussbaum (1978) investigated 8th grade (14 year old) Israeli pupils' ability to apply particulate model in explaining simple physical phenomena related to gases. They designed a 30-minute interview procedure based on three phenomena. About 150 pupils from nine urban schools participated in this study. In their first task, pupils were asked to draw the air within a flask before and after some of the air had been removed. 64 % of the pupils made particulate drawings for this task. In the second task, pupils were asked to choose the best drawing from other students' continuous and particulate drawings and 78 % of them chose the diagram that represents the particulate representation of air. In the third task, students were asked to explain what exits between the dots in the drawings probing the idea of having 'empty space' between particles. Only 45 % of the 'particulate' pupils (35 % of the sample) expressed determinedly that there was an empty space between particles, but some of the pupils who had no recognition of empty space offered that dust, other particles, other gases such as oxygen and nitrogen, air, dirt, unknown vapors exist between the particles. In the fourth task, pupils were asked to explain what holds the gas particles and why all these particles don't fall to the bottom of the flask to probe the intrinsic motion of particles. About 50 % of the 'particulate' pupils (about 40 % of the sample) proposed that gas particles have an intrinsic motion and many of them did not make a connection between space-filling property with the intrinsic motion of particles. In the second phenomena, ammonia and hydrochloric acid vapors were released from the two ends of the tube. Students were asked what the white substance is and how it is formed. Only 50 % of 'particulate' pupils (40 %

of the sample) said spontaneously that white substance is a compound consisting of different particles.

Moreover, Novick and Nussbaum (1981) conducted a cross-age study to find out how pupils' preconceptions change with age. Since the study requires fairly large sample, paper-and-pencil test was used instead of clinical interview. In addition, they developed a Test about Particles in a Gas (TAP) based on the phenomena in the previous interview study. The test consisted of 9-items each relating a phenomenon, a simple experiment, or a situation. TAP was administered to 576 pupils ranging from elementary to university level. Results indicated that generally percentage of pupils having scientific ideas increased with age. Again, majority of students thought that air is made up of particles, a minority of the students thought that there is an empty space between the particles (approximately 50 % of an age group), and intrinsic particle motion (approximately 40 % of an age group). Nearly 30 % of the junior high school and 10 % of the senior high and university students do not believe the uniform or homogeneous distribution of gases when the gas evacuation process is done. Only some 30-40 % of the students have the idea that gases have a homogeneous distribution containing heated air. In addition, subjects were asked how cooling and heating affects the gas particles. Minority of students (about 25 % senior high school and 15 % university level) explained cooling based on decreased particle motion or energy. About 50 % of the students at any age thought that particles are able to "shrink", "condense", "sink" or "settle". The results also support one of the author's observations that majority of the high school students explain the decrease in the volume of the gas on cooling not in terms of decreasing particle motion but in terms of increasing attractive forces. Moreover, about 70 % of the students aged from 13 to university level portrayed the liquefaction with respect to coming together or accumulating on the walls of the container. Before formal instruction of particle model at school, even 5th and 6th grade students had instinctive idea that approximately half of the students believe that liquefaction is the coming together of particles. Furthermore, authors asked the subjects about what exists among particles. The findings indicated that students have problems in understanding the concept of existing empty space between particles. Students claim that there is something between the particles such as dust, other particles, other gases (oxygen, nitrogen), air, dirt, germs, and unknown vapors. They also argue that there is no space between the particles. A year later, Nussbaum and Novick (1982) conducted a case study to promote conceptual change of individuals based on the evaluation of all previous studies. 6th grade (12 years old) students were included in this study. The findings of the study indicated that pupils are resistant to hold up their preconceptions though they are inclined to assimilate new conception.

In literature, there are many studies dealing with states of matter mainly applied to gases, particularly air (Séré, 1982, 1985, 1986; Andersson, as cited in Andersson, 1990; Nussbaum, 1985; Stavy, 1988; Andersson & Eliasson, as cited in Andersson, 1990). Andersson and Renström (1981) cited in Andersson (1990) reported that most of the students in primary and lower secondary levels could not differentiate gas and air from each other, a few of them realized the air as an example of gas. These students believed that gas is something poisonous, injurious or flammable such as war gas, exhaust, and color gas. On the other hand, students associated air with breathing and life. For instance, they thought that ‘air is oxygen and gas’ or ‘oxygen is something you breathe, that is air’. Andersson and Eliasson (1988) cited in Andersson (1990) stated that three to four seventh grade students (13 year old) supposed that air in a syringe is incompressible. In addition, Andersson (1983) cited in Andersson (1990) stated the views of 400 students (grade 7-8) about the well-known experiment in which a balloon is stretched over the mouth of the flask and heated below. The majority of the students thought that the balloon rises on account of rising of warm air. A similar result found by Lee, Eichinger, Anderson, Berkheimer, and Blakeslee (1993) was the rising of balloon due to the rising of warm air and filling it up. Nussbaum (1985) asked how the distribution of gases would be after evacuating some of air from the flask. While some of the students (14 years old) thought that upper part of the flask is filled with air, the others believed that lower one is filled with air.

Stavy (1988) reported a research about how the concept of gas develops in the minds of Israeli students. Six different age groups ranging from fourth to ninth grade (about 9-15 years) were involved in the study. Each group consisted of twenty students and interviews were carried out with each of them by showing the materials and processes such as gas escaping from a CO_2 cartridge and from soda water. Results of the study indicated that students could not generate idea about gases before instruction. After instruction, in seventh grade they first attain the significant nature of gases, in eighth grade they refer the gas as state of matter; in the ninth grade they explain the term of gas using particulate theory of matter. Moreover, students' ideas are inconsistent and may change from task to task. For instance, students believed that gas has no weight in the task of CO_2 escaping from soda water, however they also considered gas has weight when it is in cartridge. The finding indicated that 'air has no weight' was the common misconception among all grade level students. Besides, fourth grade students believed that since gases are lighter than liquids, when it is added to water, it adds lightless; hence, when it is released from water, the remaining part becomes heavier. The idea that gas is lighter than liquids was also stated in acetone evaporation task (Stavy, 1988; Stavy, 1990). Nevertheless, in that case though the older students held this idea more, younger students thought that gas is weightless. Disappearing of acetone drop may lead students think that it lost weight.

Stavy (1990) examined Israeli students' ability to recognize weight conservation and the reversibility process in the changes of matter like translocation, melting, dissolving, and evaporation from first grade (ages 6-7) and ninth grade (ages 14-15). Each age group consisted of 20-25 students. The materials and the processes were shown to each student while interviewing independently. The results showed that though students can solve some tasks, they could not solve the others. Moreover, their responses improve with age but not linearly. Students believed that;

- Gases have no weight.
- Gaseous phase of substance is lighter than its liquid or solid state.

According to Stavy (1990), the law of conservation of matter provides a basis in understanding the particulate theory of matter as well as modern chemistry. However, results of the study indicated that conservation of matter was comprehended by only 50 % of the seventh grade students in the process of evaporation. This might be the reason that students have difficulty in understanding particulate theory of matter.

Another difficulty that students have is about the conservation of weight or mass. Mas, Perez and Harris (1987) performed a research at 12 schools with 1198 students ranging from 12 years to 18 years. Two questionnaires were administered to students. Questionnaire 1 consisted of four items related to an experiment about the total vaporization of a liquid in a closed container. Students were asked about conservation of substance, weight, mass and moving up of gases. Questionnaire 2 included another four items and students were waited to predict the weight of various substances in a chemical process in which the material disappears because of the involvement of gases. Analysis of the results demonstrated that students have trouble in understanding mass and weight conservation though they comprehend the thought of conservation of substances. In addition, they thought the reason of raising of the gases as losing the mass and weight of liquids during vaporization. Ultimately, 75 % of the adolescents do not agree with the law of conservation of mass when gases are reagents or products. Additionally, researchers recommended the use of conceptual change strategies to improve students' understanding of phenomena about gases.

Brook, Briggs and Driver (1984) attempted a study to find out the particulate nature of matter. The sample consisted of 300, 10^{th} grade pupils (15 years old) and they were tested by open-ended questions, most of which were related to gaseous phase. More than 50 % of students used particulate ideas in their responses. Partially complete responses were given by about 20 % of students. This rate increased to about 33 % after taking physics and chemistry courses. In addition, about 33 % of students used mixed conceptions about particles such as "expand" and "contract", "get hot", and "melt" and animistic behavior of the particles. In addition, about 25 % of them gave macroscopic responses not implying particulate ideas.

In another study, Brook, Briggs and Driver (2003) studied students' initial knowledge related to gases concept at the upper secondary school level (15 years old, 10 grade). Both qualitative and quantitative approach was used in this study. In the quantitative analysis, 90 students were administered a questionnaire before and after teaching gases. The findings indicated that students had the following misconceptions;

- Gases having mass is not obvious for students.
- “Gases occupy all the space" is not part of the initial knowledge.
- Students use the macroscopic level for representing gas, they draw gas like a continuous e.g. football.

The qualitative approach involved a case study. Questionnaires and interviews were performed on six students in order to determine students’ progression of knowledge. Prior to instruction, students considered that quantity and volume is the same thing. In addition, they believed that air did not exert the same pressure in different directions. After instruction, they differentiated quantity and volume from each other and thought that air exerts the same pressure in all directions.

In another research on students’ misconceptions, De Berg (1995) conducted a study to investigate students’ understanding of Boyle’s Law of gases. One hundred and one students (17- to 18-year-olds) from two colleges were asked a task about pressure and volume relationship of air within a sealed syringe in different states of compression. Quantitative and qualitative tasks for the sealed syringe system were investigated. Results indicated that the concepts of volume and mass were not understood by 34 % and 38 % of the students respectively under the given circumstances. Many of the students responded correctly that the volumes of the gases reduce after compression but 25 % of the students believed that the volume stays the same since no air escaped.

Séré (1986) investigated the conceptions of children about the gaseous state. Results were based on a written questionnaire and interviews conducted with 11 year old secondary school French pupils. Results indicated that before teaching the physical properties of gases, they primarily associated the gases with the use and functions of objects such as suction pads, tires, tire-pump, various balls, electric fun, etc. The stereotypical views like ‘air is everywhere’ and ‘hot air rises’ were often stated by the pupils. Children had animistic reasoning. For instance, the statements of ‘air always wants to expand everywhere’, ‘Air can be tired, disturbed’ were the examples from their thoughts describing the properties of air and gases. In addition, most pupils believed that air exerts a force, only when it is heated, in the direction of the movement.

Nurrenbern and Pickering (1987) argued whether teaching students to solve problems about chemistry is equivalent to teaching them about the nature of the matter. In other words, they tried to find an answer to the question whether there is a difference between concept learning and problem solving. Their study was conducted on five different classes ranging in size from 14 to 99 in the general chemistry program. Students’ understanding was examined via both traditional problems about gases (Boyle’s law, Charles’s law, or the combined gas law) and multiple-choice questions asking merely conceptual understanding of gases. They found that freshman chemistry students are more successful in answering traditional questions than conceptual ones. Consequently, they concluded that in order to solve algorithmic problems about gases, students do not need to comprehend the nature of gases.

Sawrey (1990) repeated and supported the Nurrenbern and Pickering’s research with a larger, more uniform group of students using the same test questions so as to investigate whether solving numerical problems guarantees conceptual understanding or not. The students were mainly first quarter freshman students and nearly all of them had one or more years of chemistry in high school. The multiple-choice test including both traditional and conceptual questions, stoichiometry problems (as part of the first examination) and gas law problems (as part of the second examination) was administered to freshman chemistry students. Moreover, in both cases concept questions were asked just after the traditional questions. The results of her study indicated that even the best numerical problem solvers failed on the concept questions. In addition, she suggested to teachers to consider both qualitative and quantitative nature of the chemistry.

Likewise, the research of Nakhleh and Mitchell (1993) confirmed that students who are high algorithmic problem solvers about gas laws do not mean that they would be high conceptual problem solvers. In their study, the aim was to find out what students think about while solving conceptual and algorithmic problems and to determine the differences and/or preferences to each. They evaluated 60 freshman chemistry students' algorithmic and conceptual problem solving abilities. The traditional problem-oriented lecture was used. This study was composed of two parts; in the first part paired questions techniques were used to identify the students as being either conceptual or algorithmic problem solvers. Two problems (one conceptual gas law problem, one algorithmic gas law problem) were asked and students were grouped in one of four categories such as high algorithmic/low conceptual, high algorithmic/low conceptual and etc. In the second part, interviews were conducted with six students. The exam questions showed that % 51.7 of students were in low conceptual category; that means they did not illustrate comprehension of chemistry concepts or could not apply those concepts. Different from Nurrenbern and Pickering (1987) and Sawrey's (1990) studies, Nakhleh and Mitchel (1993) conducted interviews to analyze the strategies and the preference for solving conceptual and algorithmic problems as well as the difficulties they face. The interviews indicated that high algorithmic problem solvers used algorithms while solving conceptual based questions regardless of their conceptual-problem solving ability instead they used "test taking strategy" eliminating the given alternatives. In addition, though the majority of the students said that they do not prefer algorithmic-based problems, they do not want to be graded on conceptually based problems requiring more thought.

The research of Niaz (2000) supported the findings that have been reported in the literature (Nurrenbern & Pickering, 1987; Sawrey, 1990; Nakhleh & Mitchel, 1993). The main objective of his study was to establish a relationship between students' understanding of gases and its parallels in the history of science (rational reconstruction). In contrast to the previous studies, conceptual gas problem was given to the students as a part of their regular evaluation about a month after having seen the kinetic theory of gases. After exposing the elementary version of the kinetic theory of gases, fifty-nine freshman students were asked a question which requires conceptual understanding (due to molecular collisions, gases occupy all the available space). However, during the course, students were not directly instructed about the conceptual problem, which asked the distribution of gas at lower temperatures. Most of the students believed that attractive forces increase among gas particles as the temperature decreases though it was explained that the gas is still a gas at this temperature. This study revealed that majority of the students' alternative conceptions are resistant to change about the gas behavior and reiterated the studies in the past (Piaget & Garcia, as cited in Niaz, 2000).

In the light of the Nakhleh and Mitchell (1993)'s research in which freshman chemistry students are good at solving algorithmic problems than conceptual ones, Cornely-Moss (1995) explored students' conceptual knowledge about the kinetic theory of gases by the 10 min quiz. Her study revealed that % 31 of "low conceptual/high algorithmic" freshman chemistry students could easily use algebraic equations while solving problems although they had little understanding of the concepts described in the equations.

Rollnick and Rutherford (1993) in their research investigated 145 primary school science teacher trainees' misconceptions about air and air pressure. Different from the other studies that were only dealing with the identification of misconceptions, they provided remediation strategies both conceptual change and mixed language approaches to overcome them. The effectiveness of these two strategies to remediate the alternative conceptions on air pressure was compared. The main objective of this study was to exchange of the alternative conceptions about air and air pressure with the scientific ones with the help of conceptual change materials in which key misconceptions were embedded into them. For this purpose, conceptual change materials were developed mainly based on the human breathing system via a lung model and related questions. Some misconceptions had been detected from the previous studies of Rollnick and Rutherford (1990). Two of them were:

- Changes in pressure are explained in terms of space taken up by air.
- A rubber sheet can suck in air (contained in this is also the idea that 'a vacuum sucks').

In the experimental group, conceptual change materials and strategies were used to form scientific conceptions in all cases. Lung model was presented to experimental group students at the beginning and students were allowed to discuss how it works. Besides, students were not given a correct answer, therefore they required more information to suggest the correct answer and meantime were provided concept map representing the ideas throughout the material. On the other hand, the control group students were presented the lung model after learning about air occupying space and air pressure however, no conceptual change materials and strategies were used in this group. Teacher answered the questions only asked by the students and the teacher did not address any misconceptions during the implementation of non-conceptual change materials in control group. Quantitative (pre- and post-tests) and qualitative data (tape recordings of students' discussions while doing practical work) were obtained from this study. They found that though mixed language strategy was the most effective in overcoming misconceptions; it was not necessarily in replacing them with scientific conceptions. Therefore, the use of conceptual change strategies was found to be useful in some cases.

Lee, Eichinger, Anderson, Berkheimer, and Blakeslee (1993) conducted a study to understand the conceptual frameworks that students use to explain the nature of matter and molecules and evaluate the effectiveness of two alternative curriculum units in promoting students' scientific understanding. Fifteen sixth-grade science classes were included in this study. Interviews and pencil-and-paper tests were performed for the data collection. The findings showed that textbook definitions like "matter is anything that has weight (or mass) and takes up space "does not work because many of the students considered that gases have no weight even after instruction. Moreover, students had naive conception that there is something else between the molecules against the scientific conception of empty space between molecules. Another detected misconception was about the size of the molecules; students thought that molecules are much smaller than objects like dust speck. They still believed that they could see them with magnifying glasses or microscopes, and Griffiths and Preston (1992) and Harrison and Treagust (1996) got similar results that students believe that atoms are alive because they move. In addition, Gilbert et al. (1982) identified that students have tendency to assign objects human or animal characteristics to the atoms. This idea is widespread especially among the young students but it is also obvious in older ones (Griffiths & Preston, 1992). In addition, Lee et al. (1993) also stated that many of the students have difficulty in understanding the constant motion of particles. Some of the students thought that molecules in air move due to the blowing of wind. The results revealed that many students attributed observable properties to molecules. For instance, one of them said that the ice molecules would be colder than the ones in the water. Moreover, students believed that air flows from one place to another like water but unevenly distributed. Some of them thought that when the air was compressed in a syringe, air moved toward the opening of the syringe. In addition, students were asked why gases are compressible and liquids are not. Some students said they could not compress water in a syringe since the water is 'harder' or 'heavier' than air. Furthermore, students were asked to predict what would happen to a balloon on top of a cold bottle when the bottle was warmed up. Most students thought that the balloon would blow up or get larger due to hot air or heat instead of thermal expansion. Hence, they believed that hot air would rise and cold air would go down in the bottle, so there was hot air or heat in the top and cold air in the bottom. In addition to these, some students believed that when a substance evaporates, it becomes invisible and it no longer exists.

Benson, Wittrock and Baur (1993) investigated students' preconceptions about the nature of the gases on 1098 students from second graders to university chemistry students. A clinical interview technique of Novick and Nussbaum (1978) and the case study of Nussbaum and Novick (1982) were used in this study. Demonstration was carried out for elementary, junior high, and senior high school students. During the demonstration, two identical flasks were used; one of them was filled with full of room air (1 atm pressure) and from the other flask, half of the air had been evacuated (0.5 atm pressure) with a syringe. This demonstration was not provided, but just described for university chemistry students. All the students were asked to draw their mental images of the air in these flasks. Their drawings were classified as continuous (straight or wavy lines) or particulate (discrete dots and circles). Majority of the drawings indicated the following misconceptions:

- Air is a continuous (non-particulate) substance.
- Gas behavior is similar to liquid behavior (unlike the idea that gases expand to fill their containers).
- There is relatively little space between gas particles.

Chi-square analysis of this study indicated that there is a negative relationship between misconceptions and grade level.

Hwang (1995) explored students' understanding of concept of gas volume at different grades. One thousand and twenty nine students from junior high (grade range 8-9), senior high (grade range 9-12) and university level (grade range 13-15) participated to this study. All the students were administered two tests after studying the topic of gas phase. Students believed that;

- The volume of a gas is the size of a particle.
- The volumes of different gases are proportional to their particle numbers in a container.
- Two-liter gas cannot be placed in one-liter container.

The results showed that students still had misconceptions even after they had learnt the conception about gas volume. Similar to the study of Benson et al. (1993), the misconceptions that students hold decreased as their grade levels increased.

The study of Lin, Cheng and Lawrenz (2000) investigated high school students' and chemistry teachers' understanding of gas laws. One hundred and nineteen 11^{th} grade students and the 36 high school chemistry teachers were the subjects of the study. Four-item open-ended pencil and paper test was used. Two of the items were associated with Boyle's law, one was about Charles's Law and the other required drawing the molecular behavior after heating the mixture of gas. The analysis of the questions indicated the misuse of $PV=nRT$ formula. This shows that though students memorized the formula, they neither understood how to use it nor the meaning of it. Moreover, majority of them gave intuitive answers to explain the situation based on Boyle's Law. In addition, the common misconception found was the failure to differentiate the subjects of "system" and the "surrounding". Related to kinetic theory, the results illustrated that most of the students were not able to draw the appropriate representation of gases inside the flask. They made the intuitional assumptions by giving the human-specific characteristics to non-living molecules instead of scientific explanation of movement of gases at different temperatures. Some major misconceptions related to kinetic theory were identified as follows:

- Atmospheric pressure pushes the gas molecules down to keep them together at the bottom of the flask.
- Gas molecules rise and stay away from heat.
- Molecules expand when the temperature rises.

The research of Cho, Park and Choi (2000) focused on 11th grade high school students' conceptions and conceptual learning processes about kinetic theory of gases. Data were collected by means of semi-structured and in-depth interviews with 12 students who are different in terms of achievement scores, as high, intermediate and low levels and participant observations on three students through a case study. Prior to instruction, students considered that;

- The massive component will sink and lighter air will rise up in a sealed flask.
- Oxygen and nitrogen occupy different or separate spaces independently in a flask because it has fixed volume but in a balloon gases were mixed together because it is translatable freely.
- Gases occupy different space according to their molecular weights.
- Smaller molecular weight gases diffuse more slowly.
- Molecular motion of gases stops at an ending point in the diffusion.
- Pure substance approximates ideal gases more than compound does.
- Ratio of volume and molar number is proportional to each other for gases mixture in vessel.

Students retained misconceptions about the uniformity of the gaseous mixture before and after instruction. However, they were able to explain the movement of the gases relating with kinetic theory and molecular weight and they were aware that gas mixtures had a constant average kinetic energy. Consequently, students confounded experiential knowledge with scientific knowledge.

Sanger, Phelps and Fienhold (2000) developed an instructional approach to improve students' conceptual understanding of the molecular processes happening when a can including water is heated, sealed, and cooled. For this purpose, control and experimental groups received different kinds of instruction. Control group containing 70 students were instructed by chalkboard drawings and overhead transparencies. Experimental group students consisting of 86 students received similar instruction including the use of a computer animation of this process at the molecular level. All the students viewed a can-crushing demonstration in which a soda can containing a small amount of water was heated on a hot-plate to boil the water, removed from the heat, and sealed by inverting over a container of cold water. Results indicated that experimental group students were less likely to excerpt memorized mathematical relationships and more likely to state the significance of the condensation of water vapor and the decreased pressure inside the can and the resulting pressure differential inside and outside the can in their descriptions of the can-crushing process. Control group students quoted gas laws in their responses. Some of the misconceptions identified among control group students were as follows:

- The heated gas molecules expand and when they are cooled they shrink back not taking up as much space as before.
- The gas molecules take the shape and volume of the container they are in.
- The water vapor inside it would continue to press out against the can due to Charles law, and the can would possibly explode if the pressure was large enough.

Results also indicated that students receiving instruction including computer animations of chemical processes at the molecular level is more capable of responding conceptual questions about particulate phenomena.

She (2002) examined the process of conceptual change related to air pressure and buoyancy by virtue of instructing with the Dual Situated Learning Model. Twenty 9th grade students (ages 14-15) participated in this study. All of the students were randomly selected from an average class of a Taiwanese middle school and have learned the air pressure and buoyancy concept at the 8th grade physical science course. Interview-about events technique was used in the dual situated learning instruction to determine students' ideas before the events were presented. Students' perceptions of air pressure before discrepant events of pressing syringe were as followings:

- The syringe cannot be pressed because air pressure exists inside the syringe.
- The syringe cannot be pressed because air occupies space.

After the use of this learning, about 60 % of the students either thought that the air molecules inside the syringe could be compressed or there was a space between the air molecules. Moreover, the second dual situated learning event was about what happens to the foam rubber when the plunger of the syringe was pushed. Students' perceptions of changes in foam rubber due to air pressure before discrepant events of pressing syringe with foam rubber were stated as followings:

- The shape of the foam rubber will not change because when the syringe is pressed, the air molecules inside the syringe will be compressed to the extreme level.
- Only the shape of top and bottom parts will change because as the volume of the syringe is decreased and the air pressure increases (air molecules become compressed).

After dual situated learning, about 95 % of the students started to think that foam rubber becomes smaller on all sides by the exerted air pressure on all sides of the foam rubber. Results revealed that putting this model into real classroom teaching considering the social factors would be more effective in the improvement of knowledge construction among students.

Research of Kautz, Heron, Loverude and McDermott (2005) aimed to improve the students' understanding of the ideal gas law by the research-based instruction. This study included more than 1000 students at four universities. Students' learning was evaluated by pretests and posttests. Forty five students, many of whom took a year of chemistry course, from University of Washington were interviewed at the beginning of the study. During the interviews, students were asked about the possibility of changing the volume of air in the pump without altering the pressure. Many of the students thought that any decrease on volume is the result of increasing pressure, ignoring the decrease in volume with decreasing temperature in a non-constant volume container or in a frictionless piston. During the study, some problems were used to probe the students' understanding. One of them was the vertical syringe problem; the syringe was sealed with a frictionless piston and placed in an ice-water bath until to reach thermal equilibrium. After then, it is located in a beaker of boiling water and awaited enough for the thermal equilibrium. Students were asked to compare the initial and final volume and pressure of the gas. In the introductory physics course, equality of initial and final pressures was recognized by about 30 % of the students and approximately one third of them had the correct explanation. 45 % in thermal physics course and only 15 % of students in introductory chemistry gave the correct answer. Most common conception that students believe in all courses was that the final pressure would be greater than the initial one. In another problem, three identical cylinders (A, B and C) containing unknown amount of different ideal gases were sealed with identical frictionless pistons. Cylinders A and B contain different gases at the same temperature while cylinders B and C include the same type of gas at different temperatures. Students were asked to compare the pressures of the gases in cylinders. Since the atmospheric pressure and the weight of the pistons are the same, the pressures of the gases in all cylinders are the same, regardless of the type and the temperature of the gases. Only 15 % of the introductory students and 40 % of the thermal physics students made correct comparisons in all three cylinders. The results of this study indicated that even having taken a year of chemistry in university, students have still difficulties in understanding and applying the ideal gas law appropriately. In addition, many of them focused on the relationship between two variables in ideal gas law regardless of the others. For example, they assumed that *pressure is always inversely proportional* *to volume*, *pressure is directly proportional to temperature*. Moreover, students' understanding of macroscopic concepts of pressure and volume was improved by the interactive tutorial lectures and tutorial laboratory experiment.

The second investigation about students' understanding of the ideal gas law in microscopic perspective was performed by Kautz, Heron, Shaffer, McDermott (2005). The research was conducted with many undergraduate science and engineering majors in University of Washington. Before the study, researchers conducted individual demonstration interviews to obtain students' ideas about microscopic processes in ideal gas. In the light of the findings from interviews, written problems were developed to examine the difficulties that have been identified. These problems were asked on course exams and written quizzes requiring the explanation of reasoning for each. Three types of problems, some of which involve several tasks to improve students' understanding of the ideal gas law from a microscopic perspective were prepared. They were applied as pretests before the research-based instruction. In a kinetic energy task, students were asked about what would be the average kinetic energy of molecules (decrease, increase or remain the same) in consequence of isobaric expansion. About 80 % thermal physics students and 70 % of the introductory students believed that average kinetic energy increases. Many of the students gave correct answer but the wrong reasons. Students who gave scientifically correct answer thought that temperature must increase with an increase in volume at constant pressure. On the other hand, some of the students believed that density of the gas decreases in the consequence of expansion and so in order to keep the pressure constant, the speed of the particles must increase, "*incorrectly assuming lower (greater) particle density implies in lower (greater) temperature"*. Accordingly, the average kinetic energy and thus the temperature must increase. 20 % of the introductory students stated inaccurately that the average kinetic energy of the gas particles decreases as the volume increases at constant pressure. Therefore, the molecules will move more freely. In addition, many students had problems with using the multivariables in ideal gas equation. For instance, they considered that the average kinetic energy decreases due to ideal gas equation, $PV=nRT$. The related explanation was as the volume increases, temperature of the ideal gas decreases and this results in losing kinetic energy of molecules. The amount of ideal gas and so the pressure remains the same. In addition to these, some students "*mistakenly assumed that molecular collisions generate kinetic energy"*. They thought that when the gas is enclosed in a smaller volume, the gas particles are more likely to come together and collide with each other frequently. Consequently, the temperature and so average kinetic energy increases. Related to two-tank task, during the interviews, students had mentioned that size or mass creates the difference in the number of the moles or molecules. Therefore, in a two-tank task, students were asked to compare the number of molecules in identical containers filled with gas at the same temperature and the pressure. One of them includes oxygen, the other hydrogen. 75 % of thermal physics students and about half of the introductory students gave the correct answer that the number of moles or molecules must be equal since both gases have the same pressure, volume and temperature. Moreover, analysis of students' answers indicated that most of the students who gave incorrect answer thought that the number of particles of a gas having smaller mass would be higher, not recognizing the substance independence of the ideal gas law. More than one-third of the students believed that pressure of a gas is dependent on the mass of the molecules. They mistakenly thought that "*a greater number of lighter molecules are needed to produce a given pressure*". Molecular mass of hydrogen is lower than that of nitrogen, so there must be more from it to equalize the pressure of nitrogen. Some of the students had the opposite idea, the gas with smaller molecular weight causes greater average kinetic energy and so a larger pressure. Additionally, many students misinterpreted the quantities of n, M, N_A, and R.

Consequently, research findings about students' understanding of gases indicated that gases are one of the abstract subjects that students have difficulties in understanding and misconceptions about it. In addition, Stavy (1988) claimed that prospective teachers have an access to a very limited number of gases in everyday life and so their knowledge about gases was expected to be very poor prior to instruction and this view was supported by follow up researchers (Barker, 1995; Benson et al., 1993). Therefore, the studies about gases will shed light on not only students but also prospective teachers' understanding of gas concepts and remedying misconceptions related to it. In order to eliminate or remedy misconceptions, constructivism and teaching approaches founded on conceptual change model can be applied in classrooms. Constructivism and conceptual change approach are described in the next section.

2.2 Constructivism and Conceptual Change Approach

Constructivism has a significant impact on contemporary science and mathematics education. Educational constructivism stresses the importance of individuals' construction of own knowledge and concepts. The root of this movement lies to Piaget's cognitive development. Moreover, educational constructivism emphasizes the social diversity and the importance of the group in order to develop and validate the ideas and it has origins from Vygotsky's work of linguistic and language acquisition. In science education, constructivism alerted the importance of prior learning, existing concepts in the process of new learning by promoting student engagement in lessons (Matthews, 1998). The constructivist view of learning emphasizes the role of prior knowledge because all learning involves interpreting phenomena, situations, and event including classroom instruction through the perspective of the learner's existing knowledge. In addition, prior knowledge is important because some of the misconceptions arise due to students' prior learning either in classroom or physical or social contact with the world (Smith, diSessa, & Roschelle, 1994). Students come to class with their existing knowledge and connection of new knowledge with the existing one is strongly related to conceptual change. The relationship between prior knowledge students bring to the classroom and how this knowledge works associated to new topics to be taught are greatly connected with conceptual change. Learning needs altering in a person's conceptions by adding new information (Hewson, 1992). Conceptual change model of learning was developed based on this view by Posner et al. (1982) and improved by Hewson (1981, 1982). Conceptual change model has two major components. One of them is the *conditions* to be met, and the second component is the person's *conceptual ecology* that offers the environment in which conceptual change occurs. Conceptual ecology includes different kinds of knowledge that might enable to build new information. Learners use prior knowledge or existing knowledge (i.e. their conceptual ecology) in order to decide whether the conditions are met; namely whether a new conception is *intelligible*, *plausible* and *fruitful* (Hewson, 1992). Posner et al. (1982) specified four conditions for conceptual change to occur:

1. Dissatisfaction: Learner's new conception might conflict with the existing knowledge due to the inadvisability and unfruitfulness of the new conception. A disagreement or inconsistency generates disequilibrium in a person's mind Preexisting conceptions need to be restructured and exchanged with the new ones for the learning to occur.
2. Intelligibility: If the new conception is intelligible that is, new coming information is understandable and sensible for the learner, s/he could able to construct a meaningful representation.
3. Plausibility: If the new conceptions are plausible, it means that they are reasonable or believable for the learner and consistent with existing concepts, knowledge or experience.
4. Fruitfulness: Fruitfulness means that new conception must produce results that can be applied in other areas. In other words, it must suggest new approaches to problems.

If the new conception meets the above conditions, learning proceeds easily. The purpose of conceptual teaching of science is not to adopt teacher's or scientist's conceptions to students but, rather, to assist students to create the tendency of challenging one idea with other ones and advance suitable strategies for having different conceptions that will force one another in reception. Posner et al. (1982) stated that the first step of the conceptual change is the phase of cognitive conflict that is the consequence of the dissatisfaction with the existing concepts. Misconceptions can be used to create conflict in students' mind. Dissatisfied students should be aware that they should rearrange or restructure the existing concepts. Though it may seem that "metacognitive awareness" is needed, but is not adequate to accomplish conceptual change (Vosniadou, 1994). Therefore, it appears that a person needs to understand to change something and s/he must be eager to do it (Limón, 2001). Conceptual change may seem simple but it is a complex phenomenon. Though it has absolutely a cognitive component, student's beliefs, intentions, motivations, emotions and their social environment affect their cognitive development (Sinatra, 2002). Therefore, students should be encouraged through group discussions in order to increase their metaconceptual consciousness that is necessary to comprehend the concepts of science (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). In addition, they stated that class discussions can affect conceptual change process. Discussions not only provide students an environment to reassess their ideas whether they are correct or not but also they facilitate conceptual change by engaging students in learning. In fact, discussion is not the only way to promote conceptual change; different teaching strategies can be developed and used to help learners to gain scientific point of view by involving them in learning process. In addition to these, fruitfulness of the new conception can be met by daily life connections and applicability of the new conceptions in other areas as well as making the new information useful. Moreover, literature says that students' capability to be aware of problems (Arlin, 1986) and real problem solving ability (Perkins & Simmons, 1988) also have influence on the conditions of dissatisfaction and fruitfulness. The study of (Vosniadou, 2001) indicated that much attention should be given "*constructive aspects of learning, facilitating collaboration,* and *providing opportunities for meaningful activities*" in designing learning environment to promote conceptual change in science education. Furthermore, the teachers should encourage students to take control of their learning, give them opportunity to express their new ideas and help them to develop scientific point of view.

There can be seen many instructional methods enabling these conditions in conceptual change established by Posner et al. (1982). Some of them are cooperative learning (Slavin, 1987), refutational texts (Palmer, 2002), analogies (Dagher, 1994; Smith & Abell, 2008), conceptual change texts (Özmen, Demircioglu, & Demircioglu, 2009; Roth, 1985) and learning cycle (Musheno & Lawson, 1999; Niederberger, 2009). In the current study, effectiveness of case-based learning based on conceptual change conditions was investigated. Next section presents in depth information regarding case-based learning.

2.3 Case-Based Learning

Case-based instruction has long been accepted as an effective teaching method in schools of law and business and is increasingly being used in other disciplines such as medicine (Barrows, 1985; Irby, 1994; Sykes & Bird, 1992), political science, journalism (Knirk, 1991), teacher education (Kagan, 1993; Shulman, 1992), architecture (Schon, 1983), educational psychology and measurement (Silverman, Welty, & Lyon, 1992), instructional design (Ertmer & Russell, 1995), social work (Cossom, 1991; Jones, 2003; Jones, 2005; Jones & Woodruff, 2005; Wolfer & Scales, 2006), education (Harrington, 1991), physical education (Zeigler, 1959), nursing (Woody, Albrecht, Hines, & Hodgson, 1999) and psychology (Naumes & Naumes, 1999).

The roots of case method extends in the field of law (Merseth, 1991, p.243) and there are numerous cases in this field, "*Cases in Teaching and Law*" Carter and Unklesby (1989), "*Learning Criminal Law Through the Whole Case Method*" Zarr (1989), "*Teaching About the Law*" Gerlach and Lamprecht (1980) are the some good starting points in the case literature. An earlier work was the *Case Studies in Human Relationship in Secondary School* (Lloyd-Jones, 1956) that contains 26 cases for the study of issues of secondary school students' counseling and guidance. *Case Studies on Teaching* (Kowalski, Weaver, & Henson, 1990) include 30 cases dealing with teacher strikes, cheating, student behavior, ability grouping, and homework. *Case Studies for Teacher Problem Solving* (Silverman et al., 1992) offer 28 cases that deal with the subjects of classroom management, learning, effective teaching, diversity, evaluation, and contemporary teaching. *Case Studies for Teacher Decision Making* (Greenwood & Parkay, 1989) presents 30 cases about issues of curriculum, instruction, group motivation and discipline, pupil adjustment, conditions of work, and "additional cases". *Getting Down to Cases: Learning to Teach with Case Studies* (Wassermann, 1993) includes 26 cases that can be grouped under three main categories; teacher-as-person, teachers and students, the teacher and the curriculum categories. *Case Methods in Teacher Education* (Shulman, 1992) make important recommendations about educational theory and classroom practice. *Gender Tales* (Kleinfeld, 1995) includes cases about gender-related issues at the university level. Moreover, from the Center for Cross-Cultural Studies at the University of Alaska, Kleinfeld (1989) presents series of teaching cases in the subject of cross-cultural education. *A Casebook for English Teachers: Dilemmas and Decisions* (Small & Strzepek, 1988) contains 32 short scenarios or cases, each of them are related to teaching of English, language and literature. *Cases for Teaching in Secondary School* (Bickerton, Chambers, Dart, Fukui, Gluska, McNeill, Odermatt, & Wasserman, 1991) includes 20 cases in the fields of social sciences, journalism, Western civilization, bioethics, and art. *Case Studies: The Cowichan Collection* (1993) includes 17 cases related to issues in government, business, law, history, and health and staff development.

Case Clearinghouse at Harvard Business School is the most extensive resource containing a great number of cases for business teaching for university coursework. Its catalogue also includes a number of readings for people to improve their understanding about teaching with cases. Moreover, the Roderick MacDougall Center for Case Development and Teaching at Harvard is the center offering cases for utilizing in curriculum and instruction, human resource and management, organizational development, community and local politics, organizational development and so forth. In addition, Drs. Rita Silverman and Bill Welty from Pace University have been adding cases on the subject of teacher education. In Canada, International Case Clearinghouse provides cases about business and teacher education for students in high schools, community colleges and universities and adult education and training programs. In addition to these, *Teaching and the Case Method* (Christensen & Hansen, 1987) and *Education for Judgement* (Christensen, Garvin, & Sweet, 1991) are the two important resources about case method teaching and teaching with cases.

"Cases", "the case method", or "case-based instruction" has its origin from the cognitive psychologists and curriculum theorists. According to Shulman and Welty, a case-based pedagogy requires as Jerome Bruner names "narrative" rather than "paradigmatic" knowing (1986). The case method teaching is not a new idea but is different in terms of revealing itself in different forms and implementation relating to the nature of knowledge (Merseth, 1991).

Though cases have long remarkable history in the disciplines of business, clinical psychology, law, medicine, and public policy, Merseth (1991) indicated teacher education could benefit from these experiences: As John Dewey stated "The problem of training teachers is one species of a more general affair-that of training for the professions" (1904, p. 315). Merseth (1991) mentioned that case method comprises a good fit with conceptions of teacher knowledge and specified a number of benefits from the longer experience in other fields of disciplines, and from the studies conducted in the field of education in recent years. They are presented in the following:

1. Cases help students to develop skills of critical analysis and problem solving.
2. Case-based instruction encourages reflective practice and deliberate action.
3. Cases help students gain familiarity with analysis and action in complex situations that may not represent a perfect match between theory and practice.
4. Case-based instruction involves students in their own learning.
5. The case method promotes the creation of a community of learners (Merseth, 1991, p. 15-18).

Case studies involve generally long, detailed and rather well defined problems. Cases can vary from a paragraph or two to a dozen pages but long cases are suggested to be distributed and read before the class to prevent students get confused and become lost in details. The study questions followed by the cases facilitate class discussion. In some cases, learners can create their own cases, but newspapers, magazines, journals, personal experiences or experiences of others can contribute to the content for cases (Tomey, 2003). Learners solve the presented problem using their background knowledge (DeYoung, 2003). Learners usually read the given case, analyze, and identify the problems of the real or hypothetical situation and then they take part in a group discussion.

Cases are the educational materials including information and data such as psychological, sociological, scientific, anthropological, historical, observational, and technical material. Though they are based on a particular subject area like history, law, business, education, and so forth they are interdisciplinary by their nature. Cases are composed of two main parts: one of them is the case situation for the study and the other is the questions related to case and the process. Cases might be developed first and then the questions can be asked, or questions might be asked before and then cases are developed in order to answer these questions. At the end of each case, some study questions related to cases help students to evaluate the outcomes, concepts, subjects of the case. The purpose of the study questions is to direct students to facilitate their understanding, rather than simply asking for the names, dates, or labels in analyzing the data and suggesting solutions. Case-based teaching provides opportunities for students to study in small groups and discuss their responses related to given cases and study questions. Case based classrooms are the places in which no particular answers are tried to be found, debates or discussions do not end with a certain answer, after discussions, unanswered questions remain in students' mind. While the case method is short and specific for objective, case studies are usually longer and complex progressively including more multimedia like videos and computer programs (Wassermann, 1994).

Story-telling nature should be used in a case study and it should consist of interesting characters names and their titles, responsibilities, personalities, and recent and long-term behaviors should also be included to the case study. Characters in the case study should keep going a dialogue with reasonable details and the sequence of incidents should be followed easily. In addition, all the necessary information required for both analysis and conclusion should be included in the case. Moreover, the related additional attachments such as organizational charts, floor plans, policies, procedures, and laboratory reports might be included to the case study. Case study might be arguable, and should lead speculation, interpretation, comparisons and contrasts. The learners work in teams interactively to accomplish the objectives and there is a cooperative, collaborative and supportive learning environment (Cossom, 1991; Tomey, 2003). The case study learning approach promotes problem solving, decision-making, critical thinking, self-directed learning, self-evaluation, interpersonal communications, access to the information and use of it (Amos & White, 1998; Dowd & Davidhizar, 1999).

In addition to these, Wassermann (1994) described basic principles of the case-based method teaching. These are:

1. *Cases*: Cases are the complex teaching instruments in the form of narratives. The narratives are generally based on real life situations. Teacher and the students study on the problems related to daily life cooperatively.

2. *Study Questions*: A list of study questions are asked at the end of the each case. Study questions do not direct students know or remember certain facts, names, dates, labels, formulas, definitions, etc rather they promote understanding, encourage them to apply their knowledge in the inspection of ideas and what they know in analyzing data and in proposing solutions.

3. *Small Group Work*: Small group work provides students the opportunity to discuss the cases and questions with each other and express their opinions before the whole-class discussion. In addition, students generate discussion about possible solutions of a given case.

4. *Class Discussion*: Class discussion involves active engagement of students. During the examination of the case, teacher manages the class discussion by promoting students in the critical analysis of the real life problems and helps students to get the meaning. The teacher avoids imposing his or her own thoughts rather s/he lets students to interpret their own understanding in the period of discussion.

5. *Follow-up Activities*: Class discussions drive students to learn more because ambiguity is raised and answers are not given so they are encouraged or motivated to learn more. Follow-up activities can be performed independently or in groups and teachers decide for which activities are used by considering the needs of the students. Textbooks, articles from newspapers and magazines, tables, charts, research reports, novels, and other visual and written materials can be a good source for follow-up activities.

It should be noted that the case study method and Problem Based Learning (PBL) do overlap with each other since they are both inductive, but they are not identical approaches. A problem is a kind of case, but a case is not necessarily a problem. Simply, a case is a story with a learning message, such as a conversation, newspaper clipping, or a courtroom scene. Nevertheless, a case can also be as sophisticated as a problem used in PBL which requires longer periods of time to investigate, often over the course of whole semester (Herreid, 1997).

Before the implementation of a case-based method teaching, there must be a case written to get definite curriculum objectives. While specifying cases for class, teachers should search for the relationship of the case to lesson topics, quality of narrative, readability, and the ability of the case to produce new opinions about the issues and rouse discussion in relation to the dilemma (Wassermann, 1994). To summarize, a good case has a big idea, focuses on something controversial, is something new to the students, creates empathy with the central characters, includes quotations, is relevant to the reader, must have a pedagogic utility, is decision forcing and short. Next chapter presents types of case studies and the overview of research studies about case-based learning.

2.3.1 Types of Case Studies

In 1994, Herreid classified the case studies in eight different formats as *lectures*, *discussions*, *debates*, *public hearings*, *trials*, *problem based learning*, *scientific research teams* and *team learning*. However, after four years later he gathered the case study methods under four main headings; *individual assignment*, *lecture*, *discussion* and *small group activities*. Although the definition of the case stays the same in all formats, the role of the teacher and students change in each of them. For instance, in individual assignment format students usually work by themselves. However, in lecture format the teacher mostly works on his own. In discussion format, the teacher and students work together but the teacher controls the discussion. On the contrary to the discussion format, though the teacher and the students work together, students have control for analyzing the cases in small group activities.

2.3.1.1 Individual Assignment Format

This format is very familiar for most of us but maybe we did not call it as case study approach. Individual assignments were given to students and these assignments involve constructing a story line, which involves the case of a story with messages. For instance, many term papers, dissertations, theses, book reviews, plays, and written dialogues can be individual assignments if they include a story with message.

2.3.1.2 Lecture Format

In the 1940s, James Conant introduced the lecture version of the case method. Instructors tell stories during lecturing and the role of students is to listen to the case and take notes if it is needed. Rarely, two instructors may work together in front of a class covering a story line with different perspectives and arguments. Teachers could discuss the cases by looking from different perspectives. A single instructor may also do this using a method called as "Two Hat Debate." Firstly, a teacher gives an argument about a controversial problem. While a teacher debates himself in one side, then argues in the other side. In theatrical words, the teacher alters hats as altering standpoints (Herreid, 1994).

2.3.1.3 Discussion Format

Discussion is the well known format for conducting the case method of instruction. This format of case method is widely used in business and law schools. The role of teacher is to question the students' point of views on a case. However, sometimes students may not have a feeling of completion after the case has ended. Hence, teacher must be skillful to ensure the accomplishment of cases. Most business cases are dilemma cases and need judgment. One of the biggest problems in the use of dilemma is caused due to the teachers' inability about how to use them in class because they are not trained as discussion leaders.

2.3.1.4 Small Group Format

According to the extensive meta-analysis, the use of cooperative learning strategies in small groups is the best method for learning (Herreid, 1994). Therefore, cooperative learning strategies accompanied with case based learning method can be used to enhance learning. Team learning strategies can be used with this method also. With this strategy, students are given individual and group test, solve the related problem and analyze the case differently from formal lectures.

Problem based learning is also successful for using cases. Teacher works as a facilitator in class, while students work in small groups. Students deal with one case in three class periods. In the first period, students get a new case for example a patient with some symptoms, and clinical test results. Instead, the patient can be seen in the flesh or in the video. Then, students analyze the case using reference books and internet. By the help of the teacher, students make a decision about what the problems are and what they require to cope with the patient. The workload is subdivided among them, and they search the issue in the library or on the internet and come to class to share their findings with their group mates. In the subsequent period, they consider the problem and probably take more clinical information about the problem. In the final period, students finish the diagnosis and give their final report related to it.

In the current study, case-based learning in small group format is used since it is the best strategy for learning among other alternative formats. Moreover, by the help of this format students can learn more from each other owing to the nature of team learning strategies. Consequently, small group format is appropriate for promoting learning.

2.4 Overview of Research regarding Case-Based Learning

This section includes an overview of literature about case-based learning. This overview is presented in three main headings; research about the case-based instruction on teacher training, research about case-based instruction on undergraduate science education, and research about case-based instruction on high school and elementary school science education. The vast majority of studies in this field are associated with medical science. However, the research studies related to case-based instruction on teacher training, undergraduate science and secondary and elementary science have no long history as detailed below.

2.4.1 Research about the Case-Based Instruction on Teacher Training

In addition to other fields of science, case method was effectively implemented in teacher education. Cases can be used in teacher training more efficiently than traditional teaching methods because they reflect real life situations and related problems, subjects, and are the means for linking theory and practice (Ball & Cohen, 1999; Shulman, 1992). Barnett (1998) used cases widely for work of elementary school teachers. In teaching mathematics, for addressing dilemmas narratives written by elementary school teachers have been used by Schifter and her colleagues (1996a, 1996b). Silver and his colleagues (1999) developed cases for middle grade mathematics teachers for the project of Cases of Mathematics Instruction to Enhancing Teaching to enhance knowledge of a particular theory or construct new theories, practice analysis and assimilate different viewpoints; and encourage personal reflection. Results indicated that the use of cases improved teachers' understanding of knowledge and their reflective thinking of teaching.

In another study, Stoiber (1991) investigated the effect of case method on 67 pre-service teachers in elementary education. The sample of the study was divided into three groups. In the control group, the instruction was based on the principles of general education; in the second group, pre-service teachers were given prescriptive principles about the classroom management; and for the study group, the learning environment to promote problem solving abilities was provided. After the instruction, the participants were interviewed by showing videotape situations about the problems of classroom management. The findings indicated that study group pre-service teachers produced significantly more alternatives and consequences to the presented problems in the scenarios compared to the other two groups.

Lundeberg and Fawver (1994) conducted pre- and post-test to evaluate the effect of case-method on pre-service teachers. It was found that several dimensions of cognitive growth are improved by case-method. The post-test results indicated that students were able to approach the problems from different dimensions, able to perceive the larger picture in virtue of situations instead of a single point.

Other study conducted by Lundeberg and Scheurman (1997) included two groups of pre-service teachers in Educational Psychology, who evaluated the same case twice. It was found that second case analysis improved the students' identification of related concepts and the theories about the case more than the first case analysis. Moreover, two groups of students' ability to incorporate preexisting knowledge and recognition of problems developed significantly.

In addition to Lundeberg and Scheurman (1997), Barnett (1998) carried out a study in order to display how specific aspects of cases and case discussion process promoted learning environment. It was found that the discussion environment provided critical examination of alternative views and ideas by others in order to see the inadequacies and mistakes in their thinking.

Moreover, Lin (2002) designed a study in order to improve teachers' knowledge by constructing cases as a part of project based on the school-based professional development in Taiwan. Four classroom teachers and the researcher constructed the cases collaboratively based on real classroom events. Teachers' skills of case writing developed in the course of the study and they experienced the difficulties that students face with learning mathematics. Their pedagogical content knowledge improved during the process of constructing cases. Case construction provided the opportunity of connecting theory with practice.

Different from the studies above, Kinzie, Hrabe and Larsen (1998) indicated some important issues in case study approach as well as the usefulness of the collaborative study. Web-based instructional design case in a team case competition was conducted with 36 graduate students from six different universities. Results indicated that the reason for participation of students to the case event was the desire for learning more about instructional design due to the encouraging or motivating aspect of competition. They found that cases are a worthwhile medium for exploring and learning about instructional design. The Web was verified to be an effective delivery medium for case materials. The findings also supported the usefulness of the collaboration such as collegial dialog, negotiating, arriving at consensus, and working together as well as some important concerns in case-based study. Most of the participants felt that case was realistic, detailed and complex.

In addition to these, Arellano, Barcenal, Bilbao, Castelano, Nichols and Tippins (2001) investigated the potential for using case-based pedagogy as a context for collaborative inquiry into the teaching and learning of elementary science. The elementary science teacher preparation program at West Visayas State University was the context for this study. Six elementary student teachers, their respective cooperating teachers and a research team composed of science teacher educators participated in the study. The introduction of case-based pedagogy stimulated aspects of open-mindness, responsibility, and wholeheartedness. This study draws the attention to the advantages of posing questions and producing case-based knowledge with significance in the development of science teaching and learning. In other words, case-based pedagogy can serve as an opportunity to teach critical inquiry practices.

Whitenack, Knipping, Novinger, Coutts, and Standifer (2000) reported findings about the case study conducted for professional development of 27 primary grade mathematics teachers. Pairs of teachers developed mini-cases using six children's interviews about the children's arithmetical understanding. Teachers' journal reflections, mini-case study written assignments, daily field notes of observations, video recordings taped in the whole class discussions and group sessions comprised the data of the study. The analysis of the data indicated that teachers found the experience challenging and were able to reconstruct the children's mathematics adequately.

Baker (2000) investigated the difficulties confronted in teacher preparation and examined how case-based instruction overcomes these difficulties. Three multimedia software designs were analyzed for case-based instruction and findings indicated that understanding how case based learning theory could inform software design is significant. In another study, Baker (2005) conducted a study in a Midwestern State University in a course with 26 elementary education majors. Author aimed to examine various issues using multimedia case-based instruction (M-CBI) to improve teacher education of literacy teachers, describe Children as Literacy Kases (ChALK) in which M-CBI is used in teacher education for literacy teachers, and to examine pre-service teachers' perceptions of their growth as literacy teachers after the M-CBI/ChALK course. Multimedia cases named Children As Literacy Kases (ChALK) which consisted of 27 multimedia CD-ROMs included literacy portfolios of five elementary children. Moreover, portfolios were developed regarding each child's reading and writing development during a school year. ChALK consisted of about 22 hours of video, 135 samples of children's writings, and 115 samples of children's readings and particularly it included one or more reading and writing samples about literature, math, science and social studies each month for each child. In addition, ChALK was designed to provide pre-service teachers to examine children's literacy development over an eight-month period. Findings showed that M-CBI might be a useful tool for pre-service teachers providing meaningful experiences and it might improve the significance of field experiences.

Baker conducted a series of studies to investigate the use of ChALK. In this study, Baker (2009), author intended to report the findings in order to provide organized overarching research related to ChALK. The ChALK studies took place in three phases and each phase was conducted in literacy courses for Elementary Education majors in a Mid-Western Public University. M-CBI was incorporated in each study in university courses during 15-week semesters and between 24-34 students participated to each of them. As a result, there was a consistency among the results of M-CBI that it has many benefits for students such as enriched field experiences, development of expert pattern recognition, demonstration of reflection, improved discussion. However, author recommended more pedagogical implementation of M-CBI in literacy as future research.

2.4.2 Research about the Case-Based Instruction on Undergraduate Science Education

There are limited numbers of studies on case-based instruction in the field of undergraduate science education. Most of the research findings are based on the reports of end-of-course evaluations and beliefs or experiences of instructors.

Kleinfeld (1991) conducted a study with 54 students taught by the case method or discussion of readings in an introductory foundations course, "Diagnosis and Evaluation of Learning". The findings indicated that case method increased students' abilities to deal with problematic situations, examine educational problems in complicated ways, and produce feasible alternatives for problems. This method was effective on undergraduate students as well as more mature ones. However, the effects of case method on students' ability to analyze the classroom situations were uncertain. In addition, students taught by case method showed highly positive attitude but significant difference in attitudes could not be found between students taught with case method and students taught by discussion methods even both groups of students were instructed in small classes by the same teacher.

Allen (1995) conducted a contrast-group design for teaching educational psychology using case method. Students in the case study group showed superior moral and ethical reasoning and developed content knowledge better than the students who were instructed based on the traditional lecture.

Ertmer, Newby and MacDougall (1996) focused on students with high and low levels of self-regulation responses and their approach to case-based instruction. Fifty-eight first year veterinary students were registered in a biochemistry laboratory course and nine of them classified as high and low levels of self-regulation were interviewed three times throughout the semester in order to investigate the change in their responses and approaches to case-based instruction. Both quantitative and qualitative data were collected. Results pointed out that perceived value, goal orientation and evaluative lens, and reflective analysis strategies may have an impact on students' responses and approach in a case-based course. Interview findings indicated that some of the students found the cases enjoyable, others established a connection between the cases and their course work or career goals, as well as the positive effects on their confidence for learning and motivation were reported. In other words, students responded in a different way to the same instructional method depending on their self-regulation level. However, authors emphasized that additional research is needed to refine and verify this framework.

Brink, Goodney, Hudak, and Silverstein, (1995) found that case studies are effective instructional tools to teach specific fundamental concepts. A two-course general chemistry undergraduate curriculum was developed by the researchers about chemistry concepts such as structure and bonding, chemical reactions, chemical kinetics, chemical equilibrium. Case studies were applied in the second semester related to the chemical concepts that were also taught in the first semester. The results indicated that case study approach is favorable for teaching chemical principles. Students studying a spiral-case study approach commented positive things about the implementation of case studies and looked as if they liked it more compared to traditional introductory chemistry sequence.

Herreid (1994) used case studies in three different courses. It was found that case based instruction contributed to the development of analytical and decision-making skills, as well as the development of skills in oral communications, and teamwork and the internalization of learning. In addition, the rate of attendance increased from 50-65 % to 95 % in the course where cases were used. The researcher pointed out that case method focuses on teaching how the process of science works more than teaching the content of science. Moreover, author suggested that though this method is adapted for cooperative learning format in small groups, it could also be applied in large classes like in law and business schools or even in mega classes of students. In addition, in another study, Herreid (1997-8) proposed some features about what makes a good case. He pointed out that a good case should tell a story, focus on an interest-arousing issue, create empathy with the central characters, and include quotations. Moreover, a good case should be relevant to the reader, must have pedagogic utility, should be conflict provoking and decision forcing.

Moreover, Cheng (1995) developed a teaching program using case studies regarding the methods of removing industrial pollutants for environmental chemistry course. In this study, authors gave some recommendations about the implementation of case study. For example, students refused to accept new learning methods and had difficulty in constructing their own knowledge. Moreover, more preparation and effective communication with students were involved during the course. According to observations of author, students had positive attitudes toward the case studies and perceived the subjects more open and lively than the descriptions found in many textbooks after the implementation.

The study of Cornely (1998) was about the design of an undergraduate biochemistry course using case-based learning method. The class was divided into groups of three to five students and each group received different cases randomly. After the description of the cases, some questions related to subject matter were included. The groups of students met outside the class and tried to solve the presented case by using the course textbook, campus library, and even local health professionals. Then, they wrote three to five pages about their solution and shared their findings about the case with the whole class in 15 minutes presentation. As a result, the exercises of case study provided students a chance to work collaboratively with their friends. Moreover, case study allowed students to make connections between topics. In addition, authors mentioned that this study increased students' interest and active participation in learning of biochemistry. Lastly, authors suggested the use of this method in different areas like agriculture, nutrition, or environmental studies.

In another study, Smith and Murphy (1998) developed cases in order to be applied in mammalian anatomy and physiology, introductory biology and plant tissue culture courses. Their purpose was to increase students' learning and interest in biology in undergraduate biology education. After the instruction, students mentioned that they liked doing case studies since cases looked like puzzles that they are not easy but not impossible to solve. In the light of students' comments, authors stated that case based activities are challenging, interesting, and rewarding for students.

Similar to the study of Smith and Murphy (1998), Jones (1997) used a classroom jury trial to enhance students' perception of science as part of their lives. Case based instruction was carried out to increase the awareness of science's relevance in a general chemistry course at Illinois State University. A large section including about 200 students met four times a week and small group discussions were conducted one hour per week. The class project related to one case lasted four weeks. In the first week, roles were given to the students randomly as judges, dependent, jury, witnesses, lawyers and reporters. Students who were in the role of witnesses, defendant or lawyer made research about the issue from different resources. In the last week, jury, judge and reporters met and discussed their reactions to the data presented and wrote their group reports representing the whole class. Students found this case study as an enjoyable educational activity since it made science more associated with their lives. The author suggested using the variations of jury trial format for both chemistry and non-science major students.

Similar to previous studies, Wilcox (1999) found the case method as a useful instructional tool. This study was conducted with 285 students in anatomy and physiology class. The purpose was to provide students the opportunity to apply their learning to the real life situations and improve their critical thinking, problem solving, and decision-making skills. The researcher carried out the evaluation related to use of the cases. The first question was about the usefulness of the case studies. While 65.2 % of the students found the case studies "useful", 25.3 % of the students found them "somewhat useful" and 9.5 % students found as "not useful". The second question was about the future use of the case studies and asked to 237 students. Majority of the students (67.1 %) thought that case studies must be kept as it was, and 15.2 % wanted to increase their use, however 17.75 % of the students considered that case-studies must not be used.

Snyder and McWilliam (1999) evaluated the effectiveness of case-based approach on 67 graduate students registered in four sections of an interdisciplinary course about families by using pre- and post-test, course and instructor evaluation forms. The results indicated that case method increased students' basic knowledge on families and application skills about the family-centered service delivery. Students' problem solving abilities improved significantly in the novel cases.

Pearce (2002) investigated the impact of case-based structured conflict teaching method on undergraduate students. Research findings showed that this method improved students' willingness to participate and engage in active learning environment. Moreover, students' analytical skills enhanced when they were consistently encouraged to think rationally and argue that view to their peers. In addition, this teaching method enabled students to formulate reasonable assumptions. Moreover, case-based structured conflict teaching method helped students to improve their self-confidence.

Faux (1999) examined the effectiveness of case-based study in terms of knowledge acquisition, application and problem solving aspects in Introduction to Education Psychology course. Thirty-eight undergraduate students read and analyzed four case studies over a 15-week semester. The data from this study showed that case study is an effective instructional tool providing students to apply theoretical knowledge. The MSLQ test results indicated that while some of the students' self-regulation changed, some of them did not change after the case-based instruction.

Mayo (2002) formulated and used an imaginary case narrative of a 15-year-old male with longstanding emotional and behavioral problems in teaching major theories in general psychology. One hundred thirty six college freshman and sophomores with an average age of 26 years participated in this study. The results of the study demonstrated that case-based instruction increased the conceptual understanding and provided important theoretical perspectives for general psychology. The students' role was the problem solver as opposed to being a passive recipient in traditional instruction hereby; case studies provided students the opportunity to construct their own knowledge by integrating the hands-on principles with the theoretical principles. Classroom discussion was another advantage of using case-based instruction confirmed by this study. In addition to these, the results pointed out that case-based pedagogy increased students' interest to the topic and motivated them. In contrast to earlier evaluation of a case-based instruction in introductory psychology, based on a single fictional case study, Mayo (2004) enhanced his study including a series of real case narratives for students to analyze and discuss. Participants were the 122-college freshman and sophomores ranging from 18 to 49 years. He confirmed the results of the previous study that case-based learning helps to integrate content, process and application by improving students' comprehension and application of important course principles in psychology of adjustment.

Cliff (2006) investigated the effectiveness of case study analysis on the remediation of the misconceptions about respiratory physiology. A case study was used to teach students oxygen transport in the blood. Their understanding of the relation between hemoglobin saturation and PO_2 was assessed by the conceptual diagnostic test. It was found that case-based instruction remedied 36 % of SA/PO_2 misconception. However, other three misconceptions remained unchanged even after instruction about respiratory physiology. The results suggested that a learning strategy in which students face with their faulty ideas about respiratory physiology is useful for overcoming the related misconceptions.

Rybarczyk, Baines, McVey and Thompson (2007) explored the learning outcomes of students from biology and non-biology majors instructed by the case-based approach on cellular respiration in undergraduate cellular biology or introductory cell biology courses. In the pretest-posttest control group design, similar but not identical pre- and post-tests were used focusing on the same content of important molecules, cellular organelles, and processes in cellular respiration. In addition, multiple choice, short answer, open-ended, and true/false questions were used in the related tests, which were assigned to both control and experimental group students. Results indicated that students instructed with case-based learning demonstrated significantly better learning gains and exhibited higher-order thinking skills such as critical thinking, problem-solving skills, and data analysis with respect to the students instructed traditionally. Though case-based learning can address students' misconceptions on the subject of cellular respiration, further data are needed about the effectiveness of case studies on students' misconceptions.

Jones and Russell (2008) demonstrated the use of case-writing and case method as an instructional tool to facilitate students' understanding and application of theory to clinical situations. They investigated the effectiveness of case method teaching to improve students' ability to integrate theory with practice. A case describing the client with multiple Axis I (DSM-IV-TR) diagnoses including that of substance abuse was presented. The method of case teaching and student-written cases were discussed in terms of their assistance to integrate theory with practice. Authors mentioned that the practice of case writing and learning from cases provided students to implement a theory to case situations as well as a creative and fun way of learning.

Knight, Fulop, Marquez-Magana and Tanner (2008) developed cases for teaching a senior cell and molecular biology laboratory course in undergraduate level in the university. Experiments, internet research, class discussion, written exercises, brief student presentations, and occasional short lectures were included in the case-based format. The presentation of cases typically included four phases. First, one of the volunteer students read the case to the class. The text of each case was short enough to be read in 2 min. Second, the groups were formed and each group brainstormed the case about 10 min. Third, study questions were presented to students and discussions were performed in each group of students. In the fourth phase of case presentation, students reported the results of their group work to the class and then chosen questions were investigated independently or in small groups. They started online research in class but it was completed at home due to the limited class time. Then, the results of the group work were reported to the class. In some instances, it was allowed to share the research findings on the class instructional website. The effectiveness of the cases was assessed by both written and verbal assessment methods in order to evaluate students' learning outcomes and their attitudes toward case-based learning methods over two semesters. The results indicated that students had positive approach toward case-based learning. It was proved that students learned the laboratory techniques, gained problem solving skills and they were developed both intellectually and socially.

Yadav et al. (2008) made an investigation to understand faculty members' perceptions of the instructional benefits and barriers of using case studies in science courses. They surveyed 101 science faculty members at universities and colleges in the United States and Canada. Participants were from the faculty who attended one of the training workshops and conferences conducted by the National Center for Case Study Teaching in Science in 2005. The results indicated that although before attending a seminar or conference related to case study teaching in science, less than half of the members used case studies, after the seminar, majority of them (84%) stated using case studies in teaching. On the other hand, using case based learning was not so common, most (88%) of these faculty members used between one and five cases per semester. The majority of these cases took one class period or less to complete. In addition, faculty members denoted that students in classes using case studies showed stronger critical-thinking skills (88.8%), were capable of making connections across multiple content areas (82.6%), and evolved a deeper comprehension of concepts (90.1%). Most of the faculty members also thought that when they used case study teaching, students were able to perceive a subject better from different point of views (91.3%). Additionally, some negative responses about case-based learning were disproved by this research. The majority of the faculty disagreed with the statement that students using cases retained less from class (87.5%) and that students did worse on tests (65.1%). Moreover, respondents specified that students instructed with case-based learning had a better grasp of the practical applications of fundamental course concepts. Faculty also thought that using case studies in classrooms increased student participation. The great majority of the faculty members (95.1%) reported that students were actively involved in the process of learning in classes when the case studies were used and that students did not face any difficulties while working in small groups (65.1%). The majority (93.8%) of the faculty members also reported that students instructed with case study were more engaged in learning when using cases. Consequently, it can be concluded that faculty members think cases have a positive effect on students' learning, critical thinking, and participation.

2.4.3 Research about the Case-Based Instruction on High School and Elementary School Science Education

The use of case-based instruction has no long history in the area of high school and elementary school education. Therefore, studies in this field are limited and dated in recent years.

Barden, Frase and Kovac (1997) used a case study approach for teaching scientific ethics in high school classrooms. They developed a series of cases that included laboratory safety, working with others, respecting the research environment, obtaining data, reporting results and using computers and computer software. Single page cases followed by a series of questions assisted teacher during the discussion as well as while implementing the case. Lively and thoughtful small group discussions were conducted during the case studies and at the end, each group wrote their assessments. The discussions and writings indicated that before treatment while many of the students thought the unethical behaviors like producing data for lab reports, copying data from a lab partner, during discussions they realized the ethical problems related to this behavior. As a result, case technique is an effective method in teaching scientific ethics in high school science classes. Authors mentioned that students gained an appreciation of the scientific process and practice in ethical decision-making that was also useful in everyday life. Guilfoile (1999) conducted two case studies illustrating the application of scientific methods in order to teach how scientists make discoveries. Eventually, author stated that case studies provide students profound understanding about how scientific research is done.

Richmond and Neureither (1998) carried out a research study investigating the effect of case study in biology course at high school. They found that case study provided students the opportunity to describe the problems, design their own experiments, make an effective group work in order to reach acceptable conclusions within the group and the whole class and learn to share their data to draw effective and powerful conclusions. In addition, significant number of students reported that in the first time in their life they had established connections to their science and nonscience classes. Moreover, a problem can be treated in an interdisciplinary way by the help of the case study. For instance, the combination of concepts of chemistry, biology, mathematics or even history and politics are important in order to understand cholera.

Gabel (1999) used case studies to teach science to elementary school students. Forty-five schools in two states participated to this science inquiry. Field observation notes, videotaping, students' written materials, computer network communications and teacher interviews served as data for this study. The findings indicated that case studies could be used to teach students to think more critically. In addition, this approach stimulated students' interest in learning science

Dori and Herscovitz (1999) conducted research on 10th grade students' scientific question-posing capabilities. Students studied the Quality of Air around us unit integrated with case studies and analysis of daily life problems cooperatively. Pre- and post case study questionnaires were used in order to assess students' question-posing capabilities and three indices of question-posing capability were found as number, orientation and complexity. Based on the results, authors suggested incorporating analysis of question-posing capability as an alternative evaluation method. They stated that promoting question-posing capability into case-based teaching approach is favored especially when environmental aspects are considered.

Çakır (2002) investigated the effectiveness of case-based instruction on students' performance skills, academic knowledge, higher order thinking skills and their attitudes toward biology in a high school biology course in Turkey. The subjects of the study was 74, 10^{th} grade students from two classes of the biology course. While one of the randomly assigned classes was instructed by case-based learning, the other group was instructed traditionally. The analysis of the results indicated that case-based learning improved students' performance skills and their academic knowledge significantly. On the other hand, it had no significant effect on students' higher-order thinking skills and attitude toward biology.

Jones (2003) mentioned the historical roots of the case method teaching, development of cases and the instructor's role. It was stated that case-method of teaching provides students chance to integrate knowledge with practice and transfer learning. It also improves students' critical thinking, problem-solving abilities, oral and written communication skills, and professional decision-making skills offering them practice with real life problems.

Saral (2008) investigated the effect of case based learning on students' achievement in the context of human reproductive system and their perceived motivation (intrinsic goal orientation, extrinsic goal orientation, task value). Eighty tenth grade students (48 males and 32 females) from four biology classes of the two teachers participated in this study. While the students in experimental groups learned the human reproductive system by means of the cases, in the control group, teaching was founded on teacher's explanations and web based notes provided by the department of biology of the high school. Two cases divided into several parts were presented students in an interrupted way. Students discussed the answers of the questions posed in the cases. They studied independently in a group work while dealing with cases. She found no significant difference in both students' perceived intrinsic goal orientation and extrinsic goal orientation after the treatment. However, it was noted that both intrinsic goal orientation scores and extrinsic goal orientation scores of students who were exposed to case-based learning were higher than those of students who were exposed to traditional biology instruction. Results showed that case-based learning developed students' academic achievement and task value.

Çam's (2009) study compared the effectiveness of case-based learning with traditionally designed instruction on eleventh grade students' understanding of solubility equilibrium concepts. She also investigated students' attitudes toward chemistry and their epistemological beliefs. Sixty-two eleventh grade students from two classes were involved in this study. These classes of students instructed by same chemistry teacher were randomly assigned as experimental and control group. While students in experimental group received case-based teaching methods, the control group students received the instruction based on traditional methods. The results indicated that students taught by case-based learning showed considerably greater success in understanding of solubility equilibrium compared to traditional instruction. Furthermore, significant difference was found between experimental and the control group students in terms of their epistemological beliefs and attitudes toward chemistry as a school subject in the favor of experimental group students. In addition, results revealed that case-based learning was an effective method for remediation of students' misconceptions related to solubility equilibrium and enhancing students' understanding in comparison to traditional method.

2.5 Case Based Learning and Conceptual Change

The case study can be an effective teaching method to deal with the problems in science education. Three principals have been detected by the National Research Council relating to students' ways of learning science in the classes. Firstly, students' previous knowledge and potential misconceptions about the subjects are considered and regarding this, teachers make plan about how they can carry out conceptual change through cases. Secondly, conceptual framework of knowledge is provided, that means, how cases can be used to establish connections with concepts is argued. Thirdly, teachers must guide their students in order to use metacognitive strategies during the use of cases. Thus, students can learn to control their own learning; define their learning goals and assess their progress while using cases (Gallucci, 2006).

Gallucci (2007) examined the effect of case method of instruction on conceptual change conditions in terms of students' understanding of genes, biodiversity, and evaluation topics (non-major biology topics). She also investigated the effectiveness of case-based learning on students' attitude concerning the discipline of science, and learning about science. Students' perceptions of their learning gains based on case method of instruction were explored by this study as well. Stories, narratives, scenarios, or articles were used as a case for homework, in class and on exams. The case-method of instruction was described on the syllabus and delivered to students on the first day of class:

> This course will focus on the case study method of instruction. This inductive teaching technique uses stories, narratives, scenarios, or articles to introduce biology content. The cases encourage students to raise questions that lead to acquiring knowledge of concepts, and an understanding of the relevance of the cases to everyday life. Also, the

> case study method helps students learn about the process of science and learn to work collaboratively. Cases will be used for homework, in class, and on exams (p.42).

Results indicated that students found the case-based method of instruction interesting, motivating and relevant, so their understanding of the subjects was developed and possibly, they retained the knowledge longer. Students' misconceptions related to these topics were remedied. However, no significant effect was found about the effectiveness of case-based learning on students' attitude toward science though students' attitude about learning science was promoted. Consequently, it can be said that case based learning is a teaching strategy in promoting students' engagement in learning science and making improvement toward conceptual change.

Case-based learning is not one simple method but it includes many constructivist techniques in it, such as inquiry, active learning, student-centeredness, and small group discussion. This method can also be designed to enhance conceptual change in students' understanding of science concepts. Case studies allow students to put the inquiry method into practice, develop critical thinking skills, and assist students to be able to relate course materials to their own experiences. Students generally work collaboratively during a case study, this provides students self-directed, and student-centered learning environment, thus the opportunity is offered to students to "construct" their own knowledge (Gallucci, 2007).

In the present study, it is aimed to provide four conditions of conceptual change that Posner et al. (1982) identified; *dissatisfaction*, *intelligibility*, *plausibility*, and *fruitfulness*. The phase of dissatisfaction is intended to be created with the help of misconceptions related to the subject. Case study enables students to reveal their own misconceptions (Herreid, 1994). By this way, a disequilibrium or dilemma can be generated in students' mind. Moreover, cases in the form of stories or narratives engage and motivate students to control their own learning. Good cases, which are about the reader, increase interest to the subject matter. The group and whole class discussion allow students to reach intelligible and plausible answer(s). Therefore, students construct their own knowledge. The role of the teacher is to control the whole class discussion and guide especially in the case of extraneous or irrelevant responses of students. She or he can ask challenging questions for further thinking about the topic in order not to deviate the discussion from objective and the stage of fruitfulness is met also (Herreid, 1997).

As mentioned before, prior knowledge and misconceptions have great importance on students' learning. Literature findings also revealed students' learning difficulties and misconceptions about the concepts of gases. The gases topic is the one unit in chemistry as a school subject but this unit has also many connections with other subjects in chemistry like subject of matter, mole concept, and chemical reactions. Therefore, learning of gas concept is also important for understanding of other concepts. In addition, affective or motivational factors are also as important as the cognitive factors for students to learn a subject. Hence, unlike traditional methods appropriate teaching strategies should be developed to overcome or remedy misconceptions, promote students understanding of concepts, motivation and attitude toward science.

Based on the studies presented in this section, case-based learning can be a reasonable method or strategy to teach a subject matter, improve students' understanding, motivation and attitude toward science. In literature there are some studies recommended about the use of conceptual change to improve students' understanding of phenomena about gases (Mas et al., 1987; She, 2002; Rollnick & Rutherford, 1993). Moreover, some studies emphasized the effect of case-method of instruction on conceptual change (Abell, Bryan, & Anderson, 1998, Gallucci, 2006, 2007). However, further studies are needed in order to determine the effectiveness of case-based learning on conceptual change conditions to develop students' conceptual understanding, motivation, attitude and remedy their misconceptions. Therefore, this study aimed to investigate the effectiveness of case-based learning on conceptual change conditions to improve students' understanding of gas concepts, their motivation and attitude toward chemistry.

2.6 Affective Domain

Attitude and motivation are the important constructs of the affective domain that have an effect on students' science learning and achievement. They are often regarded as the predictors of students' decisions about science for instance attending class, reading textbook assignments, and completing homework. Pintrich, Marx, and Boyle (1993) expressed the attitudinal and motivational constructs as moderators of a conceptual change. Another view is that "affective dimension is not just a simple catalyst, but a necessary condition for the learning to occur" (Perrier & Nsengiyumva, 2003, p.1124). Though affective dimensions have been regarded as important, researchers did not give too much attention to these constructs than they did to the cognitive dimensions though they are aware of the importance of these issues in science education (Koballa & Glynn, 2007).

Though changes in students' attitudes and motivations about science appear to be hard, the change can be possible. Students' attitudes toward science and their motivation to learn science can be improved with effective science instruction. Hands-on science activities, laboratory work, field study, and inquiry-oriented lessons can be used to attain these goals (Koballa & Glynn, 2007).

Another reason to investigative attitudinal and motivational constructs is to recognize how they influence students' learning cognitively. Research studies in science education indicated that not only cognitive factors but also attitudinal and motivational constructs have an influence on students' science learning (Koballa & Glynn, 2007).

2.6.1 Attitude toward Science

Attitude is defined as "a general and enduring positive and negative feeling about some person, object, or issue" (Petty & Cacioppo, 1981, p.7). The statements of "*I love science, I hate my science teacher*, and *Science experiments are wonderful"* reflect attitudes implying the negative and positive feelings. Moreover, it has been described in various ways in literature and some terms have been used alternatively such as *interest*, *value*, *motivation* and *opinion* (Koballa & Glynn, 2007).

One of the goals of the researchers is to improve students' attitudes toward science as well as increase their understanding of school subjects. Webster and Fisher (2000) conducted a study on students from 161 Australian schools and found that students' attitudes toward science have a strong and significant effect on their science achievement. In literature, there are many studies interested in improving students' attitudes in science education. For instance, laboratory instruction affects students' attitude toward science and their achievement in science knowledge positively (Freedman, 1997). The research of McManus, Dunn and Denig (2003) revealed that students taught with student-constructed instructional resources showed statistically better science attitude than the students instructed with teacher-constructed instructional resources and students instructed traditionally. In addition, it was stated that teaching ethical issues in science had a positive effect on students' attitude toward science, their interest level as well as perception of practicality of science knowledge (Choi & Cho, 2002).

Some teaching methods play a crucial role in developing students' attitudes toward science. It was stated that students who were taught with computer-assisted instruction had significantly improved attitude toward biology than those of taught with lecture and discussion methods (Soyibo & Hudson, 2000). Cavallo and Laubach (2001) indicated that using learning cycle in classrooms led more positive attitudes and persistence in science among students. Moreover, the combination of lecture, teacher demonstrations, discussion and practical work in small groups improved students' attitudes to chemistry and understanding of electrolysis (Thompson & Soyibo, 2002). Gibson and Chase (2002) proposed that inquiry based science camp provided students higher interest in science careers and positive attitude towards science. Sometimes gender has an effect on students' attitudes and experiences related to science. The study of Jones, Howe and Rua (2000) indicated that there are significant gender differences among sixth grade students in terms of their experiences, attitudes and perceptions of science courses and careers.

Salta and Tzougraki (2004) developed a valid and reliable instrument in order to measure students' attitude toward chemistry. The purpose of this study was to investigate 11^{th} grade Greek students' attitude toward chemistry. They especially examined the students' attitudes concerning the difficulty, interest and usefulness of chemistry course and importance of chemistry. In addition, effect of gender and study specialization differences on students' attitude was explored. Analysis of the related data indicated that students have a neutral attitude toward chemistry that is; they think that chemistry course is neither difficult nor easy. Similarly, they have a neutral attitude concerning the interest of chemistry course. However, though they are aware of the importance of chemistry in their life, they do not find the chemistry course as useful for their future career. In addition to these, results showed that boys have significantly more attitude than the girls concerning the difficulty of chemistry courses. The correlation between students' achievement in chemistry and their attitudes toward chemistry was found to be positive and low. On the other hand, the stronger relationship was detected between students' achievement and their perceived difficulty of chemistry course.

A few empirical studies have been done about the effect of case-based learning on students' science attitude. Kinzie et al. (1998) found that students instructed with web-based cases were enthusiastic due to the use of these cases. Cheng (1995) stated the enthusiasm of students owing to the active participation in the learning process. The study of Jones (1997) indicated that students found the case study enjoyable as an educational activity since it made science more associated with their lives. Brink et al. (1995) stated that students instructed with case study commented positive things about the implementation and liked the lesson more compared to traditionally designed instruction. In addition to these, Flynn and Klein (2001) compared attitudes of college students who completed two case studies individually or in small discussion and results showed that significant difference was found between the treatments in favor of small discussion groups. On the other hand, Kleinfeld's (1991) study indicated that though large proportion of students found case-method "interesting and stimulating" and showed exceedingly positive attitudes toward case method, no significant differences were found between students' attitudes instructed with case methods and discussion methods. Similarly, Çakır

(2002) examined the effectiveness of case-based instruction on students' performance skills, academic knowledge, higher order thinking skills and attitudes toward biology in high school biology course in Turkey. However, no significant effect was detected on students' higher-order thinking skills and attitude toward biology. Likewise, Galluci's (2007) study revealed that case-based learning had no significant difference on students' attitude toward science but students' attitude about learning science was promoted. On the other hand, Çam (2009) found a significant difference between the students who received case-based learning and the students instructed traditionally. Her study indicated that case-based learning instruction was effective in increasing students' attitude toward chemistry as a school subject. In addition some studies implied the benefits of case-based learning on students' attitudes toward the subject (Cliff & Wright, 1996; Flynn & Klein, 2001)

To sum up, computer assisted instruction (Soyibo & Hudson, 2000), learning cycle classes (Cavallo & Laucbach, 2001), activity-based practical work (Thompson & Soyibo, 2002), formally teaching ethical issues (Choi & Cho, 2002), inquiry-based summer camps (Gibson & Chase, 2002) and students- and teacher-constructed self-teaching resources (McManus et al., 2003) are the research studies related to the attitude change interventions in recent years. In addition to these, some studies engaging learners in hands on activities indicated increase in students' attitude toward science (Haussler & Hoffman, 2002; Perrier & Nsengiyumva, 2003; Siegel & Raney, 2003). However, additional research is needed in order to define the effectiveness of case-based learning on students' attitudes.

2.6.2 Motivation

The term of motivation has been defined in different ways in the literature. It is defined as the "process whereby goal-directed activity is instigated and sustained". (Pintrich & Schunk, 2002, p.5). Alternative definition is that it is the process rather than a product so it cannot be observed directly but it can be deduced from such behaviors as "choice of tasks, effort, persistence, and verbalizations (e.g., "I really want to work on this")" (Pintrich & Schunk, 2002, p.5.).

Motivational Theories

Historically, there are four general approaches to motivation; *behavioral*, *humanistic*, *cognitive* and *social* (Koballa & Glynn, 2007). Though these approaches are depicted separately, many science education researchers adopted the features of more than one approaches such as *social-cognitive* theory (Pintrich, 2003). Deci and Ryan (1985) stated the motivational theories as the energization and direction of human behavior.

Behavioral Approaches to Motivation

Behaviorists think, "An understanding of student motivation begins with a careful analysis of the incentives and rewards present in the classroom" (Woolfolk, 2004, p.352). A *reward*, an attractive objective or event, are given to students as a result of a specific behavior. For instance, a student can be rewarded with bonus points due to drawing an excellent diagram. An *incentive*, an object or event, is used to encourage or discourage the behavior also. Promising of an A^+ is an incentive for a student but giving that grade is a reward also. According to behavioral view, if the particular behavior is reinforced constantly, some habits or propensities might be developed to act in a particular manner. For example, if a student is continually rewarded with fondness, money, or some privileges in basketball but receiving little appreciation for studying science, s/he would most likely work harder for being better in basketball than studying science. As a result, students are motivated by extrinsic ways of rewards or incentives such as grades, stars, stickers, and other reinforcements.

Humanistic Approaches to Motivation

According to humanistic view, motivation means encouraging people's inner resources such as their sense of competence, self-esteem, autonomy, and self-actualization. Maslow's theory is very significant in understanding humanistic approaches to motivation (Woolfolk, 2004).

Maslow's Hierarchy

Abraham Maslow (1970) proposed hierarchy of needs ranging from lower to upper level that people have. While lower-level needs are about survival and safety, higher-level needs are concerned with intellectual achievement and lastly self-actualization. Self-actualization is the term about the self-fulfillment, the consciousness of one's capacity. In order to reach the higher-level needs, each of the lower needs must be fulfilled. The lower-level needs or called deficiency needs are about survival, safety, belonging and self esteem from below to above respectively. After meeting these needs, motivation to satisfy them decreases. Intellectual achievement, aesthetic appreciation, and self-actualization are the top three higher-level needs called as being needs also. Contrary to deficiency needs, being needs can never be entirely satisfied. When these needs are satisfied, the motivation of a person does not stop; it increases to explore more fulfillments. For instance, when a teacher strives harder for improvement it makes the teacher more successful in his development.

Maslow's theory considers students' physical, emotional and intellectual interconnected needs. If students or teachers have a safety problem in the school, they will have little interest for learning and teaching. A child having safety and belongingness problems due to divorce of parents, she/he may show little interest in learning the concept of division (Woolfolk, 2004). Consequently, in order to motivate someone, the priority needs should be taken into consideration.

Cognitive Approaches to Motivation

Attribution Theory

On the contrary to behavioral idea, cognitive theorists consider that motivation depends on people's thinking, not simply rewarding or punishing the behavior (Stipek, 2002). According to cognitive approach, people do not respond to external incidents or physical circumstances like hunger, but rather interpretations of these events. Cognitive theorists see people as active and curious seeking the information in order to solve personal problems, so intrinsic motivation is stressed by them. Bernard Weiner's attribution theory is a good example to the cognitive approaches to motivation.

Cognitive approach of motivation assumes that we attempt to explain the meaning of our own behavior and behavior of others by seeking the clarification and reasons. Moreover, we also make attributions in order to understand our own success and failures as well as others. Attribution theories of motivation explain how a person's justifications, explanations, and apology related to self or others affect motivation. Bernard Weiner, one of the main educational psychologists, adapted attribution theory to school learning (Weiner, 2000). Weiner categorized the recognized causes for successes and failures under three dimensions:

1. Locus (location of the cause internal or external to the person),
2. Stability (whether the cause stays the same or can change), and
3. Controllability (Whether the person can control the cause).

According to attribution theory, these three dimensions are used in order to classify every cause of success or failure. For instance, aptitude is internal (locus), stable (stability), uncontrollable (controllability). Weiner believes these three dimensions have significant inferences for motivation since they have an effect on expectancy and value. For instance, *stability* dimension is related to the expectations for future. If students believe that their failure is caused by stable reasons like difficulty of the subject matter, their expectancy will be failure in that issue in the future. When success or failure is attributed to the internal factors; while success increases the motivation, failure lowers self-esteem. Weiner (2000) also stated sensation of self-esteem and *internal/external locus* appears to be related to each other. The last dimension, *controllability* is about the emotions such as anger, shame. Sometimes, people may feel guilty about their failure or proud due to the success. Individuals cannot control their feelings of shame or anger in the consequence of failing of a task.

If successful students fail, they attribute their failure to misunderstanding of directions, lacking of necessary knowledge, or not studying hard enough; internal, controllable attributions. Therefore, they develop strategies to be successful next time (Ames, 1992). On the other hand, major motivational problems emerge if students attribute their failures to stable, uncontrollable reasons. In this case, these students might look depressed, helpless or generally called unmotivated (Weiner, 2000). Consequently, these students focus on their insufficiency that may cause to decrease their attitude toward learning even further (Ames, 1992).

Sociocultural Conceptions of Motivation

Sociocultural view of motivation focuses on participation, identities, and interpersonal relations in community. This view stresses the importance of community involvement activities. When people take part in these kinds of activities, they sustain their identities and their interpersonal relations in that community. Therefore, if the classroom or school gives importance to learning, students are motivated to learn. The notion of identity is a core issue in sociocultural theory of motivation because every person whatever her/his job is has an identity within the community. Part of people socialization is shifting from legitimate peripheral participation to central participation in that community. Legitimate peripheral participation means that novices are really involved in group work though their abilities are unimproved and their contribution are less. In the group, the identities of learner and the teacher are tied in their contribution in the community. They are motivated to learn the values and practices of the community to keep their identity as community members (Lave & Wenger, 1991). The challenge in this approach is to be certain that every student is completely contributing members of the community, since motivation originates from identity and identity originates from legitimate participation.

The Table 2.1 represents the summary of behavioral, humanistic, cognitive, and sociocultural approaches to motivation.

Table 2.1 Four Views of Motivation

	Behavioral	Humanistic	Cognitive	Sociocultural
Source of Motivation	Extrinsic	Intrinsic	Intrinsic	Intrinsic
Important Influences	Reinforcers, rewards, incentives, and punishers	Need for self-esteem, self-fulfillment and self-determination	Beliefs, attributions for success and failure, expectations	Engaged participation in learning communities; maintaining identity through participation in activities of group
Key Theorists	Skinner	Maslow, Deci	Weiner, Graham	Lave, Wenger.

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In addition to the four general orientations to motivation, also other theories; *goal setting theory*, *achievement goal theory*, and *expectancy-value theory* are separately described in below.

Goal Setting Theory

Goals are definite, quite difficult, and likely to be reached in the near future and tend to increase motivation and determination (Stipek, 2002). Goal setting is a significant motivational process (Bandura, 1997). Goal properties of *proximity*, *specificity*, and *difficulty* and learners' goal commitment affects the motivational benefits of goals (Pintrich & Schunk, 2002). Proximal goals encourage self-efficacy and motivation more than the distant goals. Likewise, specific goals increase efficacy and motivation better than general goals. From the motivational point of view, goals of moderate difficulty, which are challenging and attainable for learners, are most effective though teachers generally may set easy goals at the beginning and over time they progressively increase the level of difficulty of the goals as students' abilities develop. This theory suggested by Locke and Latham (1990) have two important features, goal choice and goal commitment. Goal choice is the real goal that people are struggling to acquire and the level that they want to reach. Goal commitment is the degree to which a person is determined in achieving a desired goal. Locke and Latham (1990) determined some factors that have an impact upon goal choice and commitment. There are two main categories of factors; one of them is the personal-individual factors and the other is the social-environmental factors. The first category consists of several personal-individual factors such as previous performance, actual ability/skill level, self-efficacy, valence/values. The most important factors that will have an impact on goal choice and the commitment are the previous performance and the actual ability/skill level. For example, a good student who has had previous success is likely to attain the goals than the student with many very poor grades. In addition, self-efficacy has a significant impact on personal goal setting because people with high self-efficacy put high goals. Furthermore, casual attributions have also important affect on goal setting because if the failure is attributed to unstable causes, it causes a person to set higher goals on following tasks. In addition to these, there are two other personal factors, which are valence/values, and mood. These may have effect on goal setting (Pintrich & Schunk, 2002). Locke and Latham (1990) stated the significance of the value beliefs and mood of a person in the role of goal setting. What is more, social-environmental factors including group factors, role modeling, and reward structure have an impact on goal choice and commitment. Positive role modeling and support of peers and group influence individuals to set higher goals. Another factor that may have an effect on the goals is the reward structure though its relationship is complex and depends on goal difficulty (Pintrich & Schunk, 2002). In addition to reward structure, Locke and Latham (1990) proposed that competition also has positive impact on goal setting but not the commitment of the goals. The role of authority figure and the type of feedback are the two final factors that can influence the level of goal and goal commitment.

Achievement Goal Theory

Achievement goal theory is a major social cognitive theory of motivation (Pintrich & Schunk, 2002). This theory proposed by Ames (1992) focused mainly on two goals: *performance goals* and *mastery goals*. Both goals improve one's own skill levels but in different ways. People with mastery goals define success and failure with respect to self-referential standards (Shah & Gardner, 2008). Students with mastery goals are likely to focus on task in order to learn or to improve themselves, not to compare their performance with others (Woolfolk, 2004). Midgley, Kaplan and Middleton (2001) called the mastery goals as *task goals* or *learning goals*, and the performance goals as *ability* or *ego goals*. Some researchers stated that mastery goals generate the greatest academic motivation (Ames, 1992; Dweck & Leggett, 1988). An individual with mastery goal orientation focus on learning in order to master the task for his or her self-improvement, develop new skills, improve or develop capability, try to achieve something challenging, and gain understanding. Therefore, a mastery goal orientation can be linked to an intrinsic interest and value for learning (Ames, 1992). Contrary to mastery orientation, people with performance goals define success and failure with respect to normative standards such as peers, friends (Shah & Gardner, 2008). They focus on their capabilities thinking that how their ability will be judged for the others, for instance, while doing the task, they try to be the best in the group or class to avoid judgements of low capable or giving the impression of stupid, and they always consider the public appreciation of high performance levels. The term of "relative ability orientation" is sometimes used for the measures of performance orientation or ego orientation. For example, a student who sets performance goals may concentrate on getting good grades on a test in order to win or beat other friends (Wolters, Yu, & Pintrich, 1996). Therefore, performance goal orientation is often associated with a concern with grades and other extrinsic rewards rather than an intrinsic value or interest in learning (Ames, 1992). Mastery versus performance goal orientations and intrinsic/extrinsic motivation are similar to each other. While mastery-oriented students are better in motivation by intrinsic factors, performance-oriented students tend to respond to extrinsic motivation. According to earlier research, performance goals were usually unfavorable in learning (Woolfolk, 2004). On the other hand, some recent studies indicated that mastery and performance goals are related to each other in terms of using active learning strategies and high self-efficacy (Midgley et al., 2001; Stipek, 2002) and they are beneficial for encouraging academic motivation (Barron & Harackiewicz, 2001; Linnenbrink, 2005). Therefore, a person can follow mastery and performance goals at the same time similar to intrinsic and extrinsic motivation. In the light of recent findings, students might be motivated using mastery or performance goals (Woolfolk, 2004).

Expectancy-Value Theory

The expectancy-value theories have long tradition in achievement motivation research and present expectancy-value models have also substantial support in the field of education. The *expectancy construct* is about the individual's beliefs and judgements on his or her capabilities to perform the task and to do well at it. In other words, if an individual belives his or her capabilities to do a task, s/he will choose to be engaged in the task. However, if an individual has doubts about his or her abilities to be successful, s/he will be less likely to be engaged in the task. The *value component* is about the different beliefs of students to involve in a task. Students might have various reasons to involve in a task, for instance; they may find the task interesting, they may like doing the task, they may value the task since they find it important and useful, they may be willing to get a reward (e.g. grade, points), they may want to make their teachers or parents happy, and they may want to avoid punishment or avoid having problems. In the expectancy-value models, both the expectancy and value components are important to foresee students' future behavior choice, engagement, persistence, and actual achievement. Students may be self-assured about their capabilities to succeed and anticipate to do well, but if they think the task is unvaluable or useless, they will be less inclined to prefer to get involved in the task. Likewise, students may find the task or activity interesting or important but if they think they can not perform the task, ultimately they will not engage in the task. According to this theory, *expectancy* and *task value* are the two significant predictors of achievement. In terms of achievement, students who anticipate succeeding on a task will be likely to do task another time in the future. If students are curious and they need to learn, some tasks may be more attractive or valuable for them, such as computer activities or other intrinsically interesting tasks (Pintrich & Schunk, 2002).

Lewin et al. (1944, as cited in Pintrich & Schunk, 2002) defined the *level of aspiration* as the goal or standard that individuals set for themselves in a task depending on past experience and familiarity with the task. It was found that there were individual and group differences in level of aspiration. High ability students are more likely to set higher goals than those low in ability. Moreover, group goals and performance affect and adjust students' level of aspiration to the group norms (Weiner, 1992). In addition, quadripolar model proposes four general types of students: *success oriented*, *failure avoiders*, *overstrivers*, and *failure accepters*. The *success-oriented* students would be highly engaged or involved in achievement activities and not be anxious or worried about their performance since they are high in motive for success and low in fear of failure. The failure avoider students who are high in fear of failure and low in motive for success would be very anxious and try to avoid failure by using self-handicapping strategies (Covington, 1992; Garcia & Pintrich, 1994). This kind of students would be very unwilling to involve in even academic achievement work. *Overstriver* students are high in motives and attempt to approach success but at the same time fear failure very much. Though these students work very hard at achievement tasks, they feel very anxious and stressed due to their fear of failure. These students look like defensive pessimists as in social cognitive theory (Garcia & Pintrich, 1994). Overstriver students almost always make best in class, but they consistently ask questions to the teacher about their grade and demonstrate signs of anxiety and anxious about doing well. Lastly, *failure acceptors* are the students who are fundamentally uninterested in achievement, although this may be because of lack of concern and caring or active anger and resistance to achievement values (Covington, 1992).

Developmental, gender and ethnic differences are effective in student's expectancy and value beliefs. In terms of developmental differences, research proposes that younger students are more probable to have comparatively high perceptions of their capability and in general, the level of these perceptions decreases with age. Values demonstrate a parallel decline with age. Particularly, the research implies that the decline reaches a maximum while students pass to junior high school. This decline can be explained in terms of both psychological and sociological ways. The psychological explanations stress the alteration in children's cognitive skills and beliefs as means o f this age difference, while the sociological explanations emphasize the change depending on school environment as the students go into secondary schools. The research indicates that gender and ethnic differences seem important in the role of expectancy and value constructs but additional research studies are needed (Pintrich & Schunk, 2002).

In addition to these, outcome expectation is related to expectancy for success construct from expectancy-value theories. As Bandura (1986) explained, "The belief that one can high jump six feet is an efficacy judgement; the anticipated social recognition, applause, trophies, and self-satisfactions for such a performance constitute the outcome expectations" (p. 391). In the academic field, students have efficacy judgements about their competences, skills and knowledge and they have also outcome expectations related to their grades. Though their efficacy beliefs and outcome expectations are generally associated, it is likely for a student to have relatively high self-efficacy but a low outcome expectation for a task. Individuals may vary in self efficacy and outcome expectations but it is desirable to be high in both. Individuals who have both high self efficacy and outcome expectations are confident and assured in their performance, show high levels of effort, persistance, and have high cognitive engagement in academic tasks. Students who have high in efficacy but negative outcome expectations are expected to study hard and be engaged in task but also may disapprove the grading system. They may leave the setting due to the incongruity between the learning and the outcomes such as grades not because of the low self-efficacy. Individuals low in self-efficacy and outcome expectations may demonstrate lack of concern and reluctance or incapability to exert much effort. Students with low self-efficacy but high outcome expectations believe that they cannot perform the task but know that they would be rewarded properly, if they were capable of doing it. Contrary to students low in self-efficacy and outcome expectations, they are likely to assess themselves negatively and find themselves quilty for failure (Pintrich & Schunk, 2002).

The motivational effect of self-efficacy can be remarkable. If students have high self-efficacy, they will engage in tasks that promote the improvement of their skills and competence. However, if the tasks exceed students' capabilities greatly, students can experience anxiety and failure, thereby they quit easily in case of difficulties and this diminishes their self-efficacy (Bandura, 1997).

Self-efficacy is strongly related to effort and task persistence (Schunk, 1995). Individuals high in self-efficacy beliefs are likely to exert effort when they encounter difficulty and carry on at a task when they have the required abilities. Salomon (1984) found that students high in efficacy were more likely to be cognitively engaged in learning when they find the task difficult but less likely to be effortful and less cognitively engaged when they perceive the task easy.

In addition to motivational theories, recent developments in the motivational literature suggested that motivational factors play an important role on students' learning and transfer of problem-solving strategies (Bereby-Meyer & Kaplan, 2005). The study of Urdan and Schoenfelder (2006) indicated that specifying strong mastery goals in classroom or schools improve students' motivation and behavior. It was stated that there was a positive and strong effect of motivation and attitude on academic time and achievement in mathematics and science (Singh, Granville, & Dika, 2002). There are some studies emphasizing the role of motivational beliefs on students' conceptual change process (Duit & Treagust, 1998; Lee, 1989; Lee & Brophy, 1996; Pintrich, Marx, & Boyle, 1993; Strike & Posner, 1983, 1992; West & Pines, 1983).

Educational researchers revealed a number of motivational factors that include: Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance and Test Anxiety. *Intrinsic goal orientation* is a goal orientation towards an academic task indicating that students' participation in the task is not for the being means to an end such as grade, reward instead for the reasons such as challenge, curiosity, mastery. *Extrinsic Goal Orientation* refers to the degree to which students perceive themselves to be taking part in a task for reasons such as grades, rewards, performance, evaluation by others, and competition. *Task Value* refers to the student's assessment of the task about its usefulness, significance and interestingness. High task value directs students to participate in the learning issues more. *Control of Learning Beliefs* refers to students' belief that their attempts to learn will get positive outcomes. These positive outcomes are dependent on one's own effort rather than external factors like teacher. If students feel that they can control their academic performance, they are more likely to make an effort to effect the desired changes. *Self-efficacy for learning and performance* includes two features of expectancy: expectancy for success and self-efficacy. Expectancy for success denotes performance expectations, and is specifically about the task performance. Self-efficacy is an assessment of one's capability to master a task. Moreover, it is one's confidence in having the skills essential to carry out that task. *Test anxiety* is a sign of worry and concern stated by students regarding exams. Students' expectations and their academic performance are found adversely associated with each other. Test anxiety has two major components; one of them is a worry or cognitive component and the other is the emotionality component. Worry component is about students' pessimistic ideas that disturb their performance. Emotionality component means the affective and physiological arousal features of anxiety (Pintrich et al., 1991).

2.7 Motivation and Case-Based Learning

Literature presents a few studies related to the relationship between case-based learning and motivation. Dori & Herscovitz (1999) stated that case study method is effective for improving students' conceptual understanding and critical thinking abilities and their motivation. Case-based learning enhances students' motivation by displaying the significance of issue about the real life situations. Moreover, this method is effective in developing academic information. However, there is still few experiential research related to the effect of case-method on learning (Çakır, 2002; Çam, 2009; Gallucci, 2007; Herreid, 2005; Lundeberg & Yadav, 2006a, 2006b; Morgil, Özyalçın, & Erökten, 2004; Yadav et al., 2008).

In general, case-based learning increases students' interest and enjoyment toward learning (Mayo, 2002, 2004; Naumes & Naumes, 2006; Wassermann, 1994). Intrinsic interest or enjoyment, task value or usefulness are the important reasons for students being a part of the task and thus their motivation might be enhanced. If students are interested and enjoy learning, it is more possible for students to be motivated to involve in learning a task. Moreover, if their motivation is high on that task, they attempt more and insist on working on a task even they face with difficulties or problems. As a result, achievement is increased and so it can be considered as an indirect index of motivation (Pintrich & Schunk, 2002).

Case-based instruction has been considered as an effective way of learning in psychology and other disciplines in terms of promoting critical thinking and connection between theoretical and applied knowledge. Students taught with case-based learning attended actively in classroom interaction, formulated solutions to real-world problems in cooperation and constructed self-knowledge integrating theoretical constructs with personal experiences. Case narratives based on the lives of real characters were used in order to make the connections to real-life (Mayo, 2004). The previous investigation of Mayo (2002) indicated that students identified case-based instruction as realistic, challenging, interesting, enjoyable, creatively stimulating, and helpful toward learning. In addition, many studies and reports have presented that students find case-based teaching method enjoyable and interesting (Brickman et al., 2008; Heid et al., 2008; Herreid, 2006; Hoskin, 1998; Jackson, 1998; Mayo, 2002; Parilla, 2007; Ribbens, 2006; Walters, 1999). In addition, materials used in case-based instruction provide students the opportunities to experience real life situations (Mayo, 2002; Naumes & Naumes, 2006; Rybarczyk et al., 2007; Wassermann, 1994). Teachers also state that students are more engaged in learning when using cases (Yadav et al., 2008). Students take part actively in realistic problem situation and reflect their experiences that they had through case-based learning. Hoskin (1998) supports case study as an effective means of learning by engaging learners, as a group, with real-world problems.

In brief, affective and motivational beliefs are as important as the cognitive concepts in science education. Literature findings indicated that students actively engage in case-based learning environment. They enjoy classes while learning and find the assigned tasks interesting, which are also related to components of motivation and indicator of the academic achievement. Therefore, it is important to uncover the effectiveness of this new teaching method on different subjects, grade levels and cognitive and motivational variables to do better implications in classes.

Consequently, the current study will provide empirical data whether case based learning increases perceived motivation and academic achievement of students.

Another factor that has an effect on students' achievement and motivation is the school and school facilities.

2.7.1 Effect of School on Students' Understanding and Motivation

In the study of the Coleman in 1966, one of the earliest research studies about the school effectiveness, it was concluded that schools had little impact on students' attainments. Many studies have tried to investigate the salient factors that have an impact on students' academic achievement. Unfortunately, little evidence have been found that school quality has direct affect on students' outcomes (Millimet & Collier, 2008).

The effect of school type on school performance have been investigated mainly through multilevel modeling. Gray, Jesson and Jones (1984) found no evidence of differences between the attainments of pupils attending more selective and fully comprehensive schools. Tymms (1992) on the other hand concludes that there are small but significant differences on the performance of pupils attending different types of school. It is often argued by Fitz-Gibbon (1985) and Tymms (1992), that a selective environment can foster better achievement because it potentially creates some beneficial competition and co-operation among pupils.

The study of Newhouse and Beegle (2006) focused on the effect of school type on junior secondary school students' academic achievement. The findings of the study indicated that Indonesian public junior secondary schools are more effective than private ones in terms of improving cognitive skills with respect to the national test scores administered at the end of the school year. Students in public high school have higher test scores than those in private high school by controlling other characteristics. Results indicated indirectly that higher quality inputs of public junior secondary schools promote higher test scores. In the view of the general findings, public junior secondary schools use higher-quality inputs.

Tuncer, Ertepinar, Tekkaya, and Sungur (2005) examined the effect of school type (private and public) and gender on 6th, 7th, 8th, and 10th grade students' attitudes toward environment. A total of 1497 Turkish students (*n* = 603 public and *n* = 892 private) participated to this study. Likert type questionnaire consisting of 45-item with four dimensions; awareness of environmental problems, national environmental problems, solutions to the problems and awareness of individual responsibility was used to evaluate students' environmental attitudes. Results demonstrated that students in private schools had higher mean scores than those in public schools in terms of each dimension and significant difference was found between public and private school students on each aspect of the questionnaire. This research also indicated that school may have a role in the construction of students' views on the environment. A variety of explanations can be provided for the difference between students in public and private schools. For instance, family background or prior achievement; teacher experience and competence; offered curriculum; instruction quality and the social climate (Gamoran & Nystrand, 1994) may all play a role.

Urdan and Schoenfelder (2006) reviewed research studies to consider how school and classroom processes might affect student motivation. They proposed that students' motivation would probably be enhanced when they are encouraged to control their own learning and if they have a learning environment that they are cared, supported, and have socially interdependent relationship between teachers and students.

In another study, Heyneman and Loxley (1983) concluded that the effect of school and school resources are important than families in developing countries. However, the study of Hanushek and Luque (2003) does not favor the view that school resource impacts show systematic differences depending on country income or development. In addition, their examination about the family backgrounds comparison of young and old students showed that the family effect is likely to decrease with age though the related analysis is indefinite.

School climate can also have an effect on students' outcomes, their motivation and behavior. It appears obvious that positive student-teacher communications can lead positive climate at school. Therefore, students' attainment and motivation are increased. Besides, school size is the one of the external factor that smaller school size has positive influence on school culture compared to large schools with larger size (Pintrich & Schunk, 2002).

Class size in a school might be another factor that may affect students' success in higher education. The research studies that examine the class size and achievement are generally complex and difficult to incorporate. Glass and Smith (1979) found a strong relationship between class size and students' achievement in their meta-analysis using quantitative techniques but this relationship is stronger in the secondary grade than the elementary grade.

Teachers mentioned that small class size facilitates personal interaction, relationship with students and students also agreed with this idea. Large classes seem to be problematic since they increase workload and decrease the quality of the relationship between the students and the teacher. On the other hand, in smaller classes students feel self-assured and tend to ask questions as being included in learning activities. Moreover, students find the small classes preferable because they think they have more individual attention and they are encouraged to promote relations with the teaching staff (Eames & Stewart, 2008).

Blatchford and Mortimore (1994) and Day, Tolley, Hadfield, Parkin, and Watling (1996) concluded that large class size could cause lack of attention to the classroom processes by pupils. The project of Finn and Achilles (1999) and review of research by Slavin (1990) specified that the class size below 20 is required in order to prevent students' performance from sizeable effects. Despite the benefits of smaller class size, Ofsted Report (1995) concluded that the matter is not the class size, but quality of teaching.

Blatchford (2005) conducted a seven-year longitudinal study in order to determine the effect of class size differences on primary school pupils' educational progress and classroom experience. It was found that in smaller classes students were likely to interact with their teacher and teachers were likely to give more attention to the students in a group or in the whole class. In addition, according to teacher time estimates there is more teaching in smaller classes than the larger classes. In other words, as the class is becoming larger, the non-teaching time increases. Some relationships were found between class size and teaching. In smaller classes, there is;

- More teacher task time with pupils,
- More teacher support for learning,
- Easier classroom management and control.

In addition, there are some educational implications about the group sizes (Fuchs, Fuchs, Kazdan, Karns, Calhoon, Hamlett, & Hewlett, 2000; Kutnick, 1994). They stated that the interactions between children and, teacher and children working in the group might be affected by the group size. Moreover, in contrast to larger classes, smaller ones provide more opportunity for small group work and individual attention. In general, size of the groups decreased with the size of the class. Similar to the findings of size of the groups, children in small classes were more likely to interact with the teacher and group members and the classmates. The qualitative analyses showed that teachers favor smaller groups of four to six due to the teaching input, child concentration and contribution. Moreover, it was stated that larger groups were a less effective educational setting in terms of giving attention to children, quality of teaching, quality of children's work, especially for the youngest children. This study suggested 25 children in a class as a significant threshold at Reception Level. Findings proposed that class size have an effect on the size and the number of groups that might influence the experiences of learning and social relationships in classes and the children's attainments.

Finn and Achilles (1999) generated an answer to the question of "Do small classes result in improved academic achievement in the elementary grades" and presented the findings of Tennessee's Project STAR regarding students' performance and behavior. During the project, some advantages of small classes like improved teaching conditions and students' performance was identified and after the 4-year experimental period, classroom disruptions, discipline problems, students' retentions were reduced and students' learning behaviors were developed. Results indicated that students in smaller classes showed better academic performance. Moreover, the small-class advantage was statistically significant in the year group of grade four or beyond and this result was also confirmed by the analysis through Grade 7. Small classes are academically favored since students' participation in learning process is encouraged in a small-class environment. Therefore, students' motivation and achievement increase. Maehr and Midgley (1996) proposed that students' involvement in learning would assist to enhance mastery orientation.

Bourke (1986) determined instructional factors related to class size that ranges from 12 to 33 students. Thirty-three public elementary schools and almost two Year 5 teachers per school in Melbourne, Australia participated in the study. Data were collected from the observation of mathematics lessons over a term. The negative, moderate and significant relationship was found between the class size and students' achievement. Smaller classes and higher student ability have effects individually on higher achievement. Moreover, students' ability and the school were both the features connected to achievement.

In literature, there are different opinions related to class size effect. Although there are some studies that clearly support the importance of class size on students achievement (Finn & Achilles, 1999; Glass, Cahen, Smith, & Filby, 1982; Goldstein & Blatchford, 1998; Grissmer, 1999; Molnar, Smith, Zahorik, Palmer, Halbach, & Ehrle, 1999; Prais, 1996; Tomlinson, 1990), some of them claim that reductions in class size has no effect on students' achievement (Hoxby, 1998, 2000; Johnson, Jensen, Feeny, & Methakullawat, 2004; Slavin, 1989) or little evidence to claim the effect of smaller classes on students learning (Hanushek, Rivkin, & Taylor, 1996; Hanushek, 1999). In addition, some of the studies found the class size effect contradictory, insufficient and uncertain (Burstall, 1992; Goldstein & Blatchford, 1998). Despite many studies were conducted investigating the relationship between class size and students' achievement, additional research is needed to clearly define the relationship between class size and students' achievement.

Consequently, school type is concerned as one of the factor affecting students' achievement and motivation in this study because sometimes non-identical (dissimilar) implementations and school facilities might be provided to students and this might lead differences in students' academic knowledge and motivation.

CHAPTER 3

PROBLEMS AND HYPOTHESIS

The main and sub-problems of the current study and the related hypothesis tested in chapter 5 are presented in this chapter.

3.1 The Main Problems and Sub-Problems

3.1.1 The Main Problem

The purposes of this study were to investigate the effects of case-based learning based on conceptual change conditions and school type on tenth grade students' understanding of gas concepts, their attitudes toward chemistry as a school subject and their perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety). Moreover, tenth grade students' conceptions about gas concepts and their ideas about case-based learning were explored.

3.1.2 The Sub-Problems

1. Is there a significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to tenth grade students' understanding of gas concepts?

2. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students’ understanding of gas concepts?

3. Is there a significant effect of interaction between treatment and school with respect to tenth grade students’ understanding of gases?

4. Is there a significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to tenth grade students’ attitude toward chemistry?

5. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students’ attitude toward chemistry?

6. Is there a significant effect of interaction between treatment and school with respect to tenth grade students’ attitude toward chemistry?

7. Is there a significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to tenth grade students’ perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

8. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students’ perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

9. Is there a significant effect of interaction between treatment and school with respect to tenth grade students’ perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

10. What are the tenth grade students' conceptions about gas concept?

11. What are the tenth grade students' ideas about case-based learning?

3.2 Hypothesis

H_o1: There is no statistically significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to tenth grade students' understanding of gas concepts.

H_o2: There is no statistically significant mean difference between public high school and Anatolian high school with respect to tenth grade students' understanding of gas concepts?

H_o3: There is no significant effect of interaction between treatment and school with respect to tenth grade students' understanding of gases?

H_o4: There is no statistically significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction in terms of tenth grade students' attitude toward chemistry.

H_o5: There is no statistically significant mean difference between the public high school and Anatolian high school with respect to tenth grade students' attitude toward chemistry.

H_o6: There is no significant effect of interaction treatment and school with respect to tenth grade students' attitude toward chemistry?

H_o7: There is no statistically significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction in terms of 10^{th} grade high school students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, and Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety).

H_o8: There is no statistically significant mean difference between the public high school and Anatolian high school with respect to tenth grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

H_o9: There is no significant effect of interaction between treatment and school with respect to tenth grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

CHAPTER 4

DESIGN OF THE STUDY

This chapter presents the design, sample of the study, definition of variables, instruments used, and description of the treatment, methods to analyze data, and assumptions and limitations.

4.1 Experimental Design

In this study, static group comparison design or sometimes called nonequivalent control group design as a type of Quasi-Experimental Design was used. In this design, although the groups being compared are randomly assigned as control and experimental, the subjects are not randomly assigned to these groups; instead already formed groups are used (Fraenkel & Wallen, 2006). Two schools participated in the current study; one of them was the public high school the other was the Anatolian high school. Since the classes were already formed at the beginning of the semester, students could not be assigned to experimental and control groups instead classes were randomly assigned as experimental and control. Table 4.1 presents the design of the study.

Table 4.1 Research Design of the Study

Groups	Pretest	Treatment	Posttest
Experimental Groups (EG)	GCT ASTC MSLQ	CBCC	GCT ASTC MSLQ
Control Groups (CG)	GCT ASTC MSLQ	TDCI	GCT ASTC MSLQ

In this table, EG represents experimental group instructed by case-based learning on conceptual change conditions while CG represents the control group taking traditionally designed chemistry instruction. GCT is the Gas Concept Test, ASTC is the Attitude Scale toward Chemistry as a School Subject, and MSLQ is the Motivated Strategies for Learning Questionnaire. In addition, Case-Based Learning on conceptual change conditions is represented by CBCC whilst Traditionally Designed Chemistry Instruction is represented by TDCI.

In this study, GCT was administered to both experimental and control groups before the instruction to determine whether there was a significant mean difference between two groups in terms of students' pre-existing knowledge about gas concepts. In addition, ASTC and MSLQ tests were applied to both groups to compare the groups in terms of students' attitude toward chemistry and their perceived motivation respectively. After instruction, GCT, ASTC and MSLQ were administered to both groups to determine the effect of case-based learning on students' understanding of gas concepts, attitude toward chemistry and perceived motivation, respectively.

4.2 Subjects of the Study

All the 10^{th} grade students in Ankara were determined as the target population. However, since it is hard to get in touch with the whole target population, all the 10^{th} grade students in Çankaya, which is the one of the districts in Ankara, were identified as an accessible population. After conversations with high school chemistry teachers in Çankaya, the schools in which the teachers accepted to use new teaching method in their current chemistry lessons were chosen as implementation schools in this study. Therefore, one public high school and one Anatolian high school were selected from the identified accessible population by the convenience sampling technique. Two classes from each school were assigned randomly as experimental and control group. Two instructional methods (CBCC and TDCI) were randomly assigned to experimental and control groups. 45 tenth grade students (22 boys and 23 girls) from Anatolian high school and 83 tenth grade students (44 boys and 39 girls) from public high school participated in this study. Thus, while there were 63 students instructed by CBCC in experimental groups, there were 65 students instructed by TDCI in control groups in total. In each school, students were instructed by the same chemistry teacher in Ankara in 2008-2009 semesters for 12 weeks. The ages of participants were between 15 and 16.

4.3 Variables of the Study

4.3.1 Independent Variables

The independent variables of this study were the school type and teaching methods which were the instruction based on case-based instruction on conceptual change conditions and traditionally designed chemistry instruction.

4.3.2 Dependent Variables

The dependent variables of this study were students' understanding of gas concepts measured by GCT, their attitudes toward chemistry as a school subject measured by ASTC and their motivation measured by MSLQ. MSLQ has two main parts; the motivation part includes intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance and test anxiety constructs while the learning strategies section includes rehearsal**,** elaboration, organization, critical thinking, metacognitive, self-regulation, time and study environment, effort regulation, peer learning, and help seeking constructs. Since there are great numbers of dependent variables in MSLQ, the names of motivation sections and learning strategies sections were frequently used for the sake of simplicity. However, in this study only the motivation section constructs were used to determine the effect of case-based instruction on students' motivation. In fact, there were overall eight dependent variables in the current study.

4.4 Instruments

Since the classes had already been formed at the beginning of the semester by school administration; the students both in control and experimental groups could not be assigned to classes randomly. For this reason, GCT, ASTC and MSLQ were administered to both groups to determine the pre-existing differences before instruction. In addition, GCT, ASTC, and MSLQ were also used as measuring instruments to collect data after the instruction. GCT was administered to both groups after instruction to determine the effect of case-based learning on overcoming misconceptions about gas concepts. MSLQ was given before and after instruction in order to determine the change of motivational constructs of students in both groups whereas ASTC was applied to both groups of students as pre and posttest to determine the effect of case-based learning on students' attitudes toward chemistry.

In addition to these instruments, semi-structured interviews were conducted after instruction with students from both experimental and control group in order to get deeper information about their conceptions about gas concepts as well as the given responses to GCT. Additionally, ideas of experimental group students, who were exposed to case-based instruction, were obtained by means of Feedback Form for Case-Based Learning after the treatment.

4.4.1 Gas Concept Test (GCT)

Gas Concept Test included 26 multiple choice questions with five alternatives. Many of the questions in GCT were taken and adapted from the earlier thesis related to the gas topic (Azizoğlu, 2004; İpek, 2007), most of them were based on common misconceptions about gas concepts and learning difficulties in literature (Benson et al., 1993; Brook et al., 1984, 2003; Cho et al., 2000; De Berg, 1995; Lee et al., 1993; Lin et al., 2000; Mas et al., 1987; Niaz, 2000; Novick & Nussbaum, 1978, 1981; Rollnick & Rutherford, 1993; Sanger et al., 2000; Séré, 1986; She, 2002; Stavy, 1988, 1990) and in GCT some questions were taken from the university entrance examination in Turkey. At the beginning of the development stage of the test, the instructional objectives of the gas concepts were stated based on the national curriculum (See Appendix A). This test covered some subtopics related to gas topic. These were (1) Properties of Gases, (2) Volume of Gases, (3) Kinetic Theory of Gases, (4) Diffusion of Gases, (5) Pressure of Gases, (6) Gas Laws (Charles law, Boyle Marriott, Dalton, Avogadro, Gay Lussac), (7) Ideal Gas Laws, and (8) Partial Pressure of Gases.

Each item of the Gas Concept Test (See Appendix B) was examined in detail by four chemistry educators and six chemistry teachers in terms of content validity and format. Based on these recommendations, the corrections on the test were done. Afterwards, GCT was piloted with 332 high school students from different schools who had learned the gas concept beforehand. There was not any major change about the items of the test after the pilot study. Related to reliability analysis, Cronbach-alpha value of the multiple choice test was found to be 0.70. The final form of the test was administered to both group of students (control & experimental) as a pretest and a posttest in order to evaluate their understanding of concepts related to gases. Table 4.2 presents the misconceptions probed by GCT.

Table 4.2 Classification of Students Misconceptions probed by GCT

Misconceptions	**Item**
1. Gas pressure acts downward only.	1
2. Gas pressure depends on the kinds of gas.	1
3.Gases occupy different volumes according to their molecular weights.	1
4. The total pressure of gases is different than the pressure at a point in a closed system.	2
5. When the altitude increases, air pressure also increases.	3
6. Gas particles expand when heated, shrink when cooled.	4, 6, 19
7. Heated or hot air weighs more than cold air or vice versa.	6, 19
8. When the gases compressed, the gas motion gradually decreases.	5
9. When the gases are compressed, gas particles become more likely to come together and collide with each other frequently, so the temperature and the average kinetic energy increases.	5
10. Gas particles rise and stay away from heat.	9, 10
11. Gas particles are unevenly scattered in any enclosed space.	7, 8, 9, 10
12. Gases exert force in only one direction.	11
13. Matter, especially air, exists between the particles/atoms of a gas.	12
14. Gases weight can be ignorable.	13
15. Conservation of matter applicable to solids and liquids but may be ignored for gaseous reactants or products.	13
16. Gases have no mass.	13
17. In a closed container, the volume of a gas decreases when the temperature decreases. (Misuse of Charles's law.)	14
18. The existence of the gas can be ignorable in a closed container when there is some amount of liquid in it. (Misuse of Boyle's law.)	15
19. When the air is compressed, the particles stick to each other.	16
20. The air particles are all pushed to the end of the syringe.	16
21. When the air compressed, air particles heaped up or shriveled.	16
22. When the air compressed, air particles gather to the end of the syringe.	16
23. Molecules increase in size with change of state from solid to liquid to gas.	1,17
24. Air neither has mass nor can it occupy space.	19
25. Deflated bike tire or balloon has less pressure inside than outside.	20
26. The pressure of air inside the balloon is different from the pressure outside.	20
27. Gas behavior is similar to liquid behavior.	21
28. The energy gradually dies, so the gas motion stops and balloon deflates.	22
29. Collisions may result in a change of atomic size.	22
30. Misuse of ideal gas law.	23
31. Diffusion rate of gases increases with increasing molecular weight.	18, 24, 25
32. Conceptual calculations are not obvious for students.	26

4.4.2 Motivated Strategies for Learning Questionnaire (MSLQ)

MSLQ is a self-report questionnaire developed for a college course by Pintrich, Smith, Garcia, and McKeachie (1991) to evaluate the students' motivational orientations and their use of different learning strategies. It is a seven point Likert scale from "not at all true of me" to "very true of me" measuring students' motivational and learning strategies constructs. Basically there are two main sections in MSLQ, a motivation section and a learning strategies section. In the current study, only motivation section of MSLQ was used to determine the change of students' perceived motivation for both experimental and control group students before and after treatment. In the motivation part, students' goals and value beliefs for a course, their beliefs about their skill to succeed, and their anxiety about tests in a course were evaluated by 31 items in motivation section. MSLQ contains six sub-headings: (1) intrinsic goal orientation, (2) extrinsic goal orientation, (3) task value, (4) control of learning beliefs, (5) self-efficacy for learning and performance, (6) test anxiety.

The Learning Strategy section of the questionnaire consisted of 31 items concerning students' use of different cognitive and metacognitive strategies. The learning strategy section is composed of nine sub-headings: (1) rehearsal, (2) elaboration, (3) organization, (4) critical thinking, (5) metacognitive self-regulation, (6) time/study environmental management, (7) effort regulation, (8) peer learning, (9) help seeking. There are totally 81 items in this 1991 version of MSLQ and it is in English.

MSLQ was originally developed in English and the related confirmatory factor analysis was conducted on a sample of 380 Midwestern college students. Most of the students (N=356) were from public four-year university and the remaining ones (N=24) were from community college. Pintrich et al. (1991) conducted confirmatory factor analysis and calculated fit statistics for MSLQ in terms of η^2/df, GFI, AGFI and RMR. Hayduk (1987) stated that if the η^2/df ratio is less than 5, it is considered to be indicative of good fit between the observed and reproduced correlation matrices. The confirmatory factor analysis for English version resulted a $\eta^2/df = 3.49$. When the points of estimate of GFI and AGFI are greater than 0.9 and

RMR is 0.05, it shows that the model fits the input data well. The values of GFI=0.77, AGFI=0.73 and RMR=0.07 indicated that they are not in acceptable limits. Alternatively, Pintrich et al. (1991) maintained these indices are tolerable since motivational attitudes may differ depending on course characteristics, teacher characteristics, and individual students characteristics.

Sungur (2004) adapted and translated MSLQ into Turkish for biology lesson. Sungur (2004) performed Confirmatory Factor Analysis using LISREL with the participants of 319 tenth and 169 eleventh grade students. The fit statistics for Turkish version was found as $\eta^2/df = 5.3$, GFI = 0.77, and RMR = 0.11. Turkish version fit indices are tolerable compared to the English version ($\eta^2/df = 2.26$; GFI = 0.78; and RMR = 0.08). On the other hand, it is important to mention that both English and Turkish version of MSLQ do not show good fit for motivation part.

Pintrich et al. (1991) stated that the parts of MSLQ can be used singly or together according to the needs. Thus, only motivation section was used to measure students' motivation. In the current study, Turkish version of MSLQ translated and adapted with minor changes by Sungur (2004) was used for chemistry lesson in the current study (See Appendix C).

The questionnaire was piloted with 324 tenth, eleventh and twelfth class science students (ages 15-17) at different schools in Ankara. The test was administered to whole class at one time by emphasizing the purpose and the importance of the study. Confirmatory factor analysis was performed and the related fit statistics were found as $\eta^2/df = 2.79$, GFI = 0.81, AGFI = 0.77, RMR =0.27. Though the η^2/df ratio and RMR values are within an acceptable range for good fit, GFI and AGFI values are below 0.9. Table 4.3 shows fit indices of English version (ENG) and the Turkish versions (TUR) of MSLQ for motivation section.

Table 4.3 Comparison of fit indices for of English version, Turkish version by Sungur (2004) and current study of MSLQ's motivation section for 31 items

	N (Sample Size)	η^2/df	GFI	RMR
ENG	356	3.49	0.77	0.07
TUR (Sungur's)	488	5.30	0.77	0.11
TUR (Current)	324	2.79	0.81	0.27

Lambda-ksi estimates are similar to the factor loadings in an exploratory factor analysis, and values of 0.8 or higher demonstrate the well- defined constructs (Pintrich et al., 1991). Lambda-ksi estimates for the latent factors for English version of the questionnaire used in the current study were indicated in Table 4.4.

Table 4.4 Lambda ksi Estimates for Motivation

	Indicator	English Version LX Estimate	Turkish LX Estimate
Intrinsic Goal Orientation	q1	0.64	0.25
	q16	0.69	0.42
	q22	0.66	0.64
	q24	0.55	0.55
Extrinsic Goal Orientation	q7	0.71	0.44
	q11	0.58	0.51
	q13	0.48	0.56
	q30	0.44	0.64
Task Value	q4	0.57	0.55
	q10	0.64	0.65
	q17	0.88	0.71
	q23	0.86	0.76
	q26	0.88	0.65
	q27	0.84	0.75
Control Beliefs about Learning	q2	0.57	0.50
	q9	0.38	0.58
	q18	0.84	0.60
	q25	0.47	0.61

Self-Efficacy for Learning	q5	0.83	0.66
	q6	0.70	0.67
	q12	0.63	0.59
	q15	0.71	0.72
	q20	0.86	0.72
	q21	0.89	0.75
	q29	0.77	0.70
	q31	0.87	0.71
Test Anxiety	q3	0.60	0.61
	q8	0.42	0.45
	q14	0.62	0.55
	q19	0.88	0.17
	q28	0.76	0.47

As seen from Table 4.4, almost all the Lambda-ksi values were reasonable to indicate well-defined constructs. Moreover, reliability coefficients (Cronbach alpha values) were calculated by using SPSS for the current study. Table 4.5 presents the Cronbach alpha values for English version, Turkish version, and the current version of the questionnaire.

Table 4.5 Reliability Coefficients

	N(Sample Size)	IGO	EGO	TV	CLB	SELP	TA
ENG	356	0.74	0.62	0.90	0.68	0.93	0.80
TUR (Sungur's)	488	0.73	0.54	0.87	0.62	0.89	0.62
TUR (Current)	324	0.69	0.75	0.64	0.69	0.70	0.77

Caruso (2000) emphasized the importance of sample characteristics on the scores of reliability. Since the reliability is highly dependent on the population in which the sample is selected, it is normal to obtain slight differences in the values of reliability coefficients.

4.4.3 Attitude Scale toward Chemistry (ASTC)

This scale including 15 items was developed by Geban, Ertepınar, Yılmaz, Altın and Şahbaz (1994) to determine students' attitude toward chemistry as a school subject. It is a 5-point likert type scale from "strongly agree, agree, undecided, disagree, and strongly disagree". The reliability of this instrument was found to be 0.83. This test was administered to students before and after the instruction (See Appendix D).

4.4.4 Interview Questions

Semi-structured interviews were conducted with a total of sixteen students from both experimental and control groups. Eight students from each group attended the interview. Interviewees were selected from each group of students based on their post-GCT scores. Thus, two high, four medium and two low achiever students from each group attended the interview.

Interviewees were selected with the technique that Thompson and Soyibo (2002) used in their study in order to categorize students' attitudes into categories using their posttest means and standard deviations. Likewise, in the present study, students whose scores were above one standard deviation from the mean were regarded as high achiever. Subjects whose scores were within one standard deviation below the mean and one standard deviation above the mean were considered as having moderate or neutral achiever. The students with scores below one standart deviation from the mean were classified as the low or poor achiever. Extra questions were not prepared, instead concept test items were used during the interviews. The purpose of the interviews was to probe the questions asked in the concept test and detect the reasons of choosing the other presented alternatives which were not correct. In addition, deep information about students' way of thinking, learning difficulties and misconceptions, which were resistant to change and still existed after the treatment related to gas concepts, was obtained as well. Also both control and experimental group students were compared after the treatment in terms of their conceptions about gas topic in the light of interviews. Each interview was conducted individually and lasted about 50 minutes. All interviews were audio-taped and transcribed later. Detailed examination of interviews was presented in Chapter 5.

4.4.5 Feedback Form for Case-Based Learning

Feedback Form for Case-Based Learning (See Appendix E) is a survey test, adapted by the researcher, from the study of Çakır (2002). This test included five open-ended questions in order to get thoughts and suggestions of students on case based learning. Statistical data analysis was not used during the evaluation of feedback forms. The answers given by students to feedback forms were discussed in detail in Chapter 5.

4.5 Treatment (CBCC vs TDCI)

This study was carried out 12 weeks during the 2008-2009 semesters in Turkey. Two schools in Ankara were included and two classes of 10th grades in each school were selected randomly. One hundred and twenty eight tenth grade students from public high school (N=83) and Anatolian high school (N=45) were the participants of the present study. In each school, one of the classes was randomly selected as experimental and the other class as the control group. The experimental group students were instructed by case-based learning based on conceptual change conditions (CBCC) whereas the control group students were instructed by traditionally designed science instruction. All groups of students in two schools followed the same National Curriculum learning the same concepts but in different method. Students in experimental and control groups were given GCT, ASCT and MSLQ as pretest and posttest to determine whether there would be a significant difference between two groups. The classroom period was 45 minutes for each school. Before treatment, teachers were trained about the new method and how to implement case-based learning based on conceptual change conditions to gas unit in chemistry. Moreover, the role of the teacher and the students were explained to the teachers.

Students in control group were instructed by traditional instruction in which teacher-centered learning strategy was adopted. In traditionally designed classes, teachers defined and explained the concepts and solved related or similar questions for students. The role of teacher was to transmit the information to student emphasizing the main ideas of the subject. They mainly used textbook definitions and students were expected to know and use these descriptions when they are needed. Students were only motivated by teacher-directed questions, and there were not any activities like laboratory or group work included during the teaching of gas topic. Students in traditional classes asked very few questions during the learning process instead they generally responded to the questions asked by the teacher. Teachers gave certain time to solve the presented question meanwhile he or she set on his or her table or walked around in the class. After then, students' opinions about questions were usually taken verbally and the asked questions were usually solved by the teachers on board. When students asked any questions about the subject matter, teacher answered them. However, students simply acted as passive listeners taking notes. The instruction in control group was not based on addressing misconceptions instead main purpose was to inform students about gas concepts. The teaching materials used in this group were usually based on multiple-choice questions that teacher prepared or copied from several textbooks. These teaching materials did not address misconceptions rather the main purpose in traditional classes was not to make students grasp the gas concepts instead to teach them how and which gas formulas are used in solving related problems.

Experimental group students received case-based learning instruction based on conceptual change conditions by small group discussion as described by Herreid (1994). Prior to treatment, in each school experimental group students were divided into groups of four or five students by their chemistry teachers as heterogeneous as possible in terms of their chemistry achievement and general attitude toward chemistry. Then, the teachers gave the information about the new teaching method; what the case-based learning is and how it is applied in classroom settings emphasizing the roles of students in detail. The role of students in each group was to read and discuss the given problem and scenario under teacher guidance. The role of teachers was to provide arrangement of groups and meanwhile avoid giving the direct answers of the case-based learning questions. The same content was covered in experimental group classes as in control groups but they were instructed basically by means of the presented cases, problems or scenarios working in small groups. Students' misconceptions of the gas concepts were taken into account while preparing the cases and they were tried to be remedied based on conceptual change conditions. In this study, a total of fifteen cases generally based on real-life events, experiments and specific situations were used on the concepts of gases. Some of the cases used in these classes were given in the Appendix I. Students in small groups analyzed the given cases and answered the related questions. Afterward, group members shared their ideas to the whole class and class discussion began. Discussion continued until reasonable or plausible answer(s) were found to the case questions. Meanwhile, experimental group teachers guided students by asking open-ended and challenging questions and prompting further thinking. Since the discussion of cases began and ended in class, students did not have opportunities to search or investigate the subjects from different resources such as books, internet, and library. Therefore, sometimes the needed information or clues was provided in the materials necessary to solve the given problem. For example, during the implementation in air bag case, the reaction equation ($2NaN_{3(s)}$ + heat $\rightarrow$ $2Na_{(s)}$ + $3N_{2(g)}$) was given by the teacher after students' discussion about swelling of the air bag. The students answered the ill-structured questions by discussing them with their team mates. And then one of the group members wrote the answer of the questions on each material. This active learning environment provided students to work in groups, identify learning issues, share related information with their classmates and develop critical thinking ability about events.

Since one of the purposes of the present study was to eliminate students' misconceptions about gas concepts by case-based learning based on conceptual change conditions, scenarios or problems were prepared by considering these misconceptions. The teaching strategy was planned by considering conceptual change principles to assist students remove their misconceptions. Therefore, case-based learning provided four steps of conceptual change model; dissatisfaction, intelligibility, plausibility, fruitfulness. Working in small groups of four or five individuals presented students opportunities for active learning by joining problem solving-activities, discussion on the presented cases and related questions, sharing the experiences, gaining different points of view towards the events and ability to look from a scientific perspective, and so attitudes and motivations of students were expected to increase by means of case-based instruction. In addition, case-based learning is a good way to learn especially for shy students because sometimes it is easy for them to share their ideas with group mates and gain feedback from the peers instead of the whole class.

For example, experimental group students were presented the case about the atmospheric pressure asking the reason of boiling water faster above the sea level. Dissatisfaction was tried to be created in students' mind by means of the given case and this learning environment provided students opportunities to discuss the given scenario or event with both their group mates and classmates. During discussions, it was observed that students had memorized how air pressure changes with altitude, and they generally hesitated answering related questions. Teachers gave groups the opportunity to discuss on the case and chance to convince the groups having different viewpoints from each other. This step provided dissatisfaction. The whole class discussion continued until the intelligible and plausible answer(s) were found by the students. Teachers in experimental group might be seen to do nothing but the teachers had great role about controlling and directing the whole class. Sometimes students gave extraneous or irrelevant responses, in this case teachers asked challenging questions for further thinking about the topic without changing the direction of the discussion from the aim. In order to make the information more meaningful and permanent, other questions related to subject were asked. For example, students were asked regarding with the atmospheric pressure case "*why do the climbers make a camp at certain altitudes while climbing the mountain or why do their nose bleed while climbing?*", "*why do the football players go camping above the sea level for training?*", *"Why the people living in uplands or plateau are ruddy-cheeked?"*. By this way, fruitfulness (or usefulness) stage of the conceptual change was provided.

After completing case activities, the researcher and a chemistry education PhD student observed the groups once a week and filled the treatment verification checklist (See Appendix F) which was prepared by the researcher in order to check whether the case-based learning method was applied as required. Treatment verification checklist consisted of two parts: first part included “yes” or “no” type items and second part items were 5-point Likert-type scale (always, usually, sometimes, rarely, and never). The percentages of items marked as”usually” and “yes” were 75 %. This checklist indicated that case method of learning was implemented in accordance with the purpose of the study. Thus, treatment fidelity was provided with the help of treatment verification checklist.

At the end of the instruction, GCT, ASTC and MSLQ were administered to both group of students as posttests to measure the change in misconceptions about gases, their attitude toward and motivation toward chemistry respectively. In addition to these tests, students in experimental group opined their ideas and suggestions to presented feedback forms (Feedback Form for Case-Based Learning) after the treatment. Students’ responses to each item of the questionnaire were discussed in detail in results and conclusion chapter.

Before the implementation of the current study, necessary legal permissions were received and all the materials used during the instructions were examined by the ethical committee of the university. During the implementation of the study, students were not harmed in any way (physically or mentally). All the students consented to participate in the study. Besides, the issue of confidentiality was emphasized in a way that names of the students would not be reported in anywhere and the accessible data would be limited only by the researcher. In addition, since they would not be graded according to their responses to the instruments and their names would not be used in anywhere, it was emphasized to the students to respond the presented tests as sincerely as possible.

4.6 Threats to Internal Validity

Internal validity means that the observed differences on dependent variable are directly associated with the independent variable not because of some other unintended variable. Possible threats were identified while planning the current study and the researcher tried to eliminate or at least minimize these threats. Internal validity threats were identified as subject characteristics, mortality, location, instrumentation, testing, history, maturation, attitude of subjects, regression and implementation (Fraenkel & Wallen, 2006).

Subject characteristics threat was described as the possibility of individuals differing from one another in unintended ways such as their age, intelligence, socioeconomic background, science process skills etc (Fraenkel & Wallen, 2006). In this study, already formed groups were used and students were not assigned to experimental and control groups randomly. Therefore, there was no possibility of selection bias or subject characteristics threat by the researcher. As statistically, students' previous knowledge about the gas concepts, their attitudes and motivation was checked at the beginning of the study for the equalance of the groups. In addition, both groups of students were at the same grade level and almost at the same age (16-17 years old).

Mortality refers to loss or absence of subjects during the study progress or collection of data or due to the failure to complete tests, questionnaires, or other instruments (Fraenkel & Wallen, 2006). All the students in both groups regularly attended to the chemistry lessons and almost all of them answered pretests and posttests. And, since the rate of missing values of pretests and posttests less than 5 %, mortality threat was controlled statistically by replacing missing values with mean value for both experimental and control groups thus introducing no advantage to either.

Location threat occurs when particular locations were used for data collection and intervention performed (Fraenkel & Wallen, 2006). In Anatolian high school, all the instruments were administered to students as pretests and posttests in their regular classes at school. However, in public high school, since the class size was not appropriate for the group work, experimental group students received instruction and the measuring instruments at school laboratory. Therefore, location might be a threat for public school students, not for the Anatolian school students. Moreover, interviews were conducted after posttests to both groups of students in their schools. In public high school, an empty, regular class was used for interviewing both groups of students. In Anatolian high school, all the interviews were performed in school library. Therefore, during interviews, location was held constant for all participants in each school.

The instrumentation threat refers to unreliability, or lack of consistency of measuring instruments that can cause an invalid evaluation of performance (Gay & Airasian, 2000). If the nature of instrument (including scoring procedure) is altered in some way, instrumentation can be a problem. This is called usually as instrument decay. The characteristics of the data collector such as gender, age, ethnicity, language patterns may affect the nature of the data and also the results. Data collector(s) and/or scorer (s) may unconsciously distort the data and this is referred as data collector bias (Fraenkel & Wallen, 2006). The same measuring instruments (GCT, ASTC and MSLQ) were used and the nature of the instrument including the method of scoring was not changed in any way. So, instrumentation threat was controlled. In order to overcome the data collector bias, the same data collector (researcher) collected all the instruments from experimental and control groups throughout the whole study. During the collection of data, both groups were treated equally while giving necessary explanations and directions about the tests. In addition to these, all the interviewees in two schools were selected by the same procedure that Thompson and Soyibo (2002) used in their study. Semi-structured interview technique was used in each interview. After giving the post concept test papers to students, each test items were asked again as well as asking the reasons of their selection. No leading or extra questions were tried to be asked during the interviews neither to experimental nor to the control group students. And also, no hints were tried to be given in any way about the answers to test questions. Therefore, all the interviews were tried to be standardized applying the same procedure to each group and each school. Therefore, the possibility of data collector bias was tried to be minimized.

Testing threat is the improvement of posttest scores due to having pretests administered at the beginning of the treatment not due to the intervention (Fraenkel & Wallen, 2006). Sometimes, pretesting may alert students to what is being studied and this situation may lead to the development of test results. In the current study, since the measuring instruments were administered to both experimental and control groups, presumably pretests affected these groups equally. Cook and Camphell (1979) stated that testing is a problem if factual information is measured and if there is less time between pretests and posttests in the study. Factual information is likely to remain in mind more than the algebraic equations. Since all the instruments were used to measure the misconceptions about gas concepts and the instruction lasted 12 weeks for each group, testing did not form a threat for this study.

History is the occurrence of extraneous events which are not part of the treatment but happens during the course of the study and might affect the outcome (Fraenkel & Wallen, 2006). On the other hand, since these events are likely to affect both experimental and control group equally, history did not constitute a threat for the current study. Throughout the whole study, researcher continually observed the lessons and was in contact with the both group of students and teacher. However any unusual event to affect the students' responses was not noticed during the treatments.

Maturation is the change of students physically, intellectually and emotionally in time. All the students were at the same age and the same grade; all of them were likely to mature but since the instruction continued same period of time for each group, maturation should not be a threat (Fraenkel & Wallen, 2006). Moreover, all the instruments were administered approximately at the same time. Then, interviews were conducted just after analyzing posttest results. Consequently, maturation threat was under control for the study.

The attitude of subjects can make a difference on the results of the study. This effect is generally defined as the attitude of subject threat (Fraenkel & Wallen, 2006). During administration of tests, the significance of each student's answer was stressed. By this way, attitude of subject threat was tried to be overcome among either experimental or control group students. Moreover, since both groups are the important parts of the study, they were behaved in the same way while conducting tests and interviews. Therefore, attitude of subject threat was tried to get under control.

A regression threat is caused by when the subjects are selected based on their extremely high or low scores (Fraenkel & Wallen, 2006). Regression threat was not a problem in this study because already formed groups were used instead of selecting subjects based on their extreme scores individually.

Implementation threat can happen when the one group was treated unintentionally and unnecessarily in favor of one method over the other or when the different individuals are assigned to different methods, since one of them might be more qualified than the other (Fraenkel & Wallen, 2006). In this study, one teacher in each school implemented the instruction to both experimental and control groups trying to treat each group equally because s/he has responsibilities for both groups of students as a teacher.

4.7 Threats to External Validity

According to Gay and Airasian (2000), there are seven major threats to external validity which limit the generalization of the results to other populations including; pretest-treatment interaction, selection-treatment interaction, multiple treatment interference, specificity of variables, treatment diffusion, experimenter effects, and reactive effects.

Pretest-treatment interaction occurs when students reply or react differently to the treatment due to pretesting. Pretesting may make students conscious to the nature of the treatment, so pretested students are exposed to potentially treatment effect more than the participants not being pre-tested. Therefore, related results can be generalized to the other pre-tested groups, not to the population, which is not pre-tested. Pretest-treatment interaction threat occurs depending on participants of the study, the nature of the independent and dependent variables, and the period of the study. This threat is expected to be reduced in studies in which young children are involved since they most likely not perceive or remember the association between the pretest and the following treatment. Likewise, the effects of pretest can be significantly minimized in studies over a period of months or longer (Gay &

Airasian, 2000). In the current study, pretest-treatment interaction cannot be a major threat since the treatments lasted 12 weeks.

Selection-treatment interaction is about the "differential selection of participants" problem related to internal invalidity. This threat primarily occurs in the case of nonrandom selection of participants for treatments because nonrandom selection of participants from a population restricts the generalizability of the results. Experimental group may be different in some way from the control group even if the intact groups are selected at random from the larger population. Selection-treatment interaction also occurs due to the nonrepresentativeness of groups so results are generalized only to the groups involved and not to the extended population (Gay & Airasian, 2000). In the current study, experimental and control groups are selected from the target population but since the classes had already been formed at the beginning of the semester by the school administration, there was no chance to assign the students to the groups randomly. Therefore, selection-treatment interaction was unavoidable and inevitable threat.

In addition, short- or long-term incidents may affect the generalizability of the results. This threat is known as the *interaction of history and treatment effects*. However, extraneous short- or long-term events or incidents did not take place during implementation of this study. Interaction of time of measurement and treatment effect is another threat to external validity. This threat occurs depending on the timing of the posttesting because posttesting may show different results depending on when it is done (Gay & Airasian, 2000). In the present study, posttests were administered to both groups of students immediately following the treatment.

Multiple-treatment interference occurs when the same group of participants receives more than one treatment consecutively. The effective assessment of the later treatment may become difficult due to the carryover effects of the earlier one(s). Students in the current study had not participated in this kind of treatment recently therefore there was no possibility of multiple-treatment interference (Gay & Airasian, 2000).

Treatment diffusion takes place when participants from different treatment groups interact with and learn from each other. Knowledge of each other's treatments often leads to the groups borrowing aspects from each other so that the study no longer has two distinctly different treatments, but two overlapping treatments (Gay & Airasian, 2000). In Anatolian high school, students received the treatments on the same floor of the school so interaction between experimental and control group was inevitable in this school. However, in public high school experimental group students received instruction in chemistry laboratory due to unavailability of the regular classes to group work. In order to prevent treatment diffusion, researcher collected teaching materials after each implementation in both schools. Therefore, the possibility of treatment diffusion was tried to be minimized.

Researchers may be potential threats to the external validity of their own studies. The experimenter may unintentionally influence the study procedures, the participants' behavior, or the evaluation of their performance in several ways. The effects of experimenter may be passive or active. Passive elements comprise the characteristics of the experimenter such as gender, age, race, anxiety level, and hostility level. These, all together, are called as the *experimenter personal-attributes effects*. When the results of the study are affected by researchers' expectations and behavior, active experimenter effect occurs. This influence is called as the *experimenter bias effect*. Therefore, research results can be affected by experimenter's unintentional looks, feels, or acts. Moreover, researcher may influence participants' behavior due to previous knowledge of the participants. Being aware of which participants are in the experimental and control groups may be effective in evaluating their performance. Consequently, identification of experimenter bias effect is difficult. (Gay & Airasian, 2000). In order to avoid this threat, researcher did not establish emotional connection with the students and did not get into emotional expectations to participants in the study as being aware of these consequences on the external validity of the study. In addition, in order to reduce experimenter bias researcher used numbers rather than names during scoring and evaluation of the results in both qualitative and quantitative analysis.

Reactive arrangements or *participant effects* refer to a number of factors related with the way of implementation of the study and the feelings and attitudes of the participants. This effect is also caused by participants' knowledge of participating in the study or their feeling due to somehow receiving "special" attention for the study. The effects that such knowledge or feelings can have on the participants are called as *Hawthorne Effect*. Hawthorne effect is referred to describe any situation in which participants' behavior is affected not by the treatment per se, but by their knowledge of participating in a study. If control group students become aware that they are the control group in the study, they may put an extra effort so compulsory rivalry may occur between the groups. Posttest performance of control group students will be affected by this situation so the treatment under study would not seem to be very effective. This related reactive effect is known as *compensatory rivalry*, or the *John Henry effect*. Both groups of students did not know that they were instructed as either experimental or control group in the study. Another related participant effect is the *novelty effect*, which means the increased interest, motivation, or engagement of participants because of doing something different, not because it is effective or better. In order to control this threat, the sufficient time was allowed for conducting the current study.

4.8 Analysis of Data

Two-way Analysis of Variance (ANOVA) based on gain scores was used to determine the effects of case-based learning and school on students' understanding about gas concepts and their attitudes toward chemistry. Two-way Multivariate Analysis of Variance (MANOVA) based on gain scores was used to investigate the effect of case-based learning and school on students' motivation.

4.9 Assumptions and Limitations

4.9.1 Assumptions

1. Teachers were not biased during the treatments.
2. There was no interaction between the experimental and control group students.
3. The students in the study answered the questions of the instruments sincerely.

4. All instruments were administered under standard conditions.

5. The only reason of difference between experimental and control group students' test scores of posttests was the case-based instruction based on conceptual change approach.

4.9.2 Limitations

1. The subjects of the study were limited to 128 tenth grade students at public high school and Anatolian high school in Ankara during 2008-2009 semesters.

2. This study was limited to "gas concept" unit in chemistry.

3. The subjects were not randomly assigned to the groups.

4. All the fit indices acquired through Confirmatory Factor Analysis were not within acceptable limits though they were reasonable values. Therefore, the results should be interpreted cautiously.

CHAPTER 5

RESULTS AND CONCLUSIONS

This chapter aims to present the results of the study in three main sections. The first section includes the statistical analysis of pre-test scores. The second section consists of statistical analysis of hypotheses stated in Chapter 3. The third section deals with the analysis of interviews and students' opinions about the case-based study.

5.1 Statistical Analysis of Pretest Scores

Prior to treatment, two-way ANOVAs were conducted to examine whether there was a statistically significant mean difference between control and experimental group students and school type in terms of students' pretest scores about gas concepts (pre-GCT) and pre-attitudes toward chemistry (pre-ASTC). Moreover, two-way Multivariate Analysis of Variance (MANOVA) was performed to investigate whether there was a statistically significant mean difference between control and experimental group students and school type in terms of students' perceived motivation (pre-MSLQ). All statistical analysis was carried out at 0.05 significance level by using Statistical package for Social Sciences (SPSS).

Before interpreting the outputs, the assumptions of the statistical analysis of each separate test were checked whether they were met or not. Independence of observations, homogeneity of variance and normality assumptions were tested for each separate two-way ANOVA's.

For the independence of observations assumption, as a researcher, I administered all the instruments to all group of students and explained that each student should answer the test individually. During the administration process, I tried to ensure that students are answering the test items individually, not affecting from each other. Thus, the independence of the observation was tried to be provided by this way. Homogeneity of variance assumption was tested by means of Levene's Test for Equality of Error Variances. For the normality assumption, skewness and kurtosis values were checked for individual dependent variables.

For the multivariate analysis (MANOVA), independence of observations, homogeneity of the variance-covariance matrices and multivariate normality assumptions were tested. All the pretests were performed by the researcher in a usual class environment by giving necessary information and directions about test items. The assumption of homogeneity of the variance-covariance matrices was checked with Box's M statistics. For multivariate normality assumption, skewness and kurtosis values for each individual dependent variables were also tested. In addition to skewness and kurtosis values, Box's M test results should be interpreted carefully since the Box Test is very sensitive to nonnormality. Therefore, before utilizing the Box M test results, it is important to check whether multivariate normality assumption is tolerable or not. The significant result may be caused by the violation of the multivariate normality (Green, Salkind, & Akey, 2000; Crocker & Algina, 2002).

5.1.1 Statistical Analysis of Pre-ASTC Scores and Pre-GCT Scores

5.1.1.1 Statistical Analysis of Pre-GCT Scores

Two-way ANOVA was conducted to determine whether there was a significant mean difference between control and experimental group students and school type in terms of students' understanding of gas concepts before the treatment. The descriptive statistics of pre-GCT scores across the groups for each school was presented in Table 5.1.

Table 5.1 Descriptive Statistics of with respect to students' pre-GCT scores across the Groups in Two Schools

School	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Public High School	45	20	9.39	12.05	2.47	1.67	-0.082	0.179	-0.637	-0.137
Anatolian High School	38	25	9.29	11.92	2.90	2.61	0.441	0.080	-0.105	0.788
Total	83	45	9.35	11.98	2.66	2.22	-0.272	0.026	-0.392	-0.123

Skewness measures to what extent a distribution of values deviates from the mean value. As for kurtosis, it is a measure of the "peakedness" or the "flatness" of a distribution. Skewness and kurtosis values are considered excellent between +1 and -1 but a value between +2 and -2 is also acceptable in many cases (Bachman, 2004). As seen from Table 5.1, tolerable skewness and kurtosis values met normality assumption for EG and CG students in two schools. Levene's Test was used in order to check the homogeneity of variances assumption. Levene's Test results were presented in Table 5.2

Table 5.2 Levene's Test of Equality of Error Variances for all Groups in TwoSchools

Dependent Variable	*F*	df1	df2	*p*
Pre-GCT	0.310	3	124	0.080

Nonsignificant Levene's Test results showed that the homogeneity of variances assumption was met across the groups. Also, the scores on the test variable were independent of each other, thus independence assumption was satisfied. Having checked the assumptions, two-way ANOVA was performed to investigate whether there was a significant mean difference between the groups and school type in terms of students' understanding of gas concepts before the treatment. Table 5.3 indicates the ANOVA results.

Table 5.3 ANOVA Results with respect to Gas Concept Test

Source	df	*F*	Sig.(*p*)	Partial Eta-Squared	Observed Power
Group	1	0.062	0.803	0.001	0.057
School	1	31.377	0.000	0.202	1.000
Group*School	1	0.001	0.979	0.000	0.050

The results revealed that there was not a significant mean difference between experimental and control group students with respect to students' pre-existing knowledge about gas concepts (pre-GCT) before the treatment whereas students in two schools were significantly different in terms of their pre-existing knowledge about gas concepts. What is more, the partial eta-squared value of 0.20, which means that 20 % of the variance of the dependent variable was associated with school, implied the very large effect of school on the scores of pre-GCT. Weinfurt (2000) stated that in the randomized designs ANCOVA would be statistically more powerful than the gain-score analysis, if the groups are not different in terms of pretest mean. In Quasi-experimental designs in which intact groups are used, if the groups are different on the mean pretest score, gain score analysis is the valid analysis instead of ANCOVA. In this case, gain values can be calculated and used to analyze the results instead of analyzing only posttest scores. Afterwards, the two-way ANOVA results for pre-ASTC scores and two-way MANOVA results for pre-MSLQ were checked. The following analysis presents the results concerning the effects of group and school on students' attitude toward chemistry and motivation dependent variables before the instruction.

5.1.1.2 Statistical Analysis of Pre-ASTC Scores

Two-way ANOVA was conducted to determine whether there was a significant mean difference between control and experimental group students and school type in terms of students' attitudes towards chemistry before the treatment. The descriptive statistics of pre-ASTC scores across the groups for each school were presented in Table 5.4.

Table 5.4 Descriptive Statistics with respect to Attitude toward Chemistry Scale across the Groups in Two Schools

School	N		Mean		Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Public High School	45	20	55.25	52.83	8.41	7.85	0.328	-0.970	-0.035	0.840
Anatolian High School	38	25	53.02	52.66	11.72	9.64	0.483	-0.322	0.137	0.293
Total	83	45	54.23	52.74	10.06	8.79	-0.680	-0.089	1.250	0.249

Table 5.4 indicated the reasonable skewness and kurtosis values satisfying univariate normality assumption across the groups. In order to check the homogeneity of variance assumption, Levene's Test of Equality of Variances was used. Table 5.5 indicates the Levene's Test results for all groups in two schools.

Table 5.5 Levene's Test of Equality of Error Variances for all Groups in Two Schools

Dependent Variable	*F*	df1	df2	*p*
Pre-ASTC	1.487	3	124	0.221

The results revealed that the homogeneity of variances assumption was met across the groups. Moreover, the scores on the dependent variable were independent of each other satisfying the independence assumption. Two-way ANOVA was conducted after checking the assumptions. ANOVA results were displayed in Table 5.6.

Table 5.6 ANOVA Results with respect to Attitude toward Chemistry

Source	df	*F*	Sig.(*p*)	Partial Eta-Square	Observed Power
Group	1	0.441	0.508	0.004	0.101
School	1	0.600	0.440	0.005	0.120
Treatment*Group	1	0.330	0.567	0.003	0.088

The two-way ANOVA results revealed that there was no statistically significant mean difference between experimental and control groups as well as school type on their pre-ASTC scores before the instruction.

5.1.2 Statistical Analysis of Pre-MSLQ Scores

Two-way MANOVA was conducted before the treatment to determine whether there was a statistically significant mean difference between experimental and control groups and school type on students' motivational collective dependent variables of Intrinsic Goal Orientation (IGO), Extrinsic Goal Orientation (EGO), Task Value (TV), Control of Learning Beliefs (CLB), Self-Efficacy for Learning and Performance (SELP), Test Anxiety (TA). Descriptive statistics with respect to IGO, EGO, TV, CLB, SELP and TA across the groups for each school and in two schools were presented in Table 5.7.

Table 5.7 Descriptive Statistics with respect to IGO, EGO, TV, CLB, SELP and TA for across the Groups in Two Schools

	School	Mean		Std. Dev		Skewness		Kurtosis	
		CG	EG	CG	EG	CG	EG	CG	EG
IGO	Public High School	20.16	21.73	0.67	0.73	-0.537	-0.953	0.309	1.113
	Anatolian High School	17.40	19.08	1.01	0.91	0.326	-0.374	-0.302	1.114
	Total	19.31	20.68	4.522	4.841	-0.202	-0.622	-0.241	0.472
EGO	Public High School	22.83	22.84	0.75	0.82	-1.391	-0.790	2.216	-0.579
	Anatolian High School	20.47	20.04	1.13	1.01	-1.211	-1.535	2.097	2.384
	Total	22.11	21.73	4.928	5.403	-1.155	-1.361	1.547	2.297
TV	Public High School	30.88	31.58	1.09	1.18	-0.501	-1.030	-0.177	0.883
	Anatolian High School	29.25	29.66	1.63	1.46	-0.846	-0.452	1.371	-0.450
	Total	30.38	30.81	6.856	7.731	-0.525	-0.789	0.075	0.406
CLB	Public High School	22.39	21.68	0.66	0.72	-1.148	-0.664	1.835	-0.276
	Anatolian High School	21.32	21.54	0.99	0.89	-0.154	-0.890	0.305	0.830
	Total	22.06	21.62	4.336	4.526	-1.014	-0.717	2.374	-0.023
SELP	Public High School	40.23	42.10	1.23	1.34	-0.291	-0.588	0.301	0.079
	Anatolian High School	40.15	36.83	1.85	1.65	0.422	-0.639	-0.128	0.284
	Total	40.20	40.01	7.271	9.456	-0.206	-0.579	0.489	0.134
TA	Public High School	22.44	20.39	0.85	0.92	-0.503	0.345	0.386	-0.553
	Anatolian High School	17.60	18.46	1.28	1.14	0.244	-0.397	0.996	0.274
	Total	20.95	16.62	5.993	5.852	-0.296	0.155	-0.066	-0.116

As seen from Table 5.7, skewness and kurtosis values were tolerable satisfying the multivariate normality assumption for each groups of schools though some of the kurtosis values of EGO deviated from +2 for in in both schools. In addition, since the score on a variable for any one participant was independent from the scores on this variable for all other participants, the independence assumption was satisfied. The homogeneity of variance-covariance matrices assumption was checked by Box's M Test results. The significant Box's M test result did not satisfy the homogeneity of variance and covariance matrices, F (63, 1.949) = 1.949, $p = 0.00 < 0.05$. However, the homogeneity of variance and covariance matrices was conditionally robust since the group sizes were approximately equal, being largest/smallest < 1.5 (Crocker & Algina, 2002). In the current study, the group sizes were nearly similar. Levene's Test of Equality of Error Variances was tested for each individual dependent variable whether each dependent variable of motivation had the similar variance across the groups. The related results revealed that all the significance values, p, were greater than 0.05 except for CLB but F value of CLB is not large, the significant value of it can be ignored and MANOVA analysis can be accepted as valid for all groups in two schools (George & Mallery, 2003). Therefore, homogeneity of variance assumption was met for most dependent variables. The results of Levene's test for each dependent variable were presented in Table 5.8.

Table 5.8 Levene's Test of Equality of Error Variance for all Groups in Two School

Dependent Variables	*F*	df1	df2	*p*
IGO	0.764	3	124	0.516
EGO	0.857	3	124	0.466
TV	1.088	3	124	0.357
CLB	4.423	3	124	0.005
SELP	2.409	3	124	0.070
TA	0.474	3	124	0.701

After satisfying the assumptions, MANOVA was run to evaluate whether there was a statistically significant mean difference between EG and CG students with respect to the group and school type on students' motivation based dependent variables of IGO, EGO, TV, CLB, SELP and TA, prior to the treatment. MANOVA results with respect to students' pretest scores on MSLQ for all groups in two schools were displaced in Table 5.9.

Table 5.9 MANOVA Results with respect to Dependent Variables of IGO, EGO, TV, CLB, SELP, TA

Source	Wilks' Lambda	*F*	Hypothesis Df	Error Df	Significance (*p*)	Eta Squared (η^2)	Power
School	0.851	3.47	6.000	119	0.003	0.149	0.938
Group	0.929	1.521	6.000	119	0.177	0.071	0.570
School*Group	0.944	1.180	6.000	119	0.322	0.056	0.450

The results showed that there was no statistically significant mean difference between experimental and control group students with respect to the motivation based dependent variables. However, there was a statistically significant mean difference in terms of school effect on motivation based dependent variables of IGO, EGO, TV, CLB, SELP and TA prior to treatment. As it was shown in Table 5.9, the partial-eta squared value for school effect was found to be 0.14 which indicates the difference between students in two schools with respect to motivation based dependent variables was not small before the treatment. Since the groups are different on the pretest scores, it is recommended to use the gain score analysis instead of ANCOVA analysis (Weinfurt, 2000). Therefore, it was decided to use the gain scores in the continuity of the analysis.

5.2 Statistical Analysis of Gain Scores

Gain values (posttest-pretest) were calculated for concept test scores, attitude toward chemistry and for each motivational dependent variable for the analysis of posttest scores throughout the current analysis of this study. Two-way ANOVA and two-way MANOVA based on gain scores were used for the analysis of hypothesis.

5.2.1 Statistical Analysis of Gain-GCT Scores

Statistical analysis of gain-GCT scores are based on the below three sub-problems. These are as follows:

1. Is there a significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally *designed chemistry instruction with respect to tenth grade students' understanding of gas concepts?*

2. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students' understanding of gas concepts?

3. Is there a significant effect of interaction between treatment and school with respect to tenth grade students' understanding of gases?

Two-way ANOVA based on gain scores was performed to seek answers to the above problem sentences. In this analysis, treatment and school were the independent variables; students' understanding of gas concepts based on gain scores was used as a dependent variable to determine the effect of treatment and school on students' understanding of gas concepts. Table 5.10 shows the descriptive statistics for the dependent variables across the experimental and control groups.

Table 2.10 Descriptive Statistics with respect to the Gain-GCT across Experimental and Control Groups

School	N		Pretest		Posttest		Gained Mean Score		Gained Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Public High School	45	38	9.39	9.28	10.75	16.00	1.36	6.71	3.65	5.15	-0.069	-0.721	-0.709	-0.125
Anatolian High School	20	25	12.05	11.92	13.95	18.12	1.90	6.20	2.93	4.03	0.040	-0.204	-0.222	-0.361
Total	65	63	9.34	11.97	13.15	16.26	1.52	6.51	3.43	4.71	-0.092	-0.560	-0.569	-1.172

In Table 5.10, it was indicated that experimental group students in public high school had gained more from the case-based learning than students in the Anatolian high school. On the other hand, control group students in Anatolian high school gained more from traditionally designed chemistry instruction than the students in public high school. In addition, all the skewness and kurtosis values were tolerable satisfying the bivariate normality assumption for both groups in each school. Levene's Test was performed to test the homogeneity of variance assumption. Table 5.11 indicates the Levene's Test result.

Table 5.11 Levene's Test of Equality of Error Variances

Dependent Variable	*F*	df1	df2	*p*
Gain-GCT	2.083	3	124	0.106

Nonsignificant value of Levene's Test indicated that homogeneity of variance assumption was met for the dependent variable across the groups. And, independence assumption was satisfied because the scores on the dependent variable were independent of each other. After satisfying assumptions, two-way ANOVA was performed and the related results were presented in Table 5.12.

Table 5.12 ANOVA results with respect to Gain-GCT

Source	Df	*F*	Sig.(*p*)	Partial Eta-Squared	Observed Power
School	1	0.000	0.985	0.000	0.050
Treatment	1	39.26	0.000	0.240	1.000
Treatment*School	1	0.465	0.497	0.004	0.104

Two-way ANOVA results demonstrated that there was a significant mean difference between experimental and control group students with respect to the treatment effect on students' understanding of gas concepts. The Eta-Squared value of 0.24 indicated the difference between experimental and control group was not small. In other words, % 24 of the variance of the dependent variable was associated with the treatment. Also, the power value of 1.000 showed the difference between experimental and control group aroused from the treatment effect and this effect had the practical value. On the other hand, there was no significant mean difference between the groups in terms of school effect on understanding of gas concepts, $p = 0.985 > 0.05$. Moreover, there was no significant effect of interaction between treatment and school with respect to tenth grade students' understanding of gases, $p = 0.497 > 0.05$. In addition to this, as seen from the Table 5.10, in both schools (public and Anatolian high school) there was an increase in the mean values of gain-GCT scores from control to experimental group. Besides, control group students in Anatolian high school (1.90) gained more from the treatment than that of the public high school students (1.36). In addition, the experimental group students in public high school students (6.71) gained more from the treatment than that of the Anatolian high school students (6.20).

5.2.2 Statistical Analysis of Gain-ASTC Scores

Three sub-problems for the statistical analysis of gain-ASTC scores are given below: These are respectively:

4. Is there a significant mean difference between the groups exposed to case-based learning based on conceptual change conditions and traditionally designed chemistry instruction with respect to tenth grade students' attitude toward chemistry?

5. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students' attitude toward chemistry?

6. Is there a significant effect of interaction between treatment and school with respect to tenth grade students' attitude toward chemistry?

Two–way ANOVA based on gain scores was conducted in order to determine the effect of treatment and the school on students' attitude toward chemistry. Treatment and the school were the independent variables; attitude toward school based on gain scores was the dependent variable. Table 5.13 shows the descriptive statistics for the dependent variables across the experimental and control groups.

Table 5.13 Descriptive Statistics with respect to the Gain-ASTC across Experimental and Control Groups

School	N		Pretest		Posttest		Gained Mean Score		Gained Std. Dev		Skewness		Kurtosis	
	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
Public High School	45	38	55.25	53.02	57.13	54.19	1.877	1.167	6.797	8.486	0.221	0.342	0.505	0.374
Anatolian High School	20	25	52.82	52.66	51.2	59.24	-1.628	6.573	7.872	6.519	0.020	0.699	-0.216	0.212
Total	65	63	54.23	52.73	55.78	55.66	0.798	3.313	7.267	8.157	0.036	0.151	0.231	0.262

In Table 5.13, it was indicated that in Anatolian high school while the control group students' attitudes toward chemistry decreased, experimental group students' attitudes increased substantially after the treatment. On the other hand, in public school, control group students' gain was more than the experimental group students in terms of students' attitude toward chemistry. The skewness and kurtosis values were checked for the measures of normality and all of them were reasonable satisfying the bivariate normality assumption for both groups in two schools. In addition, Levene' Test was used to test out the homogeneity of variances assumption. Table 5.14 indicates the Levene's Test result.

Table 5.14 Levene's Test of Equality of Error Variances

Dependent Variable	*F*	df1	df2	*p*
Gain-ASCT	0.609	3	124	0.611

Levene's Test for homogeneity of variance with a nonsignificant value of 0.611 indicated that the variances for experimental and control groups were equal. In addition, independence assumption was not violated due to the independence of scores on each other on the dependent variable. After meeting assumptions, two-way ANOVA was conducted to investigate the effect of treatment and school with respect to students' attitude toward chemistry. Two-way ANOVA results with respect to the dependent variable of attitude toward chemistry were displayed in Table 5.15.

Table 5.15 ANOVA results with respect to Gain-ASTC

Source	Df	*F*	Sig.(*p*)	Partial Eta-Squared	Observed Power
School	1	0.469	0.495	0.004	0.104
Treatment	1	7.286	0.008	0.056	0.764
Treatment*School	1	10.308	0.002	0.077	0.890

Table 5.15 indicated that treatment had a main effect for the attitude towards chemistry. In other words, there was a significant mean difference between experimental and control group students with respect to students' attitude toward chemistry. The Eta Squared value showed the proportion of variance that is

accounted by the treatment variable; that means 5.6 % of the variance of the dependent variable was accounted by the treatment. On the other hand, there was no significant mean difference between the schools with respect to students' attitudes toward chemistry, $p = 0.495 > 0.05$. Furthermore, the results indicated a significant treatment by school interaction ($p = 0.02 < 0.05$) regarding students' attitude toward chemistry. Partial Eta-Squared value of 0.077 demonstrated a moderate relationship between the treatment by school interaction and dependent variable. In other words, 7 % of the variance of the dependent variable was associated with the treatment by school interaction. The power value found to be 0.890 indicated the difference between experimental and control group aroused from the treatment by school interaction having practical value.

Since there is a significant effect of treatment by school interaction with respect to students' attitude toward chemistry, the related syntax is written in SPSS to perform multiple comparisons. The related syntax is given below:

```
UNIANOVA
  gainattitude BY treatment school
  /METHOD = SSTYPE(3)
  /INTERCEPT = INCLUDE
  /PLOT = PROFILE(treatment*school)
  /EMMEANS=TABLES(school)COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(treatment)COMPARE ADJ(BONFERRONI)
/EMMEANS=TABLES(treatment*school)compare(treatment) ADJ(BONFERRONI)
/EMMEANS=TABLES(treatment*school) compare(school) ADJ(BONFERRONI)
 /EMMEANS=TABLES(treatment*school)
/PRINT=DESCRIPTIVE
/CRITERIA=ALPHA(.05)
/DESIGN=treatment school treatment*school.
```

Table 5.16 Pairwise comparisons for treatment*school interaction

School	Treatment		Mean Difference (I-J)	Std Error	Sig. (p)
Public High School	EG (I)	CG (J)	-0.709	1.643	0.667
Anatolian High School	EG (I)	CG (J)	8.202	2.237	0.000

As it can be seen from Table 5.16, although in public high school control group students gained more attitude than experimental group students as a result of the given treatments, there is no significant mean difference between these groups in terms of their attitudes toward chemistry. On the other hand, in Anatolian high school, experimental group students gained more attitude to chemistry than control group students after the instruction and also there is a statistically significant mean difference between students in experimental and control group students with respect to their attitude toward chemistry.

Table 5.17 Pairwise comparisons for treatment*school interaction

Treatment	School		Mean Difference (I-J)	Std Error	Sig. (p)
Control Group (CG)	Anatolian High School (I)	Public High School (J)	-3.505	2.004	0.083
Experimental Group (EG)	Anatolian High School (I)	Public High School (J)	5.406	1.920	0.006

Table 5.17, presents the comparison of two schools in terms of the control and experimental groups by means of the gain-ASTC values. It can be seen that, control group students in public high school gained more attitude toward chemistry than that of Anatolian high school students however; there is no statistically significant mean difference between control group students in public and Anatolian high school in terms of their attitude toward chemistry. Conversely, experimental group students in Anatolian high school gained more attitude than that of public high school students after treatment and there is a significant mean difference between experimental group students in two schools in terms of their attitude toward chemistry.

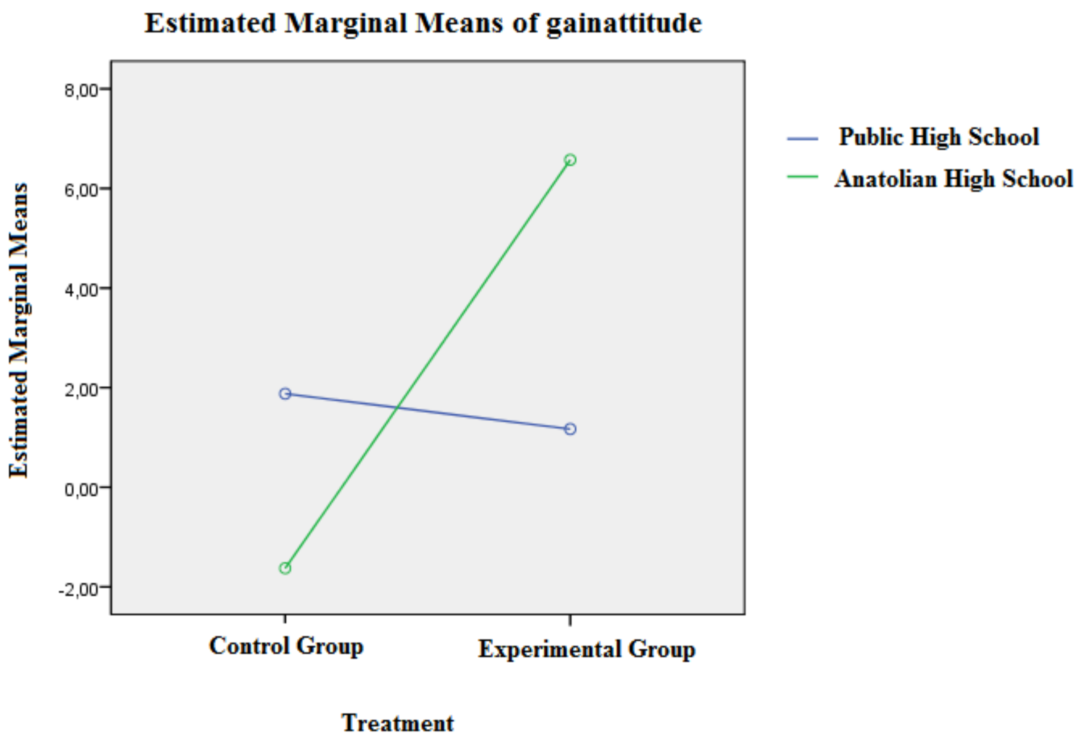


Figure 5.1 The graph of Treatment by School interaction for gainattitude value

The related results of two-way ANOVA showed the significant treatment by school interaction with respect to students' attitude toward chemistry. As indicated by eta-squared value, the treatment by school interaction accounted for 7 % of the variance in total. As seen from Figure 5.1, an interaction is proved graphically by nonparallel lines. In addition, in public high school there was not much difference between control and experimental group students in terms of gain-ASTC scores after the treatment so the blue line was nearly parallel to x-axis. However, in Anatolian high school, there was a substantial difference between control and experimental group students' attitude toward chemistry after the instruction. Also, descriptive statistics with respect to gain-ASTC values across experimental and control groups in Table 5.13 gave the exact values pointed out in the graph. In Anatolian high school, though control group students' attitudes decreased (-1.628) after the traditional instruction, experimental group students' attitude toward chemistry increased (6.573) therefore the graph was in the direction of the growth from control to experimental group. That means, there was an increase in the mean values of gain-ASTC scores from control to experimental group students in Anatolian high school.

5.2.3 Statistical Analysis of Gain-MSLQ Scores

The below three sub-problems are related to the statistical analysis of gain-MSLQ scores. These are as follows:

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

8. Is there a significant mean difference between the public high school and Anatolian high school with respect to tenth grade students' perceived motivation (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self -Efficacy for Learning and Performance, Test Anxiety)?

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

Two-way Multivariate Analysis of Variance (two-way MANOVA) based on gained scores was performed to evaluate the above research questions. Treatment and school were used as independent variables. Students' collective dependent variables of intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and text anxiety based on gain scores were used as dependent variables. Table 5.18 indicated descriptive statistics with respect to IGO, EGO, TV, CLB, SELP and TA across the groups for each school and for two schools together.

Table 5.18 Descriptive Statistics with respect to IGO, EGO, TV, CLB, SELP and TA across the Groups in Two Schools

	School	N		Pretest		Posttest		Gain (Posttest-pretest)		Skewness		Kurtosis		Standart Deviation	
		CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
GainIGO	Public High School	45	38	20.16	21.73	20.95	21.33	0.792	-0.403	0.487	0.020	0.413	1.551	5.533	5.634
	Anatolian High School	20	25	17.40	19.08	18.00	21.72	0.600	2.636	0.179	0.072	0.767	-0.483	4.109	3.925
	Total	65	63	19.31	20.68	20.04	21.48	0.733	0.802	0.459	-0.224	0.600	1.275	5.105	5.211
GainEGO	Public High School	45	38	22.83	22.84	22.31	21.08	-0.526	-1.758	0.203	-0.353	-0.545	-0.439	5.444	4.021
	Anatolian High School	20	25	20.47	20.04	18.35	21.28	-2.125	1.240	-0.081	1.811	-1.370	5.382	4.103	5.666
	Total	65	63	22.11	21.73	21.09	21.16	-1.018	-0.568	0.259	1.198	-0.440	4.986	5.092	4.926
GainTV	Public High School	45	38	30.88	31.57	32.20	32.38	1.316	0.810	0.769	0.692	1.668	1.183	6.485	7.105
	Anatolian High School	20	25	29.25	29.66	26.35	33.00	-2.900	3.336	-0.380	0.101	1.214	3.073	9.706	3.702
	Total	65	63	30.38	30.81	30.40	32.63	0.019	1.812	-0.205	0.352	2.170	1.535	7.793	6.081
GainCLB	Public High School	45	38	22.39	21.68	22.62	22.77	0.227	1.092	0.129	1.148	0.605	3.067	4.709	5.114
	Anatolian High School	20	25	21.32	21.54	20.35	24.04	-0.975	2.500	-0.042	0.701	-0.188	1.665	3.514	4.062

	Total	65	63	22.06	21.62	21.92	23.27	-1.142	1.651	0.196	0.910	0.659	2.371	4.384	4.741
	School	N		Pretest		Posttest		Gain (Posttest-pretest)		Skewness		Kurtosis		Standart Deviation	
		CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG
GainSELP	Public High School	45	38	40.23	42.10	40.31	41.11	0.0787	-0.994	0.006	0.877	-0.199	0.846	7.497	8.195
	Anatolian High School	20	25	40.15	36.83	36.30	43.64	-3.850	6.808	0.220	0.434	-1.557	-0.149	7.693	7.239
	Total	65	63	40.20	40.01	39.07	42.11	-1.130	2.101	0.045	0.427	-0.646	-0.211	7.717	8.670
GainTA	Public High School	45	38	22.44	20.39	21.62	23.94	-0.819	3.549	-0.117	0.538	1.325	1.048	6.937	6.373
	Anatolian High School	20	25	17.60	18.46	21.25	20.84	3.650	2.380	1.319	0.188	1.941	-0.255	4.373	7.726
	Total	65	63	20.95	19.62	21.50	22.71	0.555	3.085	-0.265	0.296	1.576	0.318	6.564	6.905

As seen from Table 5.18, for public high school, when the gain values for each group were examined, it was noticed that there was an increase in TV and CLB values in both groups after the treatment. On the other hand, although the values of IGO and SELP fell in the experimental group students, students in control group showed an increase in terms of these values. In addition, while the value of TA decreased in the control group students, TA values for experimental group students increased. Moreover, for both of the groups, EGO values reduced after the treatment in public high school.

As for the Anatolian high school, both IGO and TA values for each group increased after the treatment. However, when results were reviewed in terms of EGO, TV, CLB and SELP variables, it was seen that while the control group students' values decreased with respect to each variable, students in experimental group increased. Also, the size of the difference between two groups is very striking. When the descriptive statistics were examined with respect to IGO, EGO, TV, CLB, SELP and TA across the groups in two schools, it was seen that there was an increase in IGO, TV and TA values for both groups. In addition, while CLB and SELP values decreased in control group students, these values increased for experimental group students. Nevertheless, it was obtained that EGO values of both groups reduced after the instruction.

Before carrying out two-way MANOVA based on gain scores, its assumptions were tested. For the normality assumption, most of the skewness and kurtosis values were tolerable satisfying the multivatiate normality assumption for all dependent variables except for the slight deviation of kurtosis value of GainTV and GainEGO in EG in Anatolian high school as well as kurtosis value of GainCLB in EG in public high school so the univariate normality assumption was met.

The homogeneity of variance-covariance matrices assumption was checked by Box's M Test results. The significant Box's M test result did not satisfy the homogeneity of variance and covariance matrices, F (63, 19040) = 1.988, $p = 0.00 < 0.05$. According to Green et al. (2000) a significant result might be due to violation of the multivariate normality assumption. On the other hand, the homogeneity of variance and covariance matrices was conditionally robust when the group sizes were approximately equal, being largest/smallest < 1.5 (Crocker & Algina, 2002). In the current study, this ratio was found to be 1.18 and 1.25 for public and Anatolian high schools respectively, so group sizes were comparable. Moreover, the score on a variable for any participant was independent from the scores on this variable for all other participants hence the independence assumption was satisfied for MANOVA. Levene's Test of Equality of Error Variances was performed for the homogeneity of variance assumption. The results revealed that homogeneity of variance assumption was met for all dependent variables except for the task value. In other words, each dependent variable of motivation had equal variance for experimental and control groups. The results of Levene's test for each dependent variable were presented in Table 5.19.

Table 5.19 Levene's Test of Equality of Error Variance for all Groups in Two School

Dependent Variables	*F*	df1	df2	*p*
IGO	0.860	3	124	0.464
EGO	0.791	3	124	0.501
TV	3.646	3	124	0.015
CLB	0.562	3	124	0.641
SELP	0.288	3	124	0.834
TA	1.471	3	124	0.226

After satisfying the assumptions, two-way MANOVA was run to determine the effect of treatment and school on students' perceived motivation (IGO, EGO, TV, CLB, SELP, and TA). MANOVA results with respect to students' gain scores on MSLQ were displaced in Table 5.20.

Table 5.20 MANOVA Results with respect to Dependent Variables of IGO, EGO, TV, CLB, SELP, TA

Source	Wilks' Lambda	*F*	Hypothesis Df	Error Df	Significance (*p*)	Eta Squared (η^2)	Power
School	0.929	1.508	6.000	119.0	0.181	0.071	0.566
Treatment	0.881	2.685	6.000	119.0	0.018	0.119	0.851
School*Treatment	0.806	4.768	6.000	119.0	0.000	0.194	0.988

The results showed that there was a significant mean difference between the groups in terms of treatment whereas there was not a significant effect of school on students' overall motivational dependent variables. Moreover, school by treatment interaction had a significant effect on students' overall motivation based dependent variables after treatment. As it was shown in Table 5.20, the partial eta squared (η^2) value of 0.19 showed a large effect of school by treatment interaction on students' perceived motivation. In other words, it means that % 19 of multivariance of the perceived motivation was associated with school by treatment interaction. The power value was found to be 0.988 indicating that the difference between the groups aroused from the school by treatment effect and this effect had practical value (Gay & Airasian, 2000).

Univariate ANOVAs were performed in order to find the effect of treatment as well as school and school by treatment interaction on each dependent variable. Table 5.21 indicates the results of univariate ANOVAs for all groups in two schools.

Table 5.21 Follow-up Univariate ANOVAS

Source	Dependent Variable	Df	*F*	Sig.(*p*)	Eta-Squared	Observed Power
School	IGO	1	2.258	0.135	0.018	0.320
	EGO	1	0.586	0.445	0.005	0.118
	TV	1	0.438	0.509	0.004	0.101
	CLB	1	0.015	0.904	0.000	0.052
	SELP	1	1.830	0.179	0.015	0.269
	TA	1	1.800	0.182	0.014	0.265
Treatment	IGO	1	0.196	0.658	0.002	0.072
	EGO	1	1.360	0.246	0.011	0.212
	TV	1	5.033	0.027	0.039	0.605
	CLB	1	6.552	0.012	0.050	0.719
	SELP	1	11.202	0.001	0.083	0.913
	TA	1	1.587	0.210	0.013	0.240
School*Treatment	IGO	1	2.911	0.090	0.023	0.395
	EGO	1	6.321	0.013	0.049	0.704
	TV	1	6.970	0.009	0.053	0.745
	CLB	1	2.367	0.127	0.019	0.333
	SELP	1	16.779	0.000	0.119	0.982
	TA	1	5.254	0.024	0.041	0.623

As seen from Table 5.21, there was not any significant effect of school, treatment and school by treatment interaction on students' gain values of IGO. However, there was a significant effect of treatment on students' gain values of control of learning beliefs whereas there was not any significant effect of school as well as school by treatment interaction on students' CLB. It can be seen from Table 5.18 that mean score of perceived control of learning beliefs of students in experimental group was higher than that of the control group students. It can be said that students in experimental group students in both schools believed their own efforts to study make a difference in their learning more than the control group students and they felt that they can control their academic performance. The related values for CLB were 21.92 and 23.27 for CG and EG respectively in total. In public high school, experimental group students benefited more from the instruction than control group students, and the related gain values were 1.09 and 0.22 respectively. Likewise, in the Anatolian high school, while the mean scores of gainclb values for control group students shows a decrease (-0.975), experimental group students gained from the treatment (2.500).

When the school by treatment interaction was considered, the results of the univariate ANOVAs revealed that the dependent variables of extrinsic goal orientation, task value, self-efficacy for learning and performance and test anxiety were significant ($p < 0.05$) indicating that there was a significant mean difference between experimental and control group students with respect to dependent variables of extrinsic goal orientation, task value, self-efficacy for learning and performance and test anxiety (Table 5.21). Since there is a significant treatment by school interaction with respect to students' perceived motivation of the above dependent variables, the syntax below is written.

```
GLM
  gainego gaintv gainse gainta BY treatment school
  /METHOD = SSTYPE(3)
  /INTERCEPT = INCLUDE
  /PLOT = PROFILE( treatment*school)
  /EMMEANS = TABLES(treatment) COMPARE ADJ(BONFERRONI)
  /EMMEANS = TABLES(school) COMPARE ADJ(BONFERRONI)
  /EMMEANS = TABLES(treatment*school) COMPARE (school)
ADJ(BONFERRONI)
  /EMMEANS = TABLES(treatment*school) COMPARE (treatment)
ADJ(BONFERRONI)
  /CRITERIA = ALPHA(.05)
  /DESIGN = treatment school treatment*school.
```

Table 5.22 presents the pairwise comparisons for treatment*school interaction for gainego, gaintv, gainse and gaintv values respectively.

Table 5.22 Pairwise comparisons for treatment*school interaction

Dependent Variable	School	Treatment		Mean Difference (I-J)	Std Error	Sig. (*p*)
Gainego	Public High School	EG (I)	CG (J)	-1.233	1.082	0.257
	Anatolian High School	EG (I)	CG (J)	3.365	1.474	0.024
Gaintv	Public High School	EG (I)	CG (J)	-0.506	1.512	0.738
	Anatolian High School	EG (I)	CG (J)	6.236	2.058	0.003
Gainse	Public High School	EG (I)	CG (J)	-1.073	1.695	0.528
	Anatolian High School	EG (I)	CG (J)	10.658	2.308	0.000
Gainta	Public High School	EG (I)	CG (J)	4.369	1.456	0.003
	Anatolian High School	EG (I)	CG (J)	-1.270	1.983	0.523

Table 5.22 shows that in public high school control group students gained more extrinsic goal orientation than students in experimental group. However, there was no significant mean difference between students in experimental and control group in terms of their gainego values in public high school. In Anatolian high school, the gainego values were higher in experimental group than control group students and there was a statistically significant mean difference between the groups in terms of gainego values ($p = 0.024 < 0.05$).

Similar to gainego results, control group students gained more task value construct than experimental group students in public high school but there was no significant mean difference between these groups of students in terms of gaintv values. On the other hand, in Anatolian high school experimental group students gained more task value construct than control group students in Anatolian high school. In addition, there was a significant mean difference between in experimental and control group students in terms of gaintv values ($p = 0.003 < 0.05$).

Table 5.22 indicates that though public high school control group students gained more self-efficacy for learning and performance than experimental group students did, there was no significant mean difference between both groups of students in terms of gainse values in this school. On the other hand, in Anatolian high school the mean difference between experimental and control group was on favor of the experimental group students. Moreover, there was a significant mean difference between experimental and control group students in terms of gainse values ($p = 0.000 < 0.05$).

In public high school, there was a statistically significant mean difference between experimental and control group students in favor of the experimental group students with respect to the gainta values ($p = 0.003 < 0.05$). As for the Anatolian high school, control group students had higher gainta values than experimental group students did but there was no statistically significant mean difference between these groups in terms of gainta values.

Table 5.23, presents the comparison of two schools in terms of the control and experimental groups by means of the gainego, gaintv, gainse and gainta values.

Table 5.23 Pairwise comparisons for treatment*school interaction

Dependent Variable	Treatment	School		Mean Difference (I-J)	Std Error	Sig. (*p*)
Gainego	CG	Anatolian High School (I)	Public High School (J)	-1.599	1.320	0.228
	EG	Anatolian High School (I)	Public High School (J)	2.999	1.265	0.019
Gaintv	CG	Anatolian High School (I)	Public High School (J)	-4.216	1.844	0.024
	EG	Anatolian High School (I)	Public High School (J)	2.526	1.767	0.155
Gainse	CG	Anatolian High School (I)	Public High School (J)	-3.929	2.068	0.060
	EG	Anatolian High School (I)	Public High School (J)	7.802	1.981	0.000
Gainta	CG	Anatolian High School (I)	Public High School (J)	4.470	1.776	0.013
	EG	Anatolian High School (I)	Public High School (J)	-1.169	1.702	0.493

The mean difference between Anatolian and public high school control group students with respect to gainego was in favor of the public high school students but there was no significant mean difference between control group students of these schools in terms of gainego values. On the other hand, there was a significant mean difference between experimental group students of Anatolian high school and public high school in favor of the Anatolian high school. As it can be seen from Table 5.23, control group students in public high school had higher gaintv values than those of Anatolian high school and there was a statistically significant mean difference between control group students in both schools. However, although there was a mean difference between experimental group students of Anatolian and public high school in favor Anatolian high school, there was no significant mean difference between experimental group of students in public and Anatolian high school. As for the gainse values, there was a significant mean difference between experimental group students of Anatolian and public high school in terms of their gainse values, and also there was a high mean difference between experimental group students of these two schools in favor of the experimental group students of Anatolian high school. On the other hand, control group students in public high school had higher gainse values than that of Anatolian high school but there was no significant mean difference between these groups of students in terms of gainse values in two schools. In addition, though experimental group students in public high school had higher gainta values than that of Anatolian high school, there was no significant mean difference between experimental groups of students in these schools in terms of gainta values. Nevertheless, there was a high mean difference between the control group students of two schools in favor of the Anatolian high school and there is a significant mean difference between the control group students of Anatolian high school and public high school. The below Figures of 5.2, 5.3, 5.4 and 5.5 also show the treatment by school interaction for gaingeo, gaintv, gainselp and gainta.

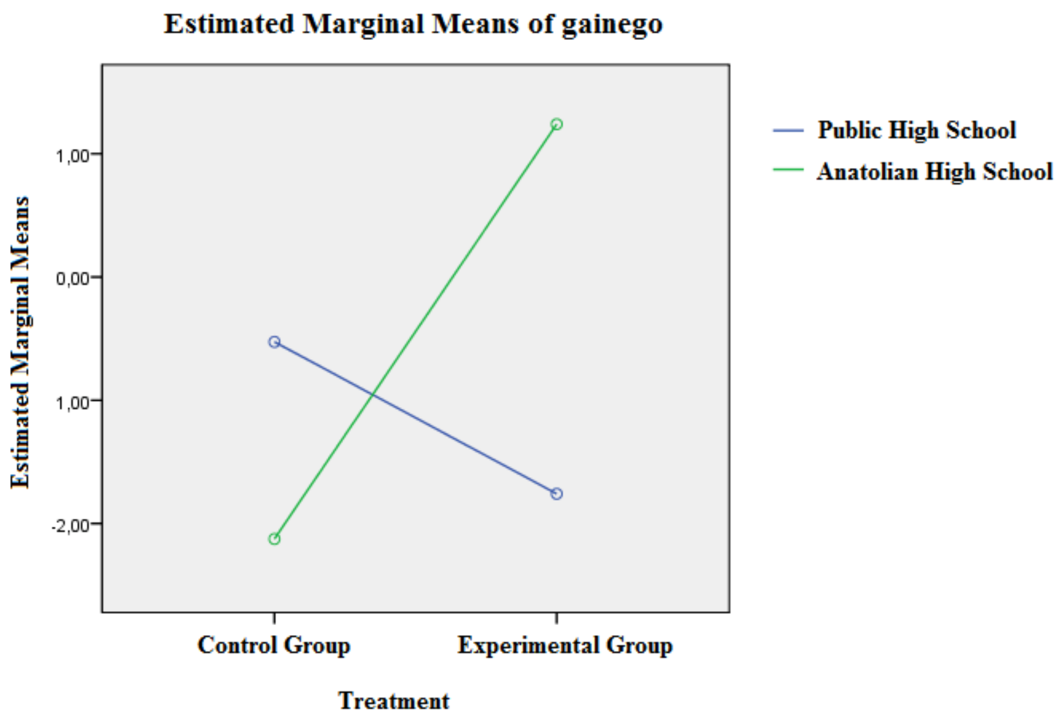


Figure 5.2 The graph of Treatment by School interaction for gainego value

The treatment by school interaction can be clearly seen from the above graph for gainego. Also, ANOVA results displayed the significant treatment by school interaction with respect to students' extrinsic goal orientation and this interaction accounted for about 5 % of variance in total. In public high school, neither the experimental nor the control group students positively gained from study (See Table 5.18). However, in Anatolian high school while the control group students did not gain positively (-2.125) from traditional instruction in terms of gainego, experimental group students gained (1.240) from the treatment. In addition, the Figure 5.2 shows the significant increase from control to experimental group in Anatolian high school.

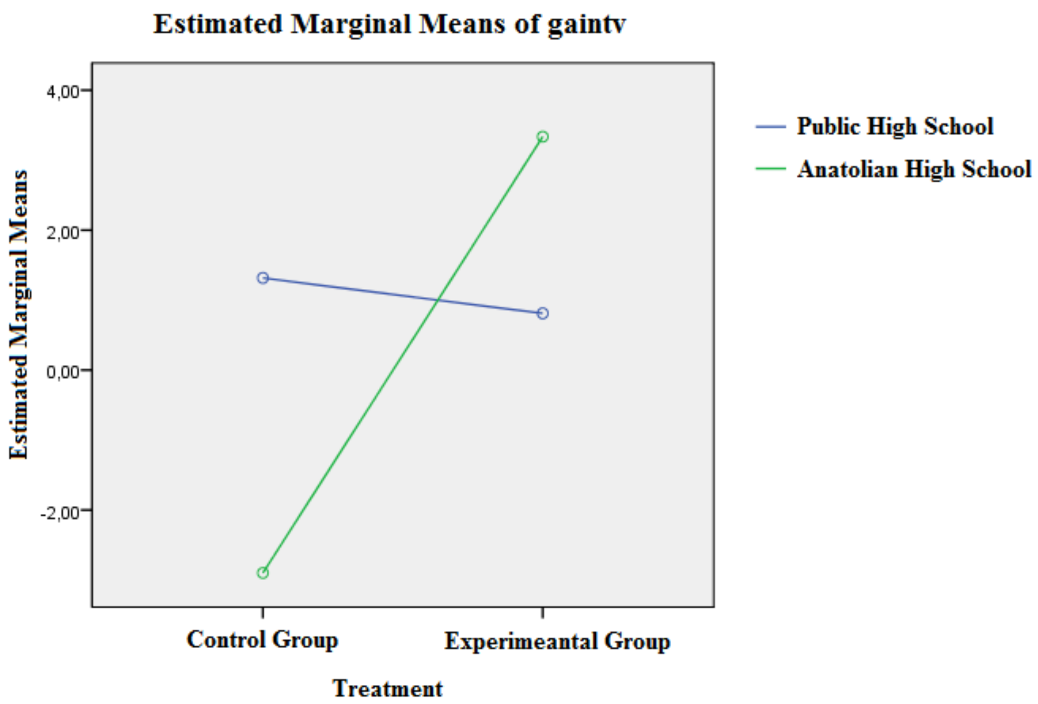


Figure 5.3 The graph of Treatment by School interaction for gaintv value

Similiarly, both the graph above and the related ANOVA outputs indicated the significant treatment by school interaction with respect to students' task value. And, this interaction accounted for 5 % variance in total. In public high school, both control (1.316) and experimental (0.810) groups gained from treatments, but there was a decrease in the mean scores of gaintv from control to experimental group in this school. On the other hand, though control group students did not gain from the traditional instruction (-2.900) in terms of task value scores in Anatolian high school, experimental group students gained from the treatment (3.336). Therefore, the line from control to experimental group indicates a sharp increase for Anatolian high school.

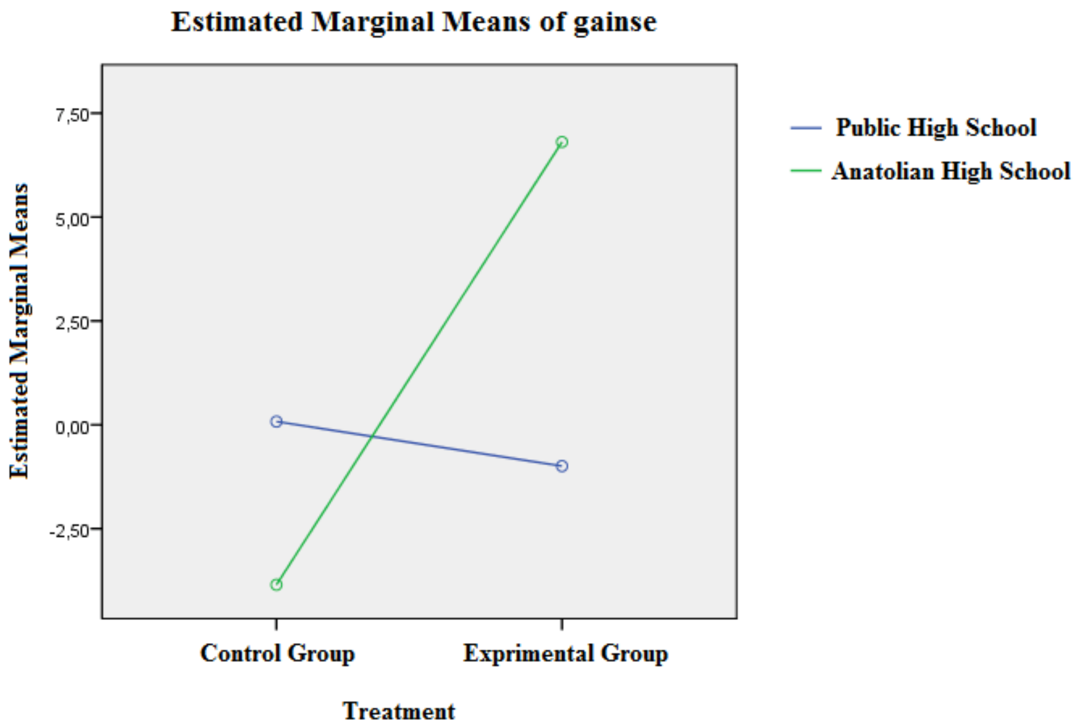


Figure 5.4 The graph of Treatment by School interaction for gainse value

Both the above graph and ANOVA results indicated the significant treatment by school interaction with respect to students' self-efficacy for learning and performance. Table 5.21 shows the partial-eta square value, the treatment by school interaction accounted for about 12 % of variance in total. In public high school, though the experimental group students did not benefit from the study in terms of gainse values, control group students gained from the treatment. The related mean values of gainse were -0.994 and 0.078 for experimental and control groups respectively. In contrary to these results, in Anatolian high school there was a distinct decrease in the mean scores of gainse in control group (-3.850), whereas there was a sharp increase in the mean scores of gainse in experimental group (6.808).

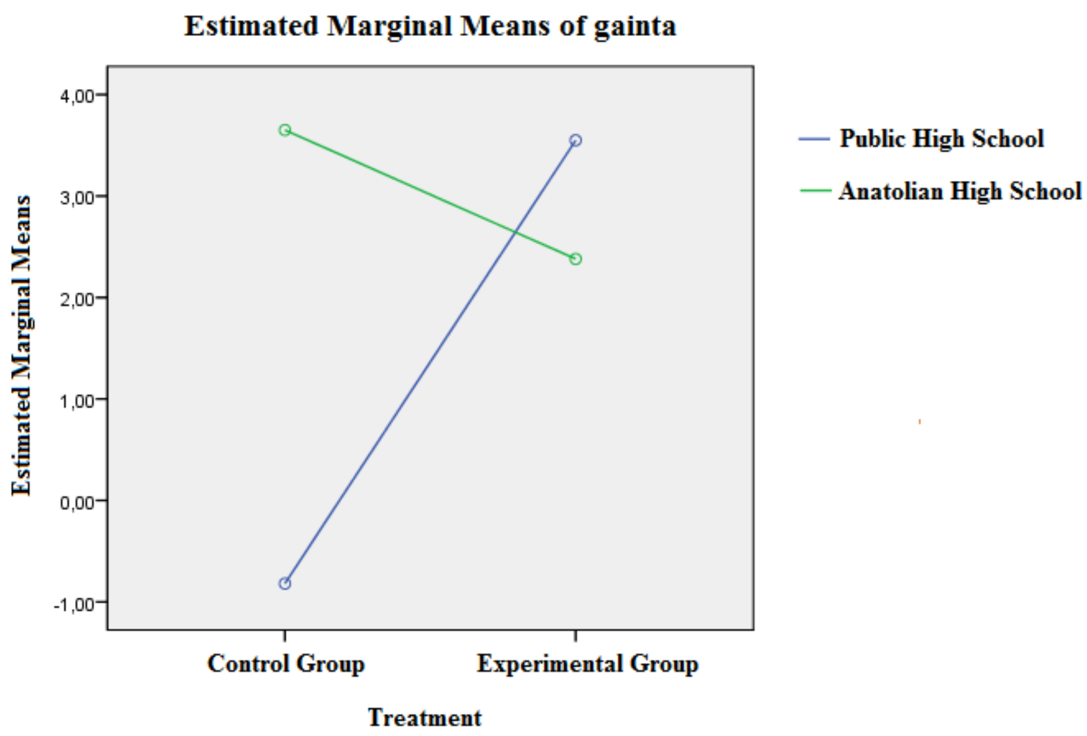


Figure 5.5 The graph of Treatment by School interaction for gainta value

The significant treatment by school interaction with respect to task anxiety can be seen both from the ANOVA results and the above graph and this interaction accounted for the 4 % variance in total. In Figure 5.5, in general while there was an increase in the mean scores of gainta in public high school, there was a decline in those scores in Anatolian high school from control to experimental group. In Anatolian high school, both control and experimental group students gained from the instruction in terms of gainta and 3.650 and 2.380 were the related gain values respectively for these groups. As for the public high school, while the mean scores of gainta decreased (-0.819) in control group students, there was an increase in those scores (3.549) in experimental group students.

Table 5.24 presents the percentages of agreement with the selected items for significant dependent variables such as extrinsic goal orientation, task value, self-efficacy for learning and performance, control of learning beliefs, and test anxiety across experimental and control groups in both schools.

Table 5.24 Percentages of responses to selected item of the EGO, TV, CLB, SELP and TV scale in both schools

Scale	Item No	Groups	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
EGO	13	CG	1.5	0.0	6.2	16.9	13.8	18.5	43.1
		EG	0.0	1.6	4.9	3.3	6.6	23.0	60.7
TV	4	CG	3.2	7.9	14.3	20.6	23.8	15.9	14.3
		EG	1.6	8.2	11.5	13.1	19.7	24.6	21.3
	26	CG	4.6	9.2	10.8	16.9	20.0	23.1	15.4
		EG	4.9	6.6	6.6	18.0	13.1	36.1	14.8
	27	CG	1.5	3.1	7.7	15.4	20.0	26.2	26.2
		EG	0.0	1.8	0.0	8.8	17.5	29.8	42.1
CLB	25	CG	4.7	1.6	6.3	23.4	25.0	12.5	26.6
		EG	1.6	3.3	11.5	6.6	27.9	21.3	27.9
SELP	20	CG	1.5	4.6	12.3	18.5	24.6	24.6	13.8
		EG	1.7	0.0	16.7	1.7	21.7	25.0	33.3
	29	CG	0.0	3.1	9.4	26.6	25.0	18.8	17.2
		EG	0.0	1.8	5.3	10.5	28.1	33.3	21.1
	31	CG	1.6	0.0	7.8	17.2	20.3	25.0	28.1
		EG	0.0	0.0	1.6	11.5	18.0	36.1	32.8
TA	3	CG	10.8	4.6	10.8	15.4	26.2	20.0	12.3
		EG	3.3	1.6	11.5	19.7	16.4	23.0	24.6

Higher scores in extrinsic goal orientation means, students engage in activities for some reasons such as grades, rewards, performance, evaluation by others, and competition (Pintrich et al., 1991). For example, the statement of item 13 “If I can, I want to get better grades in this class than most of the other students” rated as 6 and 7 indicates the agreement of this statement by 61.6 % of control group students while 83.7 % of experimental group students agreed with it. Moreover, the mean score of students’ task value was higher in experimental group students than that of control group students. In other words, experimental group students found the used instructional materials more interesting, important and useful than the control group students. For example, item 4 stating “I think I will be able to use what I learn in this course in other courses” was rated as 6 and 7 by 30.2 % control group students whereas 45.9 % experimental group students. Also, while the 50.9 % experimental group students agreed the item 26 stating “I like the subject matter of this course”, 38.5 % control group students held the same idea. In addition, the statement of item 27 “Understanding the subject matter of this course is very important to me” was rated as 6 and 7 by 52.4 % control group students whilst 71.9 % experimental group students chose this statement. Moreover, there was a significant mean difference between experimental and control group students with respect to their control of learning beliefs. In other words, experimental group students thought that their efforts to learn would bring positive outcomes (Pintrich et al., 1991). For instance, the statement of item 25 “If I don’t understand the course material, it is because I didn’t try hard enough” was agreed by 49.2 % experimental group students (rated as 6, 7), whereas the percentage of control group students that agree this statement was 39.1%. Furthermore, there was a significant mean difference between students in experimental and control groups in terms of their self-efficacy for learning and performance. Self-efficacy means students’ judgment and confidence in their skills to carry out the task and performance is particularly related to task performance (Pintrich et al., 1991). For example, item 20 stating that “I’m confident I can do an excellent job on the assignments and tests in this course and test” was rated as 6 and 7 by 38.4 % control group students and 58.3 % experimental group students. In addition, although the item 29 stating “I’m certain I can master the skills being taught in this class” was rated as 6 and 7 by 36 % control group students, 54.4 % experimental group students agreed with it. Besides, the statement of item 31 “Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class” was agreed by 53.1 % of control group students and 68.9 % of experimental group students. For test anxiety, the statement of item 3 “When I take a test I think about how poorly I am doing compared with other students” was rated as 6 and

7 by 32.3 % control group students with the agreement of 47.6 % experimental group students.

On the other hand, the results of ANOVAs indicated that there was no significant mean difference between experimental and control group students in terms of intrinsic goal orientation when the post-MSLQ scores of students from both schools were analyzed together.

5.3 Students' Misconception about Gas Concepts

GCT was administered to both experimental and control group students as pretest and posttest. This test was prepared to measure students' misconceptions and learning difficulties in the subject of gases including: (1) Properties of gases, (2) Volume of gases, (3) Kinetic Theory of gases, (4) Diffusion of gases, (5) Pressure of gases, (6) Gas Laws (Charles law, Boyle Marriott, Dalton, Avogadro, Gay Lussac), (7) Ideal Gas Law, (8) Partial pressure of gases. Students' misconceptions included in GCT were presented in Chapter 4, Table 4.2. As presented in Chapter 5, case-based learning based on conceptual change conditions resulted in better results in terms of students' motivation and attitude toward chemistry and overcoming misconceptions on the subject of gases compared to traditionally designed instruction. In the following sections, related misconceptions were examined in detailed via analyzing the answers given to GCT and interviews with students.

5.3.1 Analysis of Students' Responses to GCT

When experimental and control group students' responses were analyzed, remarkable differences were detected between the group answers for some of the items in GCT. Items 4, 6, 8, 9, 10, 11, 12, 13, 17, 19, 22, 23, 24, 25, 26 were the questions that students in experimental group outperformed the test with respect to the control group students. However, analysis of students' responses showed that 1, 14, 18, 21 numbered item results were in favor of the control group students. Figure

5.6 indicates the means of correct responses for each question in post-GCT for both experimental and control groups students.

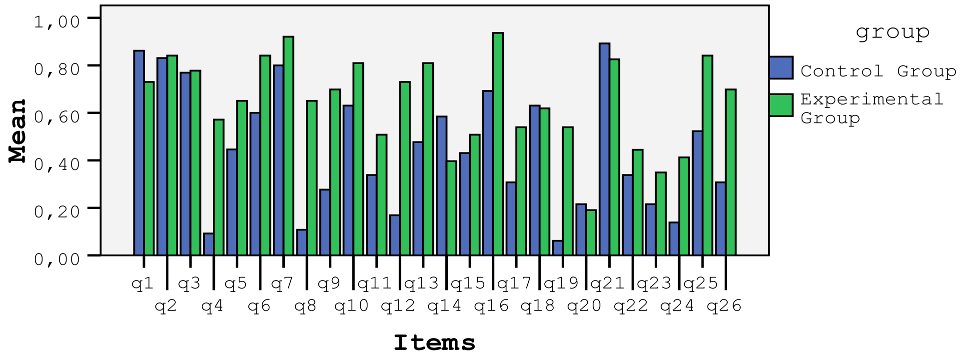
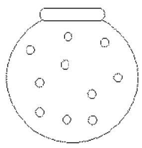


Figure 5.6 Means of Correct Responses versus post-GCT Items for Experimental and Control Groups

Item 4 was a conceptual problem not requiring mathematical calculation and it measured whether the gas particles expand when heated, and shrink when cooled. The percentages of students' selection of alternatives in the post-GCT for item 4 were represented in Table 5.25. As seen from this table, while 58.1% of the experimental group students answered this question correctly, 9.5% of the control group students answered this item as correct. However, 25.8% of experimental group students chose the alternative B as a correct answer, indicating that they still had the misconception that *when the gas in the container is cooled, each of the gas particles shrinks or gets smaller* (Brook et al., 1984; Novick & Nussbaum, 1981; Sanger et al., 2000). Moreover majority of the control group students, 42.9 % selected alternative E representing *when the gas is cooled, gas particles accumulated at the bottom of the container like liquids* however this alternative was chosen by 8.1 % of experimental group students. Minority of students, 4.8 % control group students and 3.2 % experimental group students, selected alternative C representing *when the gas is cooled, particles of gas are distributed homogeneously but the size of each particle increases.*

Table 5.25 Percentages of Students' Selection of Alternatives for Item 4

 The distribution of hydrogen gas molecules in a closed container at 25°C and 1 atm pressure was given in the next. (The circles (o) represent the distribution of hydrogen molecules.)**Which of the following diagrams illustrate the distribution of H_2 molecules when the temperature of the container is lowered to -15 ^oC?** (Note: Before responding to this problem students were told that at -15 ^oC hydrogen is still gas.)					
Percentages of Students' Responses (%)	*A)  ***Correct Alternative**	B) 	C) 	D) 	E) 
Control Group	9.5	27	4.8	15.9	42.9
Experimental Group	58.1	25.8	3.2	4.8	8.1

Item 6 was asked to explain the reason for the increasing pressure of gas when the gas is heated in a constant-volume container. The percentages of experimental and control group students' selection of alternatives in the post-GCT for item 6 was given in Table 5.26. As Table 5.26 indicates, most of the experimental (84.1 %) and control group students (60.9 %) selected the scientifically correct response as stating that *when the gas is heated in a constant-volume container*, *the number of collisions increase so do the pressure.* However, 25 % of students in control group believed that *when the gas is heated in a constant-volume container, gas particles condense in the wall of the container,* also 3.2 % of experimental group students thought like that (Alternative E). In addition, 3.1% of the control and 7.9% of experimental group students considered that *when the gas is heated, the size of the of gas particles increases* (Alternative A). Another misconception selected by minority of students from both groups was the *increase in the numbers of particles* and *gain in weight of the gas when the gas is heated* (Novick & Nussbaum, 1981).

Table 5.26 Percentages of Students' Selection of Alternatives for Item 6

When a constant-volume closed container filled with a gas is heated, increase in pressure is observed. **In which of following alternative explains the reason of this event most accurately?**	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Increase the size of gas particles	3.1	7.9
B) Increase in the numbers of particles when the gas is heated	6.3	1.6
C) Becoming heavier of the gas when it is heated	4.7	3.2
* D) Increase in the number of the collisions when the gas is heated *** Correct Alternative**	60.9	84.1
E) When the gas is heated, gas particles condense in the wall of the container	25.0	3.2

Similar to item 4, item 8 was a conceptual problem measuring the distribution of air in a constant-volume closed container when decreasing the temperature of the container. In addition, before responding to this problem, students were informed that at 0 ^{o}C air is still gas. The percentages of experimental and control group students' selection of alternatives in post-GCT for item 8 was presented in Table 5.27. Results indicated that though 66.1 % of the experimental group students selected alternative D, 10.8 % of the control group students selected this scientifically correct answer, which represents the homogeneous distribution of air with decreasing temperature. Most of the control group students (52.3 %) and some of the experimental group students (16.1) thought that *when decreasing temperature, air molecules are getting closer to each other and accumulated in the middle of the container* as figured in alternative C. The surprising answer was that none of the control group students but 8.1 % of the experimental group students selected alternative B figuring out that *air molecules accumulated at the top of the container with decreasing temperature.* On the other hand, 9.7 % experimental group students and majority of the 36.9 % control group students believed that *air molecules accumulated at the bottom of the container with decreasing temperature* as figured out in alternative E. None of the students from both experimental and control groups chose the figure represented in alternative A, *accumulating of air molecules on the walls of the container with decreasing temperature*.

Table 5.27 Percentages of Students' Selection of Alternatives for Item 8

A constant-volume container filled with air is placed into a bath and connected to a computer. Temperature changes are followed by a thermometer placed. Moreover, container is connected to device for measuring pressure and pressure can be read on the computer. The temperature of the bath is 25 °C and the pressure is 1 atm. The temperature of the container is reduced to 0 °C by adding ice into bath. After waiting to affect the temperature change on air particles, **which of the following diagrams shows the distribution of molecules within the container the best?** (Note: Before responding to this problem students were told that at 0 ^{o}C air is still gas.)					
Percentages of Students' Responses (%)	A) 	B) 	C) 	*D)  ***Correct Alternative**	E) 
Control Group	0	0	52.3	10.8	36.9
Experimental Group	0	8.1	16.1	66.1	9.7

Item 8 and item 9 were the sequential questions having the same question root. Item 9 was asked to measure the distribution of air molecules in a constant-volume container with increasing temperature. The percentages of experimental and control group students' selection of alternatives in post-GCT for item 9 was provided in Table 5.28. Scientifically correct answer, figured in alternative D, was the homogeneous distribution of air molecules even if the temperature is increased. When both group of students' answers were compared, large difference between experimental (71.0 %) and control (28.1 %) group students giving the correct answer was detected. When the students' responses were examined for each alternative, the frequency of selecting alternative A by the control group students (42.2 %) draws the attention. In other words, most of the control group students believed that air *molecules accumulates on the walls of the container with increasing temperature*. In addition, 28.1 % of the experimental and 17.7 % of the control group students thought that *with increasing temperature air molecules rises and accumulates at the top of the container.*

Table 5.28 Percentages of Students' Selection of Alternatives for Item 9

A constant-volume container filled with air is placed into a bath and connected to a computer. Temperature changes are followed by a thermometer placed. The temperature of the bath is 25 °C and the pressure is 1 atm. The temperature of the container containing gas is increased to 60 °C by heating the water bath with the help of heater. **In this case, which of the following diagrams shows the distribution of molecules within container the best?**					
Percentages of Students' Responses (%)	A) 	B) 	C) 	*D)  ***Correct Alternative**	E) 
Control Group	42.2	28.1	0	28.1	1.6
Experimental Group	9.7	17.7	1.6	71.0	0

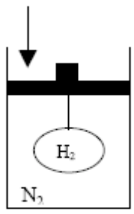
Related to item 9, item 10 aimed to investigate the distribution of air molecules when the constant-volume container connected to a balloon as shown in the figure in Table 5.29 is heated. The percentages of students' selection of alternatives for item 10 were indicated in Table 5.29. Scientifically correct answer was given in alternative C showing the homogeneous distribution of air within the container and the balloon even if the container was heated. Results indicated that the majority of experimental (81.0 %) and control (64.1 %) group students were aware of the homogeneous distribution of gases when the tap of the container connected to balloon is opened and the container is heated simultaneously. On the other hand, 3.2 % of experimental group and 14.1 % of the control group students selected alternative D repeating the misconception that *hot air increases.* These results of Item 10 supported the results of the item 9 in terms of risen of hot air towards the top of the container and the accumulation of gas molecules on the walls of the container with increasing temperature. Additionally, 9.5 % of experimental group and 14.1 % of the control group students selected the figure given in alternative B, which means they believed that some of the *heated air accumulated on the walls of the balloon*. Furthermore, minority of experimental and control group students thought that when the tap between the container and balloon is opened, most of the air molecules or all of them are transferred to the balloon.

Table 5.29 Percentages of Students' Selection of Alternatives for Item 10

A constant-volume container filled with air is connected to a balloon as shown in the figure.  When the tap of the container is opened and the container is heated, it is observed that balloon is swelling. **Which of the following illustrate the distribution of air the best after swelling the balloon?** (Dots (.) represent the molecules within air.)					
Percentages of Students' Responses (%)	A) 	B) 	*C)  ***Correct Alternative**	D) 	E) 
Control Group	4.7	14.1	64.1	14.1	3.1
Experimental Group	1.6	9.5	81.0	3.2	4.8

Item 11 was about the effect of changing pressure on an elastic balloon, the related figure was given in the Table 5.30. Scientifically correct answer was the increasing of pressure inside the non-constant volume container when movable frictionless piston is pushed towards the downward. And therefore, since the gases distributes homogenously wherever they are placed, the balloon inside the container shrinks from everywhere by the effect of increased pressure on it. The percentages of students' selection of alternatives for item 11 were represented in Table 5.30. 34.9 % of control group and 51.6 % experimental group students answered this question correctly. However, the striking percentages of students' selection of alternative A showed that 34.9 % of the control and 40.3 % experimental group students believed that when movable frictionless piston is pushed towards the downward, the elastic balloon explodes. In fact, they may think that when the pressure drops on the balloon, its volume increases and so it explodes. One of the reasons of selecting this alternative might be the daily life experiences because if someone compresses the balloon from one or two sides, it generally explodes. In addition, 11.1 % of control and 3.2 % of the experimental group students thought that balloon shrinks only from the sides when the piston is pushed towards downward. Similar percentages was for the alternative D which was the balloon shrinks only from the bottom, 12.7 % of control group students and 1.6 % of experimental group students selected alternative D. Minority of students from both groups considered balloon shrinks only from the upper.

Table 5.30 Percentages of Students' Selection of Alternatives for Item 11

As shown in the figure, nitrogen gas is found in the cylindrical container with movable frictionless piston. Hydrogen gas is found in the elastic balloon connected to cylinder by a steel rope. **If the cylinder is pushed downward without touching of elastic balloon to the surface of the vessel, what will be the shape of balloon?** 	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Balloon explodes.	34.9	40.3
B) Balloon shrinks only from both sides.	11.1	3.2
C) Only upper part of the balloon shrinks.	6.3	3.2
D) Only the bottom of the balloon shrinks.	12.7	1.6
*E) Balloon shrinks from everywhere. **Correct Alternative**	34.9	51.6

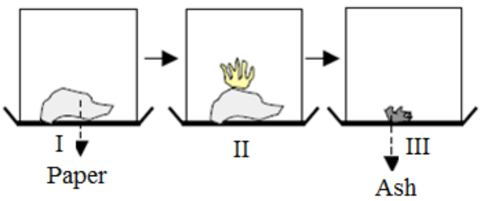
Item 12 was intended to ask what the students think about what exists among the particles of a gas. Since gas particles cannot be seen by naked eyes, different responses came from students. Scientifically correct answer should be "nothing" is found between the particles of a gas. The percentages of students' selection of alternatives for item 11 were given in Table 5.30. A big difference was detected between the two groups of students; while 74.2 % of experimental group students believed that there was nothing between the particles of a gas, 16.9 % of the control group students answered this question correctly. However, 55.4 % of the control group and 12.9 % of experimental group students believed that air is located between the particles of a gas (Novick & Nussbaum, 1978, 1981). One of the reason for choosing this option could be the finding of air in everywhere of the world. Therefore, they might think that air was found even within gas particles. Additionally, 21.5 % of control group and 8.1 % experimental group students believed that other gases exist between the particles of a single gas. Furthermore, some of the students from both groups believed that water vapor and foreign substances are located among the particles of a single gas. The most important reason to think like that might be the presence of other gases, water vapor and foreign substances in air if so, students could not see possibility of “nothing” among the particles of a single gas.

Table 5.31 Percentages of Students’ Selection of Alternatives for Item 12

What exists between the particles of a gas?	**Percentages of Students’ Responses (%)**	
	Control Group	**Experimental Group**
A) Air	55.4	12.9
B) Water vapor	4.6	3.2
C) Other gases	21.5	8.1
D) Nothing ***Correct Alternative**	16.9	74.2
E) Foreign substances (dust, dirt, etc.)	1.5	1.6

Item 13 was about the conservation of the mass of a gas. As shown in Table 5.32, a piece of paper is put in a closed glass container and left to burn. Glass container is weighted before burning, during the burning and after burning. The total mass stays the same because of the closed container. Therefore, scientifically correct answer was the equality of mass of each container actually depending on the law of conservation of mass. The percentages of students’ selection of alternatives for item 13 were presented in Table 5.32. 48.4 % of the control and 82.3 % of the experimental group students answered this question as correct. However, 25 % of control and 6.5 % of experimental group students thought that the closed container has the biggest mass in condition II. Alternative C was selected by 12.5 % of control group students and 1.6 % of experimental group students as correct mentioning the biggest mass in condition III. 10.9 % of students in control group and also 1.6 % of students in experimental group believed that container has the biggest mass in condition I. To sum up, although nearly half of the control group students and the majority of experimental group students answered the item 13 correctly, the chaos in students’ mind about whether the gases have mass or not is clearly seen by looking at the students’ responses except from the correct answer.

Table 5.32 Percentages of Students' Selection of Alternatives for Item 13

As shown in following figure, a piece of paper is put in a glass container in condition I. In condition II paper is burning and in condition III ash is formed. In all three cases, glass container is weighted. **Accordingly, which one of the following is true?** 	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Condition I has the biggest mass	10.9	1.6
B) Condition II has the biggest mass	25.0	6.5
C) Condition III has the biggest mass	12.5	1.6
D) I and II has the same weight and III is less	3.1	8.1
*E) All of them has the same mass **Correct Alternative**	48.4	82.3

Item 17 was related to the interpretation of what features of particles change during the transition of a pure matter in the phase of solid to liquid or liquid to gas at constant temperature. The correct answer was only the changing of distance between the particles during the transition of a pure matter in the phase of solid to liquid or liquid to gas. Size of the particles cannot change whether the temperature increased or decreased. In addition, average kinetic energy does not change unless there is any change in temperature. Results presented in Table 5.33 indicated that 56.5 % of experimental group students and 31.3 % of the control group students answered the question correctly by stating that the distance between particles will change during the phase transition. In contrary to this result, 50.0 % of the control and 37.1 % experimental group students thought that size of the particles, average kinetic energy and the distance between particles change in case of phase changes. Moreover, though none of the students in experimental group selected alternative D, 15.6 % of the students thought that both size of the particles and the distance between them alters during the phase transition of a pure matter.

Table 5.33 Percentages of Students' Selection of Alternatives for Item 17

At a constant temperature, during the transition of a pure matter in the phase of solid to liquid or liquid to gas, **which of the following features of particles will change?** I. Size II. Average Kinetic Energy III. The distance between particles	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Only I	1.6	1.6
B) Only II	1.6	4.8
*C) Only III ***Correct Alternative**	31.3	56.5
D) I and III	15.6	0
E) I, II and III	50.0	37.1

Item 19 was related to the properties of cold and hot air. As presented in Table 5.34, 54.8 % of experimental group students and 6.3 % control group students selected the correct alternative stating that hot and cold air may have different volumes but they have equal masses. On the other hand, majority of the control group students (48.4 %) believed that *while hot air particles expand, the cold air particles shrink*. Furthermore, 28.1% of the control and 30.6 % experimental group students had the common misconception that *hot air is lighter than cold air* whereas 12.5 % of the control group students and 1.6 experimental group students accepted that *hot air is heavier than cold air.* Minority of both group of students (% 4.7 of control group and 3.2% of experimental group) considered that *air has neither mass nor volume, whether it is hot or cold*.

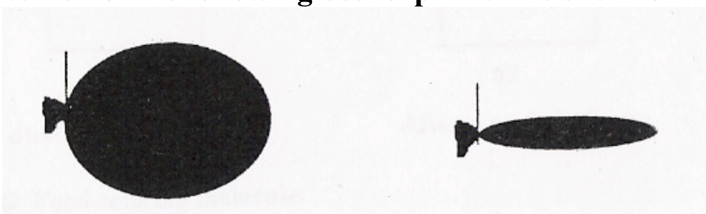
Table 5.34 Percentages of Students' Selection of Alternatives for Item 19

About the properties of cold and hot air which of the following statements is true?	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Hot air is lighter than cold air.	28.1	30.6
B) Hot air is heavier than cold air.	12.5	1.6
C) Air has neither a mass nor a volume either hot or cold does not matter.	4.7	3.2
*D) Hot and cold air may have different volumes but they have equal masses. ***Correct Alternative**	6.3	54.8
E) Hot air gas particles expand while cold air particles shrink.	48.4	9.7

In item 22, students were asked the reason to explain for collapsing of a balloon though its mouth was tightly connected. The scientifically correct answer is the escaping of gas from the pores of the balloon. As seen from Table 5.35 below, while 34.4 % of control group students gave correct answer, 45.9 % experimental group students answered this question correctly. Majority of the control (25.0 %) and experimental group (29.5 %) students believed that increased external pressure was the reason of decreasing the volume of the balloon. However, in order to change the external pressure on balloon, it should be taken to a location having different altitude and in item 22 there was no information about change in external pressure. In addition, some of the control group (26.6 %) and experimental group students (18 %) believed that *weather is cooled and the molecules in balloon were clustered due to it.* Cooling of weather might be the reason of shrinking or decreasing the volume of the balloon but the molecules in the balloon cannot be clustered somewhere upon cooling of weather which is the common misconception found in literature (Novick & Nussbaum, 1981). Moreover, some of the students in control group (12.5 %) and experimental group (6.6 %) thought that *energy of molecules are used up in time and their movements stop.* In this alternative, human or animal characteristics were assigned to the atoms but energy of atoms or molecules cannot be used up and their movements do not stop but just increase or decrease with the change of temperature.

None of the students in experimental group but 1.6 % control group students believed the idea that *the molecules inside the balloon are getting smaller as a result of collisions.*

Table 5.35 Percentages of Students' Selection of Alternatives for Item 22

A balloon made from rubber is filled with hydrogen gas and the mouth of it is tightly connected. However, after a few days later it is observed that balloon collapses. **Which of the following best explains this situation?** 	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) External pressure increases and the balloon gets smaller.	25.0	29.5
B) The molecules inside the balloon are getting smaller as a result of collisions.	1.6	0
C) The weather cools and the molecules in balloon are clustered.	26.6	18.0
D) Energy of molecules dissipated in time and their movements stop.	12.5	6.6
*E) The gas escaped from the pores of the balloon. ***Correct Alternative**	34.4	45.9

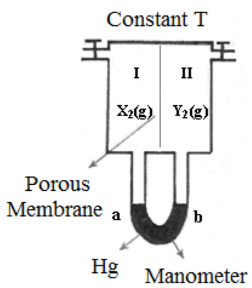
Item 23 was the one of the 1996 university entrance exam questions in the subject of chemistry in Turkey. This item aimed to make students use ideal gas law for two different gases containing the same kind of atoms. As seen from Table 5.36 below, 22.6 % control group and 35.5 % experimental group students thought that pressures of X_2 and X_3 gases are equal. However, the percentages of experimental (41.9 %) and control group (16.1 %) students choosing alternative B was remarkable. That means most of the experimental group students and some of control group students believed that densities of X_2 and X_3 gases are not different. In addition, most of the control group students (37.1 %) and a few number of experimental group students (6.5 %) thought that these gases have different numbers of moles though the equality in number of molecules was mentioned in item 23. So, the problem with the mole concept was clearly seen in this question. What is more, 17.7 % of the control group and 6.5 % of the experimental group students considered the average kinetic energy of these two gases as being different. These students were not aware of the fact that average kinetic energy of the gases depends on the temperature and at the same temperature, the average kinetic energy of gases are the same. In addition to these, some control (6.5 %) and experimental group (9.7 %) students selected the alternative C by stating that masses of these two gases are the same. One of the reasons for selecting this option might be the thought that gases with the same kind of atoms have the same atomic mass.

Table 5.36 Percentages of Students' Selection of Alternatives for Item 23

In the ideal behavior of X_2 and X_3 gases' temperature, volume and number of molecules are equal. **Which of the following comparison is wrong about these gases?**	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
*A) Pressures are different ***Correct Alternative**	22.6	35.5
B) Densities are different	16.1	41.9
C) Masses are different	6.5	9.7
D) The same number of moles	37.1	6.5
E) The same average kinetic	17.7	6.5

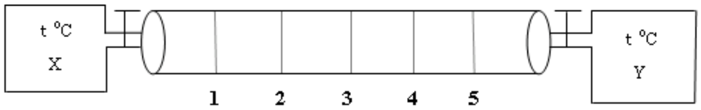
Item 24 was one of the 2001 university entrance exam questions in the subject of chemistry in Turkey. It was aimed to make the students think about both diffusion of gases through a porous membrane and gas laws. The reason for increasing mercury level in arm "a" is due to the increase in pressure in compartment II. Since the volume and temperature are equal for compartment I and II, changes in the number of moles is the only reason for pressure change. Both X_2 and Y_2 gases passes through a porous membrane but X_2 gas should be faster than Y_2 gas in order to increase the pressure of compartment II. That is, diffusion rate of X_2 is bigger than the Y_2. Therefore, it can be concluded that since the temperature is equal, molecular weight of X_2 is smaller than Y_2. As the Table 5.37 below reveals, 44.1 % of experimental group students and 15.5 % control group students answered this question correctly. On the other hand, some of the control group (39.7 %) and experimental group (32.2 %) students selected alternative D, these students did not think about the possibility of diffusion of the gases through the porous membrane. In addition, some of the students from control (13.8 %) and experimental group (16.9 %) students connected the relationship between the increase in pressure and diffusion of gases through membrane but they did not establish the relation between rate of diffusion and molecular mass. Alternative B was selected by a significant part of the students in the control group (25.9 %). According to them, the reason for a rise in the arm "a" was connected only to the molecular mass. Though few number of students from both control (5.2 %) and experimental (1.7 %) group compared the diffusion rates correctly, they could not establish other connections for the given system.

Table 5.37 Percentages of Students' Selection of Alternatives for Item 24

 As shown in figure, a container is separated into compartments I and II with a porous membrane and connected to a manometer. Being equal the levels of mercury in the arms of the manometer, compartment I is filled with X_2 gas and compartment II is filled with Y_2 gas. At the same temperature, after a short period of time it is observed that the level of mercury in arm "a" increases. **According to this observation, about the X_2 and Y_2 gases,** I. X_2 molecules are faster than Y_2 molecules. II. Molar mass of Y_2 is more than that of X_2. III. During the observation, total pressure of compartment II is increased. **Which of the above statements is true?**	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Only I	5.2	1.7
B) Only II	25.9	5.1
C) I and III	13.8	16.9
D) II and III	39.7	32.2
*E) I, II and III ***Correct Alternative**	15.5	44.1

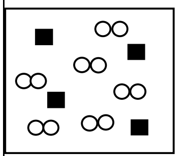
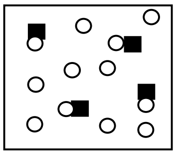
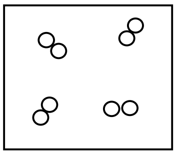
Unlike item 24, item 25 was a kind of question often encountered in textbooks about the diffusion of gases. X and Y gases with same temperature were left to diffuse toward each other and met at the 5th section of the tube. As seen from the Table 5.38 below, nearly half of students from control group (52.3 %) and majority of the experimental group students (84.1 %) did answer the question correctly. None of the experimental group students and some of the control group students (23.1 %) could not establish the connection between molecular weight and diffusion rate. Alternative A was selected by 12.3 % control and 3.2 % experimental group students, these students could not think the effect of temperature on diffusion rate of gases. Some of the students from control group (10.8 %) and experimental group (6.3 %) could not think the effect of temperature on the diffusion rate of gases and they had the wrong conception about the relationship of molecular weight of gases with their diffusion rates. In addition, alternative D was selected by minority of control (1.5 %) and experimental group (6.3 %) students.

Table 5.38 Percentages of Students' Selection of Alternatives for Item 25

 **As shown in figure, X and Y gases are left to diffuse toward each other and as they come across at the 5^{th} section of the tube,** I. The diffusion rate of X is more than Y. II. Molecular weight of X is more than Y. III. Y gas container must be heated for encountering of both gases in the middle of the tube. **Which of the statement(s) is true?**	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Only I	12.3	3.2
B) I and II	10.8	6.3
*C) I and III ***Correct Alternative**	52.3	84.1
D) II and III	1.5	6.3
E) I, II, III	23.1	0

Item 26 was related to the partial pressure concept of gases. A mixture of helium and oxygen gases was figured in a closed container and students were asked to select the correct figure that represents the partial pressure of oxygen gas. As Table 5.39 below indicates, majority of experimental (71.0 %) and some control group (32.8 %) students gave the correct response by selecting the container including only oxygen molecules. On the other hand, mixture of oxygen and helium gases, alternative A was chosen by most of the students in control group (31.1 %) and some of the students in experimental group (17.7 %). Some of the control group (23 %) and experimental group (4.8 %) students thought that, despite helium being an inert gas, oxygen and helium gases react with each other and some amount of oxygen atoms remains in the container. Some of the students from both groups thought the partial pressure of oxygen gas as the homogenously distributed oxygen atoms, not the molecules and so decided to choose the figure given in alternative C.

Table 5.39 Percentages of Students' Selection of Alternatives for Item 26

The following closed container, as shown in picture, contains a mixture of oxygen ( ) and helium ( ) gases at 25 ^oC. **Which one of the following is the partial pressure of the oxygen gas?**					
Percentages of Students Responses (%)	A) 	B) 	C)	*D) ***Correct Alternative**	E) 
Control Group	31.1	23.0	11.5	32.8	1.6
Experimental Group	17.7	4.8	4.8	71.0	1.6

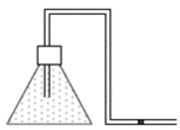
As the Figure 5.6 above indicates, percentage of correct answers given by control group students for the items 1, 14, 18, 21 were more than the students in the experimental group. For example, item 1 was about the general properties of gases. As seen from the Table 5.40 below, indicating the percentages of students' selection of alternatives for item 1, majority of control group (86.2 %) and experimental group (73 %) students was aware that there are almost non-existing forces between gas particles. On the other hand, some of the experimental group (11.1 %) and control group (4.6 %) students believed the idea that *gas pressure depends on type of the gas particles and number of atoms contained in the gas*. Moreover, minority of the control (3.1 %) and experimental (11.1 %) group students thought that there was a direct relationship between the molecular weight of the gases and their volumes. In addition to these, approximately the same percentages of control (4.6 %) and experimental (4.8 %) group students considered that *gas particles are getting smaller from the state of gas to liquid or liquid to solid*. None of the experimental group students but 1.5 % of control group students selected the alternative A, stating that *gas pressure is downward* although gas pressure is towards each direction.

Table 5.40 Percentages of Students' Selection of Alternatives for Item 1

Which of the following is true about the gases?	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Gas pressure is downward.	1.5	0
B) Gas particles are getting smaller during the transition from the state of gas to liquid or liquid to solid.	4.6	4.8
*C) There are almost non-existing forces between gas particles. ***Correct Alternative**	86.2	73.0
D) Gases occupy different volumes according to their molecular weights.	3.1	11.1
E) Gas pressure depends on type of the gas particles and number of atoms contained in the gas.	4.6	11.1

In item 14, the pressure of glass container containing mercury was changed by changing the temperature of its environment. It was expected from students to predict the direction of the mercury drop depending on the pressure change of the given system (Figure on Table 5.41). As seen from the Table 5.41, most of the control (62.3 %) and some experimental group (42.6 %) students gave correct answer by stating the way of movement as a result of decreasing pressure within the container with decreasing temperature. Many of the students in experimental group (41.0 %) compared to control group (4.9 %) selected alternative D. They considered the direction of the mercury droplet to the right since pressure inside the container decreases due to decrease in temperature and increase in volume. Although the glass container was specified, most of the experimental group students considered the change in the volume of the system since the pressure inside the container decreases. Some of the control (19.7 %) and experimental group (4.9 %) students thought that mercury droplet moves towards to right since with decreasing temperature, volume of the container decreases and so pressure increases. Like many students in both groups, these students believed that when the temperature changes, volume of the gases changes regardless of the given system. In addition, some students in both groups (6.6 % control group and 9.8 % experimental group) considered that the mercury droplet does not move as long as the external pressure or air pressure remains the same.

Table 5.41 Percentages of Students' Selection of Alternatives for Item 14

In the system, there is a drop of mercury in the glass container. The mercury drop moves to the right or left depending on the pressure and temperature change inside the glass container.  If the apparatus of the room temperature (25 ^{o}C) is taken to an environment 5 ^{o}C, **which of the following is correct regarding to the movement of the mercury?**	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) Remain moveless because air pressure is constant.	6.6	9.8
B) First it moves to left, and then it moves to right.	6.6	1.6
*C) Moves to the left, the pressure decreases within the container with decreasing temperature. ***Correct Alternative**	62.3	42.6
D) Moves to the right, the pressure inside the container decreases with decreasing temperature and volume increases.	4.9	41.0
E) Moves to the right, with/in decreasing temperature volume decreases and pressure of the container increases.	19.7	4.9

Item 18 was also related with the properties of gases. Table 5.42 representing the percentages of students' selection of alternatives for item 18 indicates that majority of students from both control (68.3 %) and experimental group (62.9 %) believed that diffusion rate of gases decreases with increasing molecular weight at the same temperature. On the other hand, a significant part of students in both groups (20 % control and 24.2 % experimental group) thought that average kinetic energy of the all gases is not equal at the same temperature. Some of the control (8.3 %) and experimental group (11.3 %) students were not aware of the fact that gas pressure depends on the number of particles in unit volume. Minority of students believed that gases do not have particulate structure. One of the reasons for this idea might be the invisibility of many gases with naked eye; so some students may not think about the particulate structure of the gases. Moreover, none of the students in both groups marked the alternative B as wrong stating the homogeneous distribution of the gases in the container in which they are present.

Table 5.42 Percentages of Students' Selection of Alternatives for Item 18

Which of the following statements is wrong about gases?	**Percentages of Students' Responses (%)**	
	Control Group	**Experimental Group**
A) They have a particulate structure.	3.3	1.6
B) Gases are distributed homogeneously in the container in which they are present.	0.0	0.0
C) Gas pressure depends on the number of particles in unit volume.	8.3	11.3
D) At the same temperature, average kinetic energy of all gas is the same.	20.0	24.2
*E) At the same temperature, when the molecular weight of gases increases their rate of diffusion increases. **Correct Alternative**	68.3	62.9

Another question about the properties of the gases was the item 21. As seen from the Table 5.43 below, a large part of the control (90.6 %) and experimental (82.5 %) group students know that gases are not located at the bottom of the container when they are placed in a closed container. However, as mentioned before, in item 8 and 9 when the temperature of the gases changes, they believed that gases are accumulated in somewhere in the container such as at the bottom, in the middle or on the walls of the container. Some of the students (4.7 % in the control group and 4.8% in the experimental group) believed that *gases cannot be liquefied*. Moreover, 1.6 % control group students and 4.8 % experimental group students thought *gases have a certain order of movement, they do not move randomly*. In addition to this, 1.6 % of experimental group students do not believe the continuous movement of gas particles.

Table 5.43 Percentages of Students' Selection of Alternatives for Item 21

Which of the following statements about the properties of gases is wrong?	Percentages of Students' Responses (%)	
	Control Group	**Experimental Group**
A) Gases can be liquefied.	4.7	4.8
B) Gas particles are constantly in motion.	0.0	1.6
*C) When gases are placed in a container, gas particles are located at the bottom of the container as liquids. ***Correct Alternative**	90.6	82.5
D) The forces between gas particles are weak as almost non existing.	3.1	6.3
E) Gas particles move randomly, there is no certain order of movement.	1.6	4.8

5.3.2 Interviews

In this study, semi-structured interviews were conducted with a total of sixteen 10^{th} grade students from both experimental and control group. Eight students from experimental group and eight students from control group were selected with the technique that Thompson and Soyibo (2002) used in their study in order to categorize students' achievements using their posttest means and standard deviations. In each group of students, one high achiever, two medium achievers and one low achiever generated interview sample of the present study. Students having the scores at least one standard deviation above the mean were chosen as high achievers whereas students scoring at least one standard deviation below the mean were selected as low achiever. On the other hand, students chosen medium achievers had the scores within one standard deviation below and above the mean. The purpose of conducting interviews was to probe the questions asked in the concept test and to get deeper information about students' reasoning of gas concepts. The concept test items were asked during the interviews, no additional questions were prepared. The subjects were coded similar to coding system that Nakhleh and Mitchell (1993) used in their study. The subject code (e.g. EG.HA.23) shows the students' place in the interview schedule as experimental group (EG) and control group (CG) as well as his/her achievements such as high achiever (HA) or low achiever (LA). The number 23 in the example, which refers to the student number during data coding, does not show their rank of success in class. All the interviews conducted with both groups of students were given in Appendix J. Some of the quotations from interviews were presented below:

Properties of Gases-Volume versus molecular weight of the gases

Students were asked whether gases occupy different volumes or not according to their molecular weights.

EG.MA.01: Gases do not occupy different volumes related to their molecular weight. Actually it is about the volume, since the molecules of gas are lighter, they can be found in anywhere in the container. If the molecules were heavier, they would sink to the bottom. It was something like that.

CG.HA.20: No, they do not occupy. They take the volume of the container in any way. Molecular weight is influential in diffusion rate. When using the formula of PV=nRT, volume has no relation with the molecular weight.

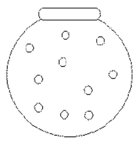
CG.MA.08: Do not occupy….(Hesitating...) I think it does not have any relation to molecular weight. I do not think that molecular weight affects the volume of the gases.

EG.LA.22: Yes, I think since the molecular weights are different from each other, they occupy different volumes.

The answers showed that most of the control group and some of the experimental group students thought that gases do not occupy different volumes according to their molecular weights. However, it was noticed that both group of students could not provide further reasoning why the volume of the gases do not depend on their molecular mass. Moreover, some of the students from both groups did not report any comments.

Properties of Gases - The distribution and the size of gas particles in a container at low temperature

The distribution of hydrogen gas molecules in a closed container at 25°C and 1 atm pressure was given in the next. Students were asked to select the correct distribution of H_2 molecules when the temperature of the container is lowered to -15 ^oC and it is mentioned that at -15 ^oC hydrogen is still gas.



EG.MA.19: The distribution of gas particles remain the same even if the temperature of the gas is lowered.

EG.LA.16: I thought there would be an expansion and the particles are getting larger and the distance between the particles decrease. I am not sure whether the gas particles accumulate in bottom when they are cooled.

CG.MA.17: When the temperature is decreased, gas particles move down. I thought that they should be accumulated at the bottom of the container. The particles which probably could have been solid become larger then it is supposed to take the shape of the container.

CG.HA.20: I thought since the volume decreases, the distance between the particles may decrease. Moreover, I thought that the molecules slow down and come closer to each other and the particle size does not change.

The interviews indicated that nearly half of the experimental group students but none of the control group students answered this question correctly. Some of the control and experimental group students thought that the size of the particles decreases with decreasing temperature and particles sink to the bottom as well. Moreover, some of them supposed that the size of the particles increases owing to the lowering of the temperature and decrease in the distance between gas particles because small molecules forms big ones by coming together. Though students were told that at -15 ^{o}C hydrogen is still gas, they believe that phase change always occurs with decreasing temperature. Interestingly, one of the experimental group students stated that gases are distributed homogeneously in a closed container however in atmosphere, warm air rises and cold air sinks to the bottom.

> *Gas properties - The distribution of air molecules at room temperature (25 °C), 0 °C, and 60 °C*
>
> *Students were asked to choose the diagrams that show the distribution of air molecules at 25 °C, 0 °C, and 60 °C implying that at these temperatures air is still gas (Please see questions 7, 8 and 9 in GCT).*
>
> *EG.MA.01: 25 °C is a room temperature; the gases are distributed equally within the container. At 0°C, they are dispersed homogeneously everywhere. When the gas is cooled down, the pressure must decrease but their distribution should not change. The pressure exerted on the walls of the container decreases, the speed of particles decreases.*
>
> *CG.MA.03: When the temperature is lowered, the particles move towards the bottom. The gas particles condense on the walls of the container when the gases are heated because the middle part of the container will be firstly affected from the heat since the heat is given from below. Hence, the rate of collision of particles onto walls increases.*
>
> *CG.MA.08: At 25 °C ,gas particles are homogeneously distributed in the container. When the temperature is lowered to 0 °C, they accumulate in the middle not in the bottom because gravitational force has no effect on them. When the temperature is increased to 60 °C, it means that temperature is too high, the speed of gas molecules increases and they make more pressure towards the walls of the container.*

EG.HA.02: Gases are not gathered in one place, since we do not see gases we cannot imagine their distribution but I think whatever the temperature is, they are homogenously distributed.

The answers indicated that almost all the experimental group students understood that gas particles are homogeneously distributed at 25ºC. On the other hand, some of the control group students believed that the gas particles condense in the walls of the container at the room temperature (25 ºC). As for the cooling of gas, most of the control group students believed that gas particles are collected in the middle of the container due to some reasons like temperature is not too cold for sinking, gravitational force has no effect on them, or they stick to each other when cooled down. A few of the experimental and control group students thought that gas particles sink to the bottom of the container when the temperature is lowered to 0 ºC. Moreover, one of the interesting answers came from experimental group lower achiever student; he stated that *"When the gas is cooled down, the gas particles move towards the upper part of the container since the upper part remains warm, the particles move towards upward".* When the temperature is increased to 60 ºC, about half of the experimental and control group students thought that gas particles may condense on the walls of the container. They mainly think that when the temperature is increased, gas particles move away from each other, they are pushed towards the sides of the container and so the pressure increases. Increasing pressure in the container leads students to have the idea that gas molecules may condense on the walls of the container. One of the control group medium achiever expressed the accumulation of particles on the walls like that *"The gas particles condense on the walls of the container when the gases are heated because the middle part of the container will be firstly affected from the heat since the heat is given from below".*

Properties of Gases - The distribution of the air in a constant volume container

A constant-volume container filled with air is bonded to a balloon as shown in the figure. When the tap of the container is opened and the container is heated, it is observed that balloon is inflated. Students were

asked to predict the distribution of air after inflating the balloon. (Dots (.) represent the molecules within air.)

EG.MA.19: Gases are homogeneously distributed throughout the container and the balloon.

EG.MA.01: After opening the tap of the container, gases are homogeneously distributed both in the container and in the balloon.

CG.MA.03: The number of gas particles would be the same in proportion. They need to be equal, need not it...I do not know I am not sure.

CG.LA.08: Since the gas particles are heated, they inflate the balloon distributing into it. Gas particles gather on the walls of the balloon, because pressure increases inside the container with increasing temperature. The accumulation occurs on the walls of the balloon since gas particles are pushed towards it.

As understood from the answers, most of the experimental group and some of the control group students recognized that gas particles are homogeneously distributed throughout the container and the balloon. However, it was noticed that most of the control and some of the experimental group students thought that the gas particles inside the balloon gather on the walls of it due to increase in pressure or inflation of the balloon. One of the control group students considered that gas is homogeneously distributed throughout both the container and the balloon because temperature does not rise too much.

Properties of Gases - What is present among the particles of a gas

Students were asked what is found among the particles of a gas.

EG.MA.01: We are talking about a gas and there is nothing among the molecules of a gas other than its own molecules.

CG.HA.20: I thought it by reasoning the air or atmosphere. I do not think that nothing is found, there are absolutely other gases among the particles of a gas. I am not sure about the foreign substances...

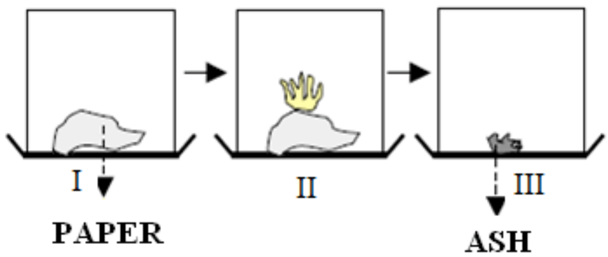
CG.MA.18: Air must be found among the gas particles since it is available in everywhere.

EG.LA.22: I think there is nothing among the particles of a gas because the particles belong to one kind of matter. Since they are only one kind of matter, there is nothing between them.

The answers indicated that most of the experimental group students knew that there is nothing between the particles of a gas. On the other hand, most of the control group students and a few of the experimental group students believed that since air is available in everywhere, it might be present among the particles of a gas.

Properties of Gases - Whether the gases have mass or not

As shown in the following figure, a piece of paper is put in a glass container in condition I. In condition II paper is burning and in condition III ash is formed. In all three cases, glass container is weighted. Students were asked to compare the mass of the containers.



EG.MA.01: All of them have equal mass due to the law of conservation of mass in chemical reactions. In this situation, there is a burning reaction, the *mass of paper decreases in time but the gas is released and since the reaction occurs in the closed container, the total mass is conserved.*

CG.MA.17: In condition III, the container is the heaviest due to the fact that it contains gas. Paper is not a heavy substance, and when it is in gas state it accumulates, so it is likely to make an effect on the pressure. The pressure would affect the mass of the container, but we cannot measure the pressure within the container and I think the mass of the container increased.

CG.HA.17: Total mass is not affected from decrease in solid mass. CO_2 *is released generally from the burning reactions but I do not know whether the gases have mass or not.*

EG.MA.04: In condition I, the mass of the solid is bigger, in II there is both mass of solid and CO_2 *and in III there is only the mass of* CO_2*. Therefore, I thought that I and II have equal mass and they are bigger than III.*

As understood from the answers, most of the experimental group students had better understanding that the total mass is conserved as a result of the burning of paper in a closed container. They expressed their reasoning by means of the law of conservation of mass in chemical reactions. However, some of the control group students and a few of the experimental group students believed that the total mass of the container is the smallest in condition III because they only paid attention to the picture ignoring the chemical reaction inside the container so their answer was, I=II > III. In addition to these, according to some control group students, condition III has the biggest mass due to the increase in pressure in the container.

Properties of Gases - Hot and Cold Air

Students were asked to compare the size, volume and the mass of the hot and cold air.

EG.MA.19: Hot air is lighter than cold air because the mass decreases as the temperature increases, hot air becomes lighter. In fact, I thought that in summer electric wires are loose in summer but stretch in winter. I think it is more meaningful that volumes of hot and cold air are different but they have the same mass.

CG.MA.03: I think that hot air is heavier than cold air. I think from the example that foots of the mountain are hotter, we feel the cold air more as getting upper and at the top it is seen that snow does not melt easily in any way therefore at the lowers there is hot air, at uppers there is cold air. Hot air is at the lower part because hot air is heavier than cold air.

CG.HA.17: Hot air is lighter than cold air because speed of gases increase with increasing temperature. In order to be faster, hot air molecules must be lighter and smaller than the molecules of cold air. The gas particles may expand or shrink but I am not sure about this.

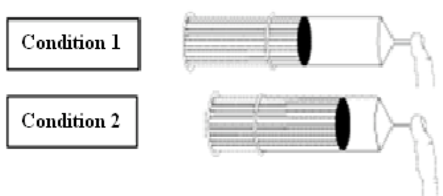
EG.LA.22: Hot air is heavier than cold air because electric wires become straight in winter while they are looser in summer from this point I think hot air is heavier than cold air. In addition, hot air particles may expand and cold air particles may shrink.

EG.MA.04: "Hot air is lighter than cold air", I remember this from geography lesson. Hot air particles rise and they are lighter than the ones in cold air, since they are distant from each other. Cold air particles shrink and go down and they are heavier than hot air. There will be no change in the size of the particles.

As understood from the interview results, "*Hot air is lighter than cold air*" is a common misconception and it is resistant to change. Apart from some students from the experimental group, none of the students thought that hot and cold air have the same mass but different volume. Students generally believe that particles of hot air must be lighter than the cold air gas particles. In addition, some of the students claimed that warm air rises and cold air sinks. An ordinary example from geography lesson or daily life may have caused students think like that. On the other hand, some students from both groups thought that hot air is heavier than cold air due to daily life experiences. Two experimental group students thought that since the electric wires are loose in summer and stretch in winter, hot air is heavier than cold air. Additionally, one of the control group students stated, "*Hot air is heavier than cold air. I think from the example that foots of the mountain are hotter, we feel the cold air more as we get upper and at the top it is seen that snow does not melt easily in any way therefore at the lower part of the mountain, there is hot air, at uppers there is cold air. Hot air is at lowers because hot air is heavier than cold air*".

Pressure of Gases – The effect of gas pressure on the particles of a gas

At constant temperature and pressure, the piston of the syringe containing an amount of air (condition 1) is pushed a bit and the air inside is compressed (condition 2). Students were asked to find the truth about the gas particles forming air after compression.



G.MA.01: Particles do not stick to each other but the distance between them decreases. Gas particles do not explode due to high pressure.

CG.LA.42: If all the particles are gathered at the mouth of the syringe, they will also stick to each other. I do not know whether they stick to each other or not. There is no relation between the size of the particles and the volume because only the place of the particles is changed. I do not know whether they may explode or not. The distance between them decreases.

EG.LA.22: The size of the particles does not change since there is no relation between the applied pressure and the particles. I think that the particles do *not stick to each other but the distance between them decreases. I am not sure whether the particles explode.*

EG.MA.11: The particles do no stick to each other but the distance between them decreases. They may explode also. Definitely, the size of the particles decreases.

The findings indicated that almost all the students from both experimental and control group agreed that the distance between particles decreases with the decrease of the volume. However, half of the students from control group and a few of the students from experimental group thought that gas particles might stick to each other due to the compression in the syringe. In addition, some of the students from both experimental and control group stated that gas particles might explode due to increase in pressure. On the other hand, though a few of the students from both groups were not sure whether the sizes of the particles change or not, most of them thought that, the size of the gas particles does not change due to the constant temperature.

Pressure of Gases - Gas pressure in a constant volume container

Students were asked whether the gas pressure is equal all over the container or not.

EG.HA.23: The pressure of gas is the same all over the wall of the container. The pressure of the gas in the base of the container is more than the pressure on the sides of the container.

EG.LA.16: The temperature of the container may not be the same all over the container for instance if the heat comes from the bottom it means that the particles collide faster upward and so it makes the pressure more upward than the right and left sides of the container.

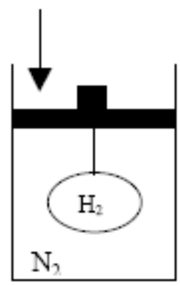
CG.MA.17: "The number of the particles striking to the surface of the container in each unit is the same" actually it can be true because it is meaningful if they are homogenously distributed in the container. Depending on the temperature, gases may condense at different points in the container. If the temperature is the same all over the container, the number of collisions becomes equal and so does pressure. If temperature is increased, gas accumulates at the top of the container and pressure increases upward.

CG.HA.20: Since the pressure is the same all over the container, the measured pressure becomes the same in everywhere.

The interviews related to gas pressure in a closed container indicated that most of the control and experimental group students thought that the pressure of the gas on the base of the container is not higher than the pressure of container's sides. On the other hand, some of the students from both control and experimental group believed that gas pressure may vary at certain points in the container due to the change in temperature.

Pressure of Gases - Gas pressure in a non-constant volume container

As shown in the figure, nitrogen (N_2) gas is found in the cylindrical container with movable frictionless piston. Hydrogen (H_2) gas is found in the elastic balloon connected to cylinder by a steel rope. Cylinder is pushed downward without touch of elastic balloon to the surface of the vessel, students were asked to predict the shape of the balloon.



EG.LA.16: The pressure increases with the compression in the vessel; balloon shrinks from everywhere since the pressure is equal in everywhere.

CG.MA.17: Since we push the piston downward, only the bottom of the balloon may shrink, there will be no change on the sides.

CG.HA.20: Piston makes a pressure from upward and N_2 gas makes a pressure from downward, therefore the balloon gets inflated from sides.

EG.LA.22: Since the pressure outside of the balloon increases, the balloon will begin to shrink from everywhere but H_2 gas will not be able to bear this and explode.

The answers indicated that most of the experimental group students made correct interpretation about the shape of the balloon when the pressure inside the cylinder is increased. They stated that balloon shrinks from everywhere due to increase in applied force all over the balloon. On the other hand, most of the control group students and a few of the experimental group students deduced that balloon shrinks only from bottom or only from above because they thought that the pressure shrinks the balloon the way that they exert the force to cylinder or the exact opposite direction of the force applied. Though two of the experimental group students knew that pressure was exerted to balloon homogeneously from everywhere, they thought that the balloon might explode due to high pressure disregarding the large empty spaces among the gas particles.

Pressure of Gases - Gas pressure in a closed constant-volume container

Students were asked to explain the reason for increase in gas pressure in a closed constant-volume container with increase in temperature.

CG.LA.08: Gas particles become heavier when heated. I mean, mass increases due to heat. The number of gas particles may increase with heating.

CG.MA.08: I think the speed of the particles increases and they make more pressure to the walls of the container so they condense on the walls of the container. I am in contradiction whether the size of the particles increases or decreases with heating but if the size of the particles increases, in parallel with this, pressure also increases. They may become heavier but I think it *does not affect the pressure much. I am not sure whether the number of collisions increases or decreases.*

EG.MA.11: When we give heat, there will be an increase in the volume and this causes an increase in the number of collisions. I am doubtful about becoming heavier of the gas particles but probably they do not become heavier. The gas particles condense when they are heated. However, the most accurate explanation is that "Increase in the number of the collisions when the gas is heated".

EG.MA.04: The size of the particles may increase due to increase in pressure. The particles do not become heavier with heating on the contrary they may get lighter. The gas particles may condense on the walls of the container but the most reasonable answer is that "Increase in the number of the collisions when the gas is heated".

As understood from the interviews, though nearly all of the experimental and control group students thought the most acceptable reason for increasing pressure in a closed container as the increase in the number of collisions with heating, interview findings indicated that students have also other misconceptions related to the reasons of increasing pressure with increasing temperature in a constant volume container. For example, some of the experimental group students believed that the size of the gas particles increases due to heating and so does the pressure and some of the control group students thought that size of the gas particles decreases with increase in temperature. Moreover, some of the control group students supposed that the gas particles might become heavier due to heat taken. In addition to these, most of the control group students and a few of the experimental group students were not sure about the condensing of the gas particles on the walls of the container because they believed that since the number of collisions increases with heating, gas particles hits the walls more frequently, and this may cause condensing of gas particles on the walls of the container.

Application of Charles's Law – Volume and Temperature Relationship

Students were asked that when the inflated balloon tied by rope was taken from its environment and placed in which environment, a decrease in the volume of it could be expected.

CG.MA.03: The same pressure and colder. From our childhood, I remember that balls and balloons deflate or shrink when they are put in cold areas like bathroom or balcony. This example came into my mind immediately. External pressure increases with the effect of temperature and the balloon gets smaller.

CG.LA.42: When I put the balloon on the balcony, its volume decreases. When the particles are taken to a cool environment, something occurs like diffusion as we learnt in biology. The air inside the balloon gets out or the molecules may be getting smaller. Gas molecules move slowly or since they move slowly, they may be getting smaller.

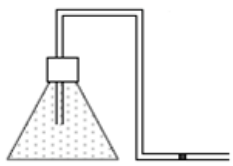
EG.LA.22: If the balloon is put in a colder environment, it shrinks. If it is taken to a hotter environment, balloon inflates. I think if the external pressure is higher than the inner pressure, it shrinks.

EG.MA.11: If the balloon is put in a colder environment, it shrinks. If the hot air is given, we can see the inflation of the balloon, volume increases, on the other hand if the cold air is given, it shrinks.

As understood from the interviews, students' comments mainly depended on the daily life observations. The dialogues with students indicated that most of the control group and a few of the experimental group students were unable to solve this question by means of the ideal gas law. For example, one of the high achiever from control group implied that pressure of the gas decreases in a cold environment and since the volume is inversely proportional to pressure, the volume of the gas increases. It was perceived that students use the ideal gas formula ignoring the change of variables in each question. In addition, the interview results indicated that some students provided correct answer to this question but sometimes with wrong reasoning. Some of the control group students thought that in order to decrease the volume of the balloon, external pressure must be increased, they believe that since the external pressure increases in a cold environment, balloon shrinks. One of the control group students thought that in cold, gas molecules accumulate in the middle and so the volume of the balloon decreases. On the other hand, some of the experimental group students gave correct answer with correct reasoning. They associated the reason for the decrease in the volume of the balloon with the decrease of the speed, kinetic energy of the particles or the distance between them.

Application of Gay Lussac's Law –Temperature and Pressure Relationship

There is a drop of mercury in the glass container as shown in next. The mercury drop moves to the right or left depending on the pressure and temperature changing inside the glass container. The apparatus of the room temperature (25 ^{o}C) is put into environment 5 ^{o}C, students were asked to predict the direction of the movement of the drop of mercury.



EG.LA.16: It does not move because the air pressure is constant. I wonder whether the mercury droplet moves when the temperature is decreased. I think when mercury droplet moves to left, gases move towards the container, so the pressure decreases.

CG.MA.17: I think that the mercury droplet moves to left because the temperature is lowered, the physical state of the gas may change and it may become solid with decreasing temperature.

CG.LA.42: When the temperature is lowered, the pressure inside the container decreases. Gas particles might be getting smaller or clustered. Since the pressure decreases, the mercury moves to left.

CG.MA.08: When the container is cooled, gas molecules will be clustered and since nothing enters or gets out from the pipe, the mercury droplet remains the same, it does not move.

EG.LA.22: I think it moves to the left because when the temperature decreases, mercury droplet will move towards the particles due to the shrinkage. Mercury comes close to the gas.

The interviews related to the effect of temperature on gas pressure in a constant volume container indicated that though most of the experimental and some control group students thought the way of the movement of mercury droplet correctly, most of the control group students and some of the experimental group students had the wrong reasoning. They believed that gas pressure decreases in the container due to the shrinking or getting smaller of the gas particles or clustering them in the container. A few of the control group students stated that gas particles move towards the container due to cooling. As well, one student from each group claimed that volume changes due to change in the pressure ignoring the constant-volume container in the given system and misusing the ideal gas law.

Application of Avogadro's Law – The Number of Mole and Volume Relationship

The pressure of air-filled balloon is measured as P_{full} in an environment in which atmospheric pressure is P_{atm}, then the mouth of the balloon is opened and expected to deflate, and the deflated balloon's pressure is measured as $P_{deflated}$. Students were asked to find the relationship between among P_{atm}, P_{full} and $P_{deflated}$.

EG.LA.16: I think the pressure of the deflated balloon may be equal to 0 because there is little air in the deflated balloon. I am in doubt that atmospheric pressure is higher than the pressure of air-filled balloon. However, the pressure of air-filled balloon and atmospheric pressure may be equal, I do not know.

CG.MA.03: $P_{deflated} = P_{atm}$, $P_{atm} < P_{full}$. *The pressure of the inflated balloon is higher than the atmospheric pressure. When the mouth of the balloon is opened, air exchange occurs until the air is equalized and when the air exchange is complete, the pressure of the deflated balloon and atmospheric pressure become equal (*$P_{deflated} = P_{atm}$*).*

CG.LA.08: I thought like $P_{deflated} < P_{atm} < P_{full}$. *When the balloon is full, its pressure increases so pressure of air-filled balloon is higher than the atmospheric pressure. The pressure of deflated balloon is lowest because there are less gas molecules in it and they exert less pressure.*

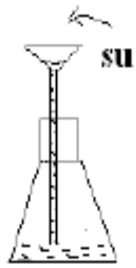
EG.LA.22: Atmospheric pressure is equal to the air-filled balloon ($P_{atm} = P_{full}$*) because there is neither expansion nor contradiction in the air-filled balloon.* $P_{deflated}$ *is smaller than the other two pressures.*

The answers indicated that except from the two students from the experimental group, none of the students could answer this question correctly. The scientifically correct answer is the equality of all the pressures, $P_{deflated} = P_{atm}=P_{full}$, because while deflating the balloon, the number of gas molecules decreases so does the volume of the balloon and the pressure of the balloon remains constant. Similar to this, when the balloon is inflating, the number of the gas molecules inside the balloon increases so does the volume of the balloon and the pressure again becomes constant. However, most of the students from both group thought that the air-filled balloon has higher pressure than atmospheric pressure because there is air inside it and it makes an extra pressure in the balloon. In addition, there are different ideas for the pressure of the deflated balloon by the students from both groups. One of them is that the pressure of the deflated balloon is equal to 0 since there is little or no air in it.

Moreover, some students thought that the pressure of the inflated and deflated balloon could not be equal since the gas goes out in the deflated balloon. In addition, some of the students believed that the pressures of the deflated balloon and the atmospheric pressure are equal to each other

Application of Boyle's Law – Pressure and Volume Relationship

According to the figure given on the right, the container connected to a funnel is closed with a stopper preventing the gas leak from the container. Water is easily entered when poured to the container but when the water level in the container is reached to the bottom of the funnel, water input is becoming difficult. Students were asked to explain the reason of this event.



EG.LA.16: I think increasing inner pressure prevents the entrance of water because the particles accumulate in the water entrance and the coming water cannot find the way to pass.

CG.LA.08: Water in the container closes water entry and the water cannot enter. In addition, other alternatives can be possible except for buoyancy of water.

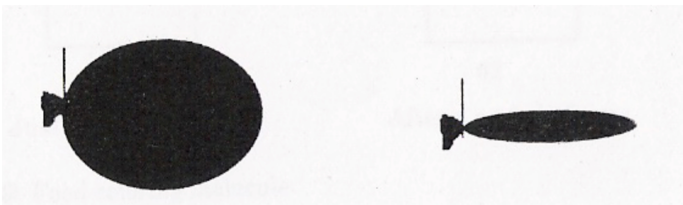
CG.MA.18: Upward force of the water in the container applies a force so water cannot enter. Let me give an example from daily life, for example, we drink cola with pipe easily but it is difficult to push it back since cola has a repelling force. After a while, it comes back. I thought that it is the repelling force of water.

EG.LA.22: I think upward force of the water in the container applies a force so water cannot enter.

As understood from the answers, half of the experimental group and some of the control group students were conscious that inner pressure increases due to the compression of the gas in the container and this prevents the entrance of water into it. Most students from control group and some of the students from experimental group thought, "Upward force of the water in the container applies a force so water cannot enter" as a reason for the difficulty of entering water into the container. Many of the students were unaware of the presence of trapped air and its exerted pressure in the container due to the invisibility of most gases. Instead, they made interpretations about the things that they see in naked eye for example, they believed "Water entry is closed by the water in the container and the water can not enter" for the difficulty of water input into the container.

Effusion of Gases

A balloon made from rubber is filled with hydrogen gas and the mouth of it is tightly connected. However, after a few days later it is observed that balloon deflates. Students were asked to choose the best explanation for this situation.



EG.MA.01: I think the most meaningful answer is the increase in the external pressure and causing the balloon get smaller. However, the environment is the same, so maybe there is gas releasing.

CG.MA.17: I remembered from our childhood. When we put things on cold floor, it was deflated and gas molecules were accumulated or clustered in the middle. However, it may become smaller due to increase in external pressure.

CG.MA.18: The weather may be cool and the molecules in balloon may be clustered. The energy of molecules may slow down in time, it happens in the *balcony of the homes also. I think the gas does not escape from the pores of the balloon, how can it be possible?*

EG.LA.22: The most meaningful answer is the cooling of weather and clustering of molecules in the balloon. Energy of molecules may used up in time and their movements stop. I think gas escape cannot happen from the balloon because the mouth of it is tightly bonded.

The best explanation of deflating balloon is the gas escape from the pores of it due to effusion. About 62 % of the experimental group and 33 % of the control group students thought that gases would escape from the pores of the balloon. As understood from the answers, both group of students emphasized on two situations as a reason for the deflation of the balloon; one of them was the increase in the external pressure and the other was the cooling of weather and clustering of molecules inside the balloon though no information was given about the changing the external pressure and the temperature of the environment in the question. Some of the control group and a few of the experimental group students thought that the energy of molecules may be used up in time and their movement stops so the balloon deflates. In addition, the option of the gas escape from balloon was not selected by some of the experimental group students since the mouth of the balloon is tightly bonded; they could think about the pores of the balloon.

Kinetic Energy and size of the gas particles during phase transition

Students were asked what features of the particles such as size, average kinetic energy, and distance between the particles, change during the transition of pure matter in the phase of solid to liquid or liquid to gas at the same temperature.

EG.MA.19: The size of the particles may decrease from solid to liquid or liquid to gas. The average kinetic energies increase because in solid phase it moves slowly, in liquid phase it moves more quickly, it is the fastest in gas *phase. The distance between them increases since they move independent from each other as the matter changes from solid to liquid or liquid to gas.*

EG.LA.16: I think that the size of the particles changes for instance I thought the size of the water and ice is not the same. The size of the particles may change during the phase change. The distance between particles also changes.

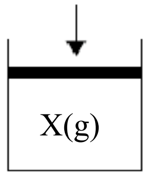
CG.HA.20: I think the distance between the gas particles changes but the particle size does not change. Average kinetic energy changes when temperature changes. It has also formula $Ek=1/2mV^2$*, it depends on both mass and the speed.*

CG.LA.42: The size changes but I do not know how the size of the particles changes. The distance between particles changes, it is the closest in solid and most remote in gases. Solids are more ordered and gases are more movable so average kinetic energy changes.

As understood from the answers, all of the students from both groups agreed that the distance between the particles changes from the state of solid to liquid or liquid to gas. However, as for the change of the particle size, although some of the experimental group students thought that the size of the gas particles remains the same, some of them were not sure whether the size of the particles changes with changing physical state. On the other hand, though some of the control group students were not sure about the particle size, most of them considered that the size of the particles increases from the state of solid to liquid or liquid to gas. It was noticed that students have confusion with the size of the particle and the size or volume of the matter. One student from experimental group stated that "*I thought the size of the water and ice are not the same"*. As for the average kinetic energy, although some of the experimental and control group students understood that average kinetic energy depends only on the temperature, most of the students thought that the movement or speed of the particles increases with the change of the physical state of matter disregarding the constant temperature. In other words, they have a basic idea that solids are more ordered but gas particles freely move so gases have more average kinetic energy than liquids and the solids. Two interesting answers came from the control group students. One of them mentioned *"Kinetic energy changes when temperature changes. It has also formula $Ek=1/2mV^2$, it depends on both mass and the speed"*.

The speed of the gas particles versus the volume of the container

At constant temperature, X gas, behaving ideally, is placed in a container and the container is compressed. Students were asked whether the speed of gas particles changes with changing the volume of the container.



EG.MA.19: The average speed of the particles increases, since the volume decreases, the number of collisions increases and so does the speed of the particles.

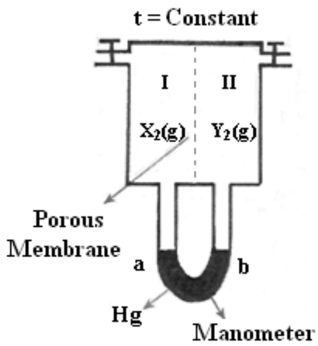
CG.MA.17: I thought that the number of the collisions and speed of the particles decrease when the field is narrowed.

CG.LA.42: "Average speed of particles decreases" is wrong because their speed may increase in a smaller area.

EG.LA.22: The speed of the particles increases because they become faster due to increase in pressure.

When the students' answers were examined in interviews, it was seen that both experimental and control group students have no problems in understanding the increase in the pressure or decrease in the distance between the gas particles when the ideal gas of X is compressed in a closed container. However, while some of the students in both experimental and control group believed that speed of the gas particles increases due to the compression or increase in the number of collisions, some of the students from both groups thought that speed of the gas particles decreases with decrease in volume. A misconception revealed by experimental and control group students was that *if the volume decreases, the speed of the particles increases due to the increase in the number of collisions.* Students made a connection between the volume and the change of the speed of the gas particles because of the change in pressure in the container. Only one of the high achiever from the experimental group and one of the high achiever from control group associated the speed of the particles with the temperature.

Diffusion of Gases



As seen from the figure, a container is separated into compartments I and II with a porous membrane and connected to a manometer. Being equal to the levels of mercury in the arms of the manometer, compartment I is filled with X_2 gas and compartment II is filled with Y_2 gas. At the same temperature, after a short period of time it is observed that the level of mercury in arm "a" increases. The reason of rising in arm "a" was asked to the students by presenting some alternatives about diffusion rate, molecular weight and pressure of these gases.

EG.MA.19: If the level of mercury increases in the arm a, it makes a pressure from here (shows the compartment II) so X_2 molecules are faster than the Y_2 molecules. I think molecular weight of Y_2 is heavier than the X_2 since the pressure is higher here (compartment II). Total pressure of compartment II increases during the observation because it makes a pressure toward this side (compartment I).

CG.LA.08: The arm of the manometer is from b to a since the molecular weight of Y_2 is higher than the X_2. X_2 molecules are not faster than Y_2 molecules. The total pressure of compartment II increases.

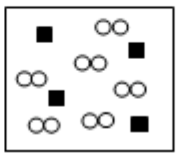
CG.MA.08: X_2 molecules cannot be faster than Y_2 molecules, if they were; they would make more pressure and increase the level of mercury in arm b. The molecular weight of Y_2 is higher than X_2. The total pressure of compartment II increases during the observation.

EG.MA.04: Y_2 molecules must be faster than X_2 molecules since they collide more and there is an increase in arm a. The molecular weight of Y_2 might be higher than X_2. The pressure of compartment II increases.

The interview answers related to diffusion rate of the gases indicated that students did not realize the diffusion of gases from the porous membrane. Some of the experimental and control group students thought that Y_2 makes more pressure than X_2 since Y_2 molecules are faster than X_2 so students have a misconception that "*The pressure of the gases increases with an increase in their diffusion rates*". Some of the both group of students believed that Y_2 gas makes more pressure than X_2 because its molecular weight is higher than that of X_2 so that increase in the level of mercury in arm a is observed. Therefore, students have another misconception that *"As molecular weight of a gas increases, its pressure increases"*. Unfortunately, only two of the experimental group students thought the possibility of diffusion of gases through the porous membrane as the cause of the increase in pressure compartment II.

Partial Pressure of Gases

The following closed container was presented containing a mixture of oxygen (∞) and helium (■) gases at 25 ^oC. Students were asked to select the picture that indicates the partial pressure of oxygen.



EG.HA.23: It is only the pressure of the oxygen. The number of the oxygen molecules should be equal and oxygen molecules should not be separated.

CG.MA.18: There should be helium in the container because it has also partial pressure. The related formula should be something like that P_1/V_1 or n=PV but I do not remember very well.

CG.LA.42: I have no idea about the partial pressure. I think they react with each other since they are together in the container.

EG.MA.04: The oxygen atoms should not be separated from each other. Partial pressure is the particular pressure of the gases in a container so I did not include the helium. There should not be any change in the number of molecules.

The answers indicated that almost all the students from experimental group understood what the partial pressure is. They thought that the container should include only oxygen molecules not the atoms. On the other hand, it was noticed that control group students had confusion about the concept of partial pressure. Though some of the control group students thought that the picture that shows the partial pressure of the oxygen should include the helium atoms, some of them tried to remember the related formula or have no idea about the concept of partial pressure. In addition to these, some of the students from control group expected to see the chemical reaction as an answer to the partial pressure of oxygen. One student from each group believed that oxygen molecules must be separated from each other in order to be distributed in the container homogeneously.

Interview results indicated that experimental group students had better understanding about gas concepts and they performed better reasoning in their answer with respect to control group students. However, some of the misconceptions were still existent among students from both groups even after instruction because misconceptions are persistent and resistant to change.

5.4 Students' Opinions about Case-Based Learning

After treatment, sixty-three experimental group students' ideas about the Case-Based Learning (CBL) were received by means of feedback form (Feedback

Form for Case-Based Instruction). Students expressed their thoughts, opinions and suggestions about the case-based learning on this form. PS and AS refers to the public high school and Anatolian high school respectively. The questions and some of the responses were presented below:

Q1. Is case-based instruction an effective method for learning gas subject in chemistry? Why?

S5-PS: Yes, it enables us to learn better.

S6-PS: It is an effective method because it is not based on memorization, instead we learn meaningfully.

S9-PS: Yes because when the examples are given, it is remembered easily and it increases our curiosity. Curiosity also brings the success and makes the teaching method effective.

S11-PS: Yes, we remember what we learnt easier.

S12-PS: Effective, we could understand the reasons for the daily life events easier.

S16-PS: I think it is an effective method because it tries to teach students without making them bored and it was successful. We learn the subjects by means of cases.

S25-PS: Yes. Learning with examples is more effective and it is a permanent way of learning.

S27-PS: Yes. It is an effective method because it provides us better understanding of subjects with daily life examples.

S28-PS: Effective because it is understood better when there are examples of everyday events.

S33-PS: Yes because we did many examples about the subject and therefore the subject was reinforced.

S35-PS: I think it is an effective method because I understand better in group work.

S3-AS: It is an effective method because learning is more permanent.

S5-AS: In the past, we covered this type of events traditionally. I used to get bored after a certain time, and I would miss some concepts in lessons. However, learning with cases is so much fun for the students.

S6-AS: Yes. Since it does not need memorization, it is easily remembered.

S12-AS: I think it is an effective method. Thus, people visualize the events in memory and learning is more permanent.

S16-AS: Yes, it is an effective method because people forget the information they hear but they do not easily forget the information they see.

S17-AS: Yes because the topic is easily remembered.

S20-AS: Yes, it is effective because people can visualize the examples and it allows us to understand the subject much more easily.

S21-AS: It is an effective method because we give examples from daily life. We understand the place of gases in everyday life. It creates more curiosity toward the subject of the gas. It directs us to study and search.

The purpose of this question was to get students' opinion about the effectiveness of case-based instruction in teaching the subject of the gases. Experimental group students' responses showed that they found the case-based instruction effective. Sixty-one students out of 63 (96.8 %) expressed their positive opinion about case-based learning. They stated that case-based instruction provided the link of the topic with daily life and illustrations and they understood the subject better with daily life examples and these illustrations. Moreover, they argued that case-based instruction was not boring, it increased their curiosity and helped them visualize the events. Some of the participants told that they learnt better in a group work. Therefore, most participants told that the learning was not based on memorization and it was permanent.

Q2. What are the features that you liked the most in case-based learning?

S1-PS: To be able to make comments.

S2-PS: Discussions in classroom.

S4-PS: Sharing ideas by group work.

S13-PS: Implementation of an activity related to each topic and visuality of these events

S15-PS: Expression with illustration

S16-PS: Teaching the subject without getting bored.

S18-PS: Discussion and not getting bored.

S22-PS: It is good for criticizing ourselves and seeing the gap in the course of subject.

S3-AS: Conjuring up a mental picture by the help of the cases.

S4-AS: It provides us to understand the events step by step.

S5-AS: The point that I like most is the daily life examples because it has a relationship with chemistry.

S6-AS: Courses are enjoyable.

S7-AS: Since it is given from daily life/everyday life, it is more natural, more understandable and more logical.

S8-AS: Presentation of events in a simple way.

S9-AS: Doing a group work.

S16-AS: Based on visualization is the feature that I like most.

S17-AS: The cases depend on an event.

S19-AS: Group work. Thus discussion platform is formed and my friends might see the things that I could not.

S20-AS: If there are such things in my own life, I visualize it in my mind and understand more easily. I understand that some of the events in daily life are related with chemistry.

S23-AS: We are doing group work and learning with pleasure.

The aim of this question was to get students' opinions about the feature(s) of case-based learning that they like the most. To sum up, students liked the features of sharing ideas in a group work, being able to make comments, developing their perspectives by taking others' opinion, learning by discussing on cases, having fun by learning, criticizing themselves and seeing their lack of understanding about the subject the most. Moreover, they wrote that expressions with illustration, implementation of an activity related to each topic and being these events visual and the examples from daily life were among the features they liked the most.

Q3. Which feature or features would you want to change in a case-based learning?

S1-PS: It is unnecessary to make too much activity, they all look like the same.
S2-PS: More experiments and competition between groups would be better.
S4-PS: The cases can be based on visuality more.
S6-PS: Examples are good, there is no need to change.
S12-PS: Visuality could be more
S13-PS: I think it is a very good method of learning, the topic is understood very well.
S22-PS: The same questions should not be asked in different sentences instead they should be asked in the same sentence.
S25-PS: I would like to remove "Why?" at the end of each question.
S27-AS: The same questions are faced with in each activity in a different format.
S28-AS: The examples could be applicable. There could be examples which we could apply in the laboratory.
S31-PS: These cases should be taught with the support of experiments
S35-PS: I would not change too much thing. Everything was very good.
S4-AS: It would be better if they could be applicable. But it was not possible. Definitely, I do not want to change something.
S21-AS: Instead of asking 4-5 questions, it would be better to ask two questions because sometimes the answers of two questions can be the same.

Students were asked which feature(s) that they absolutely want to change in case-based learning. Analysis of students' responses indicated that while 42.8 % of students specified that they do not want to change anything, 39.6 % of students stated their suggestions about the given instruction. As presented above, many of them recommended that cases should be more applicable and be taught with the support of experiments. Some of them suggested to combine alike questions in the same sentence. Moreover, some of the students offered to increase the visual property of activities.

Q4. What are your opinions about the case-based materials applied during the lessons?

S8-PS: Didactic and remembered easily
S10-PS: It was very good; it developed our vision about the topic.
S12-PS: It was interesting because it is from daily life.
S14-PS: Very didactic and logical.
S17-PS: I like cases because it allows us to learn information about the topic.
S19-PS: More examples should be given and the given examples should also be more creative.
S20-PS: It is very lively and open to discussion.
S25-PS: Usually, they are good examples.
S27-PS: It is helpful. Since the examples are given from actual events, we understand gas concept better.
S3-AS: Effective and enjoyable.
S4-AS: Useful examples for learning.
S9-AS: Sometimes, events are taken from everyday life. It developed my point of view. I had not looked at the events from this viewpoint. Events are challenging and creative. I found it excellent
S12-AS: They were very didactic.
S13-AS: It is good to see chemistry as a science in daily life and how it works in daily life.
S16-AS: I think it was very nice and very entertaining. You learn while you are having fun.
S19-AS: I think some of the cases were useful such as air bag but some of them were unnecessary.
S21-AS: It provides me to take more interest in chemistry lesson. I have learnt interesting information. Sometimes this information is even useful in my life.

Students were asked about what they think of the case-based materials applied during the chemistry lesson in the subject of gas. 90.5 % of experimental group students (57 students out of 63) gave positive answer to this question. Some of the answers were noted above. Students found the case-based materials didactic, logical, effective, entertaining, useful, challenging, lively, open to discussion, comprehensible or easy to understand. In addition, some of the students thought that interesting case-based materials arouse their interest to chemistry. On the other hand, while a few students found some materials useful like air bag, they found some of them unnecessary. A few of them suggested using more examples and these examples should have been more creative.

Q5. Have you encountered any difficulty during the implementation of case-base learning method?

S1-PS: I have difficulty in understanding the questions.
S11-PS: No, I did not have difficulty.
S12-PS: Sometimes there were some places that I had no idea.
S19-PS: No. All the events were from our daily lives.
S22-PS: No. Since I respond the questions according to me, I know the answers. In the end, it is not a test, I just measure my own performance so I really do not have difficulty.
S27-PS: We did not encounter any difficulties. We did easily due to already given annotated examples.
S1-AS: There are some boring parts.
S2-AS: No I did not encounter any difficulties except for my conflicting opinions.
S3-AS: Not much, but sometimes I got confused.
S6-AS: Some questions were not clear and confusing.
S9-AS: I've had. Some questions were difficult for me; actually I struggled in replying them.
S21-AS: Sometimes it was difficult to answer the questions. I was confused.

In the last question, students were asked whether they faced with any difficulties about the implementation of Case-Based Learning. Most of the students (79.3 %) clearly stated that they did not confront with any difficulties during the treatment. The problems they faced with were mainly about the difficulty in understanding some questions in case-based materials. Some of the students (17.5 %) mentioned that these difficult or challenging questions confused their mind and had difficulty in understanding them. In addition, a few of them said that they sometimes had no idea about the given questions. Actually, the questions used in case-based materials were based on the misconceptions in the subject of gases. Therefore, it was expected that the questions would be difficult and confusing for students.

To sum up, students' responses to case-based learning feedback form showed that most students noticed the main characteristics of case-based learning. Challenging or difficult questions were the part of the instruction used to overcome the misconceptions about the gas topic. Since the conceptual change is a difficult process, it was normal for students having confusion and difficulty in solving problems during the instruction. On the other hand, most of the experimental group students thought that case-based learning is an effective teaching method in understanding the gas concepts because they considered using real life examples facilitates learning and makes the concepts more meaningful and more permanent. They specified that case-based learning helped them to improve their ability to view others' perspective, develop their vision about the topic, and to think more logically and scientifically. In addition, some of the students mentioned that this teaching method helped to gain a different point of view by the help of small group and class discussions, directed them towards investigation. In addition, they stated that working in groups, sharing ideas, being able to make comments, learning by discussion, seeing lack of their understandings, learning by having fun provided to arouse their interest to chemistry lesson.

5.5 Conclusions

The conclusions drawn from the study were presented below:

1. The analysis of pre-GCT scores showed that there was no statistically significant mean difference between experimental and control groups in terms of students' pre-existing knowledge about the gas concepts. Moreover, the results revealed that there was a significant mean difference students in terms of school

with respect to student' pre-existing knowledge about gas concepts before the treatment.

2. The analysis of pre-ASTC revealed that there was no significant difference between experimental and control group students in terms of their attitudes toward chemistry that is, both groups of students had similar attitudes toward chemistry before the instruction. In addition, the results revealed that there was no statistically significant mean difference between experimental and control groups with respect to school and treatment by school interaction on their pre-ASTC scores before the instruction.

3. The analysis of pre-MSLQ indicated that there was no significant difference between experimental and control group students with respect to intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance and test anxiety. That means, students' motivational characteristics were similar in experimental and control group before instruction. Furthermore, there was a statistically significant mean difference in groups in terms of school effect on motivation based dependent variables of IGO, EGO, TV, CLB, SELP and TA prior to treatment.

4. Case-Based Learning based on conceptual change conditions resulted in significantly better gaining of scientific conceptions about gas concepts and most of the misconceptions about gases were remedied compared to traditionally designed instruction.

5. Though case-based learning based on conceptual change conditions was an effective method remedying students' misconceptions about the gas concepts, some of the misconceptions were still present even after the instruction.

6. Case-Based Learning based on conceptual change conditions increased students' attitude toward chemistry in Anatolian high school more than it did in public high school.

7. Case-Based Learning based on conceptual change conditions improved students' perceived extrinsic goal orientation (EGO), task value (TV), and self-efficacy for learning and performance (SELP) in Anatolian high school and test anxiety (TA) in public high school compared to traditionally designed instruction.

8. Case-based learning based on conceptual change conditions improved Anatolian high school students' perceived extrinsic goal orientation (EGO) and self-efficacy for learning and performance (SELP) however traditionally designed instruction enhanced public high school students' task value and anatolian high school students' test anxiety constructs.

9. Case-Based Learning based on conceptual change conditions had no effect on students' perceived intrinsic goal orientation but this method of learning enhanced students' perceived control of learning beliefs in both schools.

10. Case-Based Learning on conceptual change conditions was an effective teaching method for improving students' understanding of the gas concepts, ability to view from others' perspective, working in groups, sharing ideas and seeing lack of understandings, learning by discussion, and learning by having fun.

11. The interview analysis indicated that case-based learning based on conceptual change conditions helped to overcome students' misconceptions and remedied most of them in the experimental group compared to the students in the control group, who were instructed traditionally.

CHAPTER 6

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

In this chapter, firstly the results of the current study stated in chapter 5 are presented. Then, the results are discussed. Implications of the findings and recommendations are presented finally.

6.1 Discussion

The main purpose of the current study was to investigate the effectiveness of case-based instruction based on conceptual change conditions on 10^{th} grade students' understanding of gas concepts, their attitude toward chemistry and motivation (intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety).

While one of the two classes of the same teacher was assigned as experimental group, the other class was assigned as control group in both Anatolian and public high school randomly. Experimental group students were instructed with case-based instruction and the control group students were taught traditionally. In this study, three different measuring instruments were administered to both experimental and control group students as pre- and post-test: Gas Concept Test (GCT), Attitude Scale toward Chemistry Test (ASTC), Motivated Strategies for Learning Questionnaire (MSLQ) composed of six subscales (intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety). The related data were analyzed with two-way ANOVA and two-way MANOVA.

At the beginning of the instruction, students' prior knowledge on the subject of gases was assessed by GCT to determine whether there was a significant mean difference between experimental and control group students in terms of their previous conceptions of gases. The two-way ANOVA results revealed that there was no statistically significant mean difference between experimental and control group students in terms of their pre-existing knowledge about gas concepts (pre-GCT) prior to treatment whereas students in two schools were significantly different in terms of their pre-existing knowledge about gas concepts. What is more, the partial eta-squared value of 0.20, which means that 20 % of the variance of the dependent variable was associated with school, evidenced the very large effect of school on the scores of pre-GCT. Afterwards, the two-way ANOVA results for pre-ASTC scores and two-way MANOVA results for pre-MSLQ were checked. The two-way ANOVA results revealed that there was no statistically significant mean difference between experimental and control groups as well as school type on their pre-ASTC scores before the instruction. In addition, MSLQ test was applied to experimental and control group students to determine whether there was a significant mean difference between the groups in terms of their existing motivation before the instruction. Two-way MANOVA results indicated that there was no statistically significant mean difference between experimental and control group students with respect to the motivational dependent variables of IGO, EGO, TV, CLB, SELP and TA prior to treatment. However, the partial-eta squared value for school effect was found to be 0.14 implying the large difference between students in two schools with respect to motivation based dependent variables before the treatment. According to Weinfurt (2000), if the groups are different in terms of pretest mean scores, the analysis of gain score is valid rather than ANCOVA in Quasi-experimental designs in which intact groups are used. Therefore, gain values were used to analyze the results instead of analyzing only posttest scores.

Two-way ANOVA based on gain score analysis demonstrated that there was a significant mean difference between experimental and control group students with respect to the treatment effect on students' understanding of gas concepts after instruction in both public and Anatolian high school. Descriptive statistics related to gain-GCT values indicated that experimental group students in public high school (6.71) gained a little more from the case-based learning than students in the Anatolian high school (6.20). Unlike public high schools Anatolian high school students had higher scores on Anatolian High School Examination in order to enter their school, but experimental group students in both schools showed similar success on the gas concept test. The study of Çam (2009) indicated that case-based learning instruction was more effective than traditional instruction in enhancing high school students' understanding of solubility equilibrium concept. The reasons for success was shown as identification of students' misconceptions, developing conceptual framework and integration of metacognitive approaches into cased based learning instruction (Gallucci, 2006). Moreover, Saral (2008) mentioned that case-based learning improves students' academic achievement. In addition, there are other research studies showing the superiority of case-based learning compared to traditional learning explaining that case method develops academic achievement, performance skills, and academic knowledge (Çakır, 2002; Mayo, 2002; Mayo, 2004; Rybarczyk et al., 2007).

As mentioned above, the results of this study indicated that case-based learning instruction was an effective teaching method compared to traditional instruction in terms of improving students' understanding of gas concepts. On the other hand, control group students taught with traditionally designed instruction showed poor performance with respect to students in experimental group. The reason of poor performance in traditional classes might be not addressing misconceptions in learning. On the other hand, in experimental group, students' prior knowledge and misconceptions were taken into account while designing the cases and misconceptions were tried to be overcome by providing conceptual change conditions proposed by Posner et al. (1982). The theory of Posner specifies four conditions in order to provide conceptual change; *dissatisfaction*, *intelligibility*, *plausibility*, and *fruitfulness*. The related cases were designed to generate dissatisfaction with students' pre-existing knowledge or beliefs. Specific situations, generally real-life events and experiments were used in the construction of the cases and the list of study questions generally included misconceptions to create contradiction in students' mind related to subject matter. What is more, in-group and whole-class discussions also helped to stimulate misconceptions because during those discussions, existence of different ideas or points of views directed students to think and sometimes played an important role in becoming aware of and remedying their misconceptions. Small group discussions can be used to construct their own conceptions (Gallucci, 2006, 2007). Moreover, during case discussions teacher usually asked questions beginning with "*why*" and "*how*". In addition, they encouraged students to express their ideas and allowed opportunities for them to convince each other in scientific ways. After in-group discussions, each group shared their opinions with whole class providing the reasons to find out the answers of the questions. During the phase of dissatisfaction, teacher tried to avoid direct response to the questions in cases instead they gave clues or feedback to them. Moreover, fifteen cases were generally prepared based on specific situations, generally real life events and experiements so new information was easier to understand due to the nature of them. Since whole-class discussions were based on developing a scientific point of view to these events, new conceptions were plausible for the learner. Following the whole-class discussions, teacher summarized the answers of groups and provided necessary and reasonable explanations to clarify the problematical points in students mind. By this way, it was aimed to fulfill *intelligibility* and *plausibility.* It was also noticed that sometimes students felt to approve their learning whether they understood correct or not at the end of the case studies. In addition, some additional daily life examples and applicability of knowledge in other areas were discussed to meet *fruitfulness* condition.

Case method of learning is actually a one simple method instead it includes many constructivist methods such as inquiry, active learning, student-centeredness, and small group discussion. By means of case studies, students can practice the inquiry method, develop critical thinking skills, and relate course materials to their own experiences. They usually worked collaboratively in this study, this provided them self-directed, and student-centered learning environment, thus the opportunity was offered to students to "construct" their own knowledge (Gallucci, 2007). These features of case-based learning instruction may have provided better understanding of gas concepts compared to traditional instruction. As Gallucci (2006, 2007) stated case-based learning was effective in remediation of misconceptions. Concepts associated with real life facilitated students understanding and visualization of concepts.

In contrast to conceptual change based strategy, in traditionally designed classes, teacher defined and explained the concepts and solved related questions and then asked numerical or arithmetical problems to students. In the meantime, students took notes being passive listeners. The student-teacher communication was minimized and student-student interaction was almost negligible. Interaction between students was not allowed to provide the authority in class. In addition, traditional instruction disregarded students' pre-existing knowledge or background and also their needs. Consequently, students were not allowed to create their own knowledge instead, information was transmitted as much as possible from teacher to student.

Students' understanding of gas concepts was measured by multiple-choice questions with five alternatives. The proportions of correct responses in this test were determined by item analysis. The item analysis results indicated a significant difference between experimental and control group students in favor of students in experimental group. In addition, interviews were conducted with sixteen students of both experimental and control group students from two schools to get deep information about students' understanding of gas topic to identify whether there are any misconceptions even after instruction. The interview analysis indicated that case-based learning based on conceptual change conditions helped to overcome students' misconceptions and remedied most of them compared to the traditionally designed instruction.

However, it was found that students had misconceptions on some gas concepts even after instruction. For instance, after instruction, control group students had still thought that gas particles are able to "shrink", "condense", "sink", or "settle" (Novick & Nussbaum, 1981). They believed that air exists among the particles of a gas (Novick & Nussbaum, 1978, 1981). In addition, most of them ignored the mass of gases (Lee et al., 1993; Mas et al., 1987; Stavy, 1988, 1990). Some of the misconceptions of control group students found during interviews are as follows:

- The size of the particles increases from the state of solid to liquid or liquid to gas.
- In a closed container, when the gases are cooled, gas particles are accumulated in the middle of it.
- The size of the gas particles decreases with increase in temperature.
- Gas particles become heavier due to heat taken.
- Students have difficulty in conceptual understanding of partial pressure.
- In a closed container, gases do not exert the same pressure in different directions.

Although most of the misconceptions such as "*Gas particles are unevenly scattered in any enclosed space"*(Novick & Nussbaum, 1981; Lee et al., 1993; Cho et al., 2000)*, "Matter, especially air, exists between the particles/atoms of a gas"* (Novick & Nussbaum, 1978, 1981; Lee et al., 1993), *"Conservation of matter is applicable to solids and liquids but may be ignored for gaseous reactants or products"* (Mas et al., 1987)*, "In a closed container, the volume of a gas decreases when the temperature decreases (Misuse of Charles's law)"* (Lin et al., 2000)*, and "Conceptual calculations are not obvious for students"* (Nurrenbern & Pickering, 1987; Sawrey, 1990; Nakhleh & Mitchell, 1993) were remedied among experimental group students, it was observed that they still had the following misconceptions: "*Molecules increase in size with change of state from solid to liquid to gas*" (Haidar & Abraham, 1991), "*Gas particles sink to the bottom of the container when the temperature is lowered*", "*Gas particles may condense on the walls of the container*" (Novick & Nussbaum, 1981), "*Heated or hot air weighs more than cold air or vice versa*" (Lee et al., 1993), "*When the air is compressed, the particles stick to each other*", "*Misuse of ideal gas law*" (Lin et al., 2000), "*If the volume decreases, the speed of the particles increases due to the increase in the number of collisions"* (Kautz et al., 2005)*, and "Gases occupy different volumes according to their molecular weights"* (Cho et al., 2000).

In addition to these, interview findings indicated that both group of students are unable to solve the gas questions by means of ideal gas law. They also had problems in understanding the concepts of average kinetic energy and the rate of diffusion. Although literature findings indicated that students have misconceptions of "*The energy gradually dies, so the gas motion stops and balloon deflates*" (Haidar & Abraham, 1991) and "*Collisions may result in a change of atomic size*" (Griffiths & Preston, 1992), the results of this study showed that a few of the experimental and control group students had these misconceptions. The related interview analysis was presented in detail in Chapter 5. To conclude, when the gain-GCT scores were examined, students in experimental group outperformed on the test in terms of understanding and remediation of misconceptions about gas concepts. On the other hand, some misconceptions related to gas concepts were also determined in experimental group students after case-based learning instruction. This means students are persistent to use misconceptions even after instruction designed to address misconceptions (Champagne, Gunstone, & Klopfer, 1985; Anderson & Smith, 1987; Wandersee et al., 1994).

In addition, two-way ANOVA results with respect to gain-ASTC scores showed that there was no significant mean difference between control and experimental group students in terms of their attitudes toward chemistry in public high school. On the other hand, in Anatolian high school, experimental group students gained more attitude toward chemistry than control group students did after the instruction and this difference was statistically significant. Effectiveness of case based learning on students' attitudes was also proved by other researchers. For instance, Çam's (2009) study included sixty-two eleventh grade students from two classes of a chemistry course taught by the same teacher. While 27 of these students instructed with case-based learning method, 35 students from received instruction based on traditional methods. After six weeks treatment, case-based learning increased students' attitude toward chemistry compared to traditional instruction when it was applied in small discussion format. Similarly, Flynn and Klein (2001) examined the effectiveness of case-based learning on college students' attitude who studied cases individually or in small discussion groups. Significant differences were found in favor of small discussion groups. Çakır's (2002) research included 74 students from two classes of biology course in which 41 students used cases during instruction and rest of them were instructed based on traditional methods. Results showed that case method of learning enhanced students' attitude toward biology but no significant difference was found between the groups. Likewise, Gallucci (2007) investigated the effectiveness of case method of instruction on conceptual conditions however although students' attitude for learning science was promoted, the effect of this method on students' attitude toward science was not significant. In addition to these, some studies on the effectiveness of case-based learning on students' attitude evidenced the increase in students' enthusiasm due to using cases during instruction (Kinzie et al., 1998) and active participation in the learning process (Cheng, 1995). Moreover, cases were found as enjoyable and educational activity because it made science more associated with their lives. Students instructed with case study reported their positive opinions about the implementation of the study compared to traditionally designed instruction (Brink et al., 1995). In this study, case method with small group discussion provided students to present their ideas freely by engaging them in learning process; students worked in groups, discussed the given situations and answered the questions of presented cases. During the implementation of case-based learning, teacher read aloud the given cases to the class, gave enough time to them to discuss the presented cases and related questions. Teacher in experimental group directed the whole class discussion until the students found intelligible and plausible answer(s). In brief, teacher's role was to facilitate learning, not being the center of learning. Students' active involvement in learning process and constructing their own knowledge with the help of case studies may have increased their attitude toward chemistry.

However, in the present study, it seems that case-based learning based on conceptual change conditions promoted students' attitude toward chemistry in Anatolian high school rather than public high school. Tymms (1992) stated that there are small but significant differences on the performance of pupils attending different types of school. It is often argued by Fitz-Gibbon (1985) and Tymms (1992), that a selective environment can foster better achievements because it potentially creates some beneficial competition and co-operation among pupils. Since students in the Anatolian high school are selected according to the results of an examination, more selective environment exists in that school. Therefore, more cooperation may occur during small group work during the implementation of the case based learning and this may increase their attitude towards chemistry more after case-based instruction.

In addition, Tuncer et al. (2005) investigated the effect of school type (private and public) on total of 1497 students from 6th, 7th, 8th, and 10th grade students' attitudes toward environment and demonstrated that school may have a role in the construction of students' views on the environment in favor of private schools. The classes with a high level of student involvement, cooperative learning and low level of teacher control generate positive student attitudes (Myers & Fouts, 1992). The class size was smaller in the Anotalian high school. As Finn and Achilles (1999) indicate, student participation in learning process is encouraged in small class environment. To conclude, in contrast to public high school, the reason of significant increase on students' attitude in Anatolian high school may be attributed to the characteristics of participating students, and smaller class size. Moreover, in Anatolian high school control group students' attitude toward chemistry decreased (gain-ASTC= -1.628). One of the reasons for the decline in these students' attitude might be due to the teaching strategy that they have received because these students were instructed traditionally, and this might decrease students' attitude toward chemistry. Another reason might be the students' unsincere answers to test items. In addition, as instruction procceds, there is an increase in number and difficulty of chemistry related issues. This might negatively affect students' attitude toward chemistry since they begin to have trouble in understanding the chemistry concepts.

In addition to these, two-way MANOVA results showed that there was not a significant mean difference between the experimental and control group students in terms of treatment effect with respect to the students' gain values of intrinsic goal orientation in both schools. On the other hand, there was a significant effect of treatment on students' gain values of control of learning beliefs (CLB), that is, students' beliefs that their attempts to learn will get positive outcomes, developed and they felt that they can control their academic performance (Pintrich et al., 1991) whereas there was not any significant effect of school as well as school by treatment interaction on students' CLB. On the other hand, in Anatolian high school, experimental group students' gain scores of extrinsic goal orientation, task value and self-efficacy for learning and performance were significantly higher than the control group students whereas there was not any significant mean difference between control and experimental group students with respect to these variables in public high school (See Table 5.22). In other words, experimental group students in Anatolian high school took part in a task for reasons such as grades, rewards, performance, evaluation by others, and competition. In addition, students instructed with cases in Anatolian high school engaged in tasks since those are valuable to them. The study of Saral (2008) presented significant evidence that students in case-based learning environment found the tasks more valuable than students in traditionally designed learning environment. According to Wigfield and Tonks (2002), students may find the tasks useful due to some extrinsic reasons. For instance, a student has not much intrinsic interest to chemistry but in order to become pharmacist, the course of chemistry has a high utility for him or her. Pintrich and Schunk (2002) stated that intrinsic interest or enjoyment, task value or usefulness are the important reasons for students being a part of the task and thus their motivation might be enhanced. Students find case-based teaching method enjoyable and interesting (Brickman et al., 2008; Heid et al., 2008; Herreid, 2006; Hoskin, 1998; Jackson, 1998; Mayo, 2002; Parilla, 2007; Ribbens, 2006; Walters, 1999). Students especially in high school may find the tasks valuable due to different reasons but if they think that tasks are useful or valuable, they are more interested and involved in tasks thus they study harder and effectively on them (Wigfield & Tonks, 2002). Therefore, it can be concluded that Anatolian high school students' perceived task value was more than public high school students because they found the tasks valuable, interesting, enjoyable or different extrinsic reasons as stated above may have been influential. What is more, Anatolian high school students' self-efficacy for learning and performance increased significantly after case-based learning; that is, they became more confident in having the skills essential to carry out the task after case-based teaching. Courtney, Courtney, and Nicholson (1992) stated that a student's self-efficacy enhances by experiencing success of specific tasks repeatedly. Similarly, Pintrich and Schunk (2002) declared that using models in lessons increases learners' self-efficacy and motivation to struggle the task on their own. Students' motivation is increased if they see progress in learning. Students become more skilful as they work or practice on tasks, and they sustain a sense of self-efficacy for performing well (Schunk, 1989). In both schools, case studies were performed in the same manner and students in experimental group were provided enough time to complete the questions of presented cases. However, students in public high school may not perceive development in their learning so their self-efficacy for learning and performance may not enhance even after treatment. On the other hand, unlike Anatolian high school, public high school experimental group students' test anxiety, which is a sign of worry and concern about exams, increased following the case-based instruction. It was estimated by Hill and Wigfield (1984) that 25 % of the students in classrooms will face with problems about test anxiety in classrooms and proposed that very simple measures such as removing time limitation from classroom tests can assist anxious students perform better. Students' test anxiety can increase due to lack of time or perceived lack of time, especially if anxious students use certain parts of their testing time worrying about their performance. This diversion will diminish the amount of time spent thinking for the test. Moreover, knowing the intention of tests to compare students in terms of their relative ability can enhance social comparison or anxiety. Both schools of students were given enough time to answer the test questions of the study and during data collection researcher ensured that the related results will be kept confidential in order to reduce the potential anxiety that may occur in answers to questions. However, highly test-anxious students have deficiencies in skills about test-taking strategies; namely, they do not know how to work effectively and how to deal with a test strategically and in general they are not well-prepared for the test (Pekrun, 1992). In contrary to Public high school, Anatolian high school students had enrolled to their school after being successful in high school entrance examination which is a test to select students for the Anatolian high schools across Turkey, these students may be familiar to testing strategies and they may have little or similar concerns relating to test performance. In addition, students may have concerns about their performance on the tests because case-based learning is a novel and student-centered approach that they are not accustomed to it. Lastly, Hill and Wigfield (1984) stated that student's unfamiliarity to this tests or the degree of the difficulty of tests can cause anxiety in students. Consequently, time constraints of standardized tests or perceived lack of time, and difference between student characteristics between two schools may cause anxiety for test performance on Public high school experimental students.

When two types of schools were compared, case-based learning enhanced Anatolian high school students' extrinsic goal orientation and self-efficacy for learning and performance more than those in public high school. On the other hand, traditionally designed instruction improved public high school students' task value and Anatolian high school students' test anxiety constructs (See Table 5.23). In other words, Anatolian high school students' conception of success and their reasons for engaging in academic tasks changed significantly after case-based learning. Saral (2008) investigated the effect of case instruction on students' intrinsic and extrinsic motivation but no significant difference was detected in both students' perceived intrinsic and extrinsic goal orientation after the treatment though students' scores of both intrinsic and extrinsic goal orientation improved after teaching with cases. Furthermore, the results of the current study revealed that students in both schools did not participate in the tasks due to the reasons such as challenge, curiosity and mastery. There is a similarity between performance goals and extrinsic goal orientation since performance-oriented students are likely to respond to extrinsic motivation. According to earlier research, performance goals were usually unfavorable in learning (Woolfolk, 2004) but some studies demonstrated that mastery and performance goals are related to each other in terms of using active learning strategies and high self-efficacy (Midgley et al., 2001; Stipek, 2002) and they are beneficial for encouraging academic motivation (Barron & Harackiewicz, 2001; Linnenbrink, 2005). In addition, Anatolian high school students' self-efficacy for learning and performance increased significantly following the case instruction. The reason for enhancing in self-efficacy of students can be using contemporary teaching methods in their classes, they are likely to enhance students' motivation and promote learning. In addition, in the current study it was obtained that traditional instruction developed public high school students' task value and Anatolian high school students' test anxiety. Individuals may value the tasks according to their own needs and values (Eccles, 2005). Public high school students generally solve problems based on numerical calculations related to topic. These students might have found the traditional instruction and related tasks valuable or useful since this type of training would be effective in preparation for the university entrance exams. In addition, students have difficulty in conceptual learning or understanding of gas topics (Nakhleh & Mitchell, 1993; Nurrenberg & Pickering, 1987; Sawrey, 1990). Nakhleh and Mitchell (1993) stated that majority of students preferred algorithmic questions to conceptual ones since they thought conceptually based problems requires more thinking. Therefore, for Anatolian high school students instructed with traditional methods, their test anxiety may have increased after concept testing because they were not familiar with conceptual based problems. In addition to these, generally students' perceived motivation decreased after receiving traditionally designed chemistry instruction in both schools. However, in public high school case-based learning decreased students' intrinsic goal orientation, extrinsic goal orientation and self-efficacy for learning and performance whereas students' motivational constructs increased after case-based instruction in Anatolian high school (See Table 5.18). This difference may be due to the differences between two schools as mentioned before because both experimental group students in two schools were trained in the same way using the same materials.

To sum up, there might be many reasons of such a difference between two schools (Public & Private). As Pintrinch and Schunk (2002) stated that students' motivation may change depending on many factors such as type of students (e.g. achievement level, social class), school size/number of students, self-efficacy of the teacher and the student. In this study, Anatolian high school students were instructed with small class size and this may increase the interaction between student-student and teacher-student (Eccles et al., 1993), which is crucial for effective case-based instruction.

Moreover, results of this study indicated that case-based learning on conceptual change conditions did not improve students' intrinsic goal orientation in both schools. One of the reasons of this can be the implementation period because only 12 weeks for implementation of case-based learning might not be enough to change students' intrinsic goal orientation. In other words, the limited teaching period of instruction might not be sufficient for students to participate in a task for the reasons such as challenge, curiosity, and mastery not for the being means to an end such as grade, reward. Likewise, the overload curriculum might restrict or reduce the effectiveness of this study.

This study also indicated the effectiveness of case-based learning on high school students' social development. Sixty-three students instructed with case method expressed their thoughts, opinions and suggestions on Feedback Form for Case-Based Instruction. The results revealed that majority of students mentioned that case-based instruction with daily life examples helped them to understand the concepts, visualize the events, and increased their curiosity to chemistry lesson. Moreover, this method was found to be a permanent way of learning compared to traditionally designed instruction since it did not require memorization. Besides, some of the students stated that they learnt better in a group work. They mentioned that this teaching method helped them to gain a different point of view by the help of small group and class discussions. In addition, they stated that working in groups, sharing ideas, being able to make comments, learning by discussion, seeing lack of their understandings, learning by having fun provided to arouse their interest to chemistry lesson. The feature(s) of case-based learning that students liked the most was the sharing ideas in a group work, being able to make comments, developing their perspectives by taking others' opinion, learning by discussing on cases, having fun by learning, criticizing themselves and seeing lack of their understanding about the subject. What is more, they stated that expressions with illustration, implementation of case activity related to each topic and being these events visual and the examples from real life were the other features they liked. They typically found the case materials didactic, logical, effective, entertaining, useful, challenging, lively, open to discussion, comprehensible or easy to understand. On the other hand, while a few students found some materials useful like air bag, they found some of them unnecessary. Though many of the students found case-based activities effective, they proposed some recommendations. For instance, many of them suggested that cases should be applied in lessons and be taught with the support of experiments. Some of the students offered to increase the visual property of activities. In addition to these, students were asked whether they faced with any difficulties about the implementation of case-based learning. Most of them clearly stated that they did not confront with any difficulties during the treatment. The problems faced with were only about the difficulty in understanding of some questions in the materials. Some of them mentioned that difficult or challenging questions confused their mind and had difficulty in understanding them. In fact, students were expected to have difficulty in understanding the questions since they were prepared considering the misconceptions about the subject matter. Challenging or difficult questions were the part of the instruction to overcome the misconceptions about the gas topic. Since the conceptual change is a difficult process, it was usual for students having confusion and difficulty in solving problems during the instruction.

Implementation of new teaching methods like this study requires extra work and effort as well as it requires the consideration of several issues. For example, prior to research study interviews with teachers from different schools indicated that most of the teachers are not liable to apply such activities in their lessons due to the overload curriculum though the related materials had already been prepared by the researcher. Moreover, when such activities are applied in the course, the congruence between classes in terms of content coverage are disturbed inevitably and so students with the same grade level may concern about getting behind in other topics. Besides, this condition affects adversely common exam programs scheduled at the beginning of the school year because common exams do not reach their objectives in one sense. All of this limits classroom activities somehow.

In addition to these, in Turkey many of the students follow the courses given in some private educational institutions in general called as *dershane*. These private educational foundations are very common in Turkey. They follow the same curriculum with state high schools and usually present the courses in traditional ways. This kind of external influences affects the efficiency of new teaching methods in classes because how much of the misconceptions trying to be overcome in class setting, other educational institutions may have the possibility to promote them. Thus, the results of the studies like case-based learning will inevitably be affected by these external influences. In order to reduce the need for private institutions, student-centered teaching methods should be adopted instead of teacher-centered ones and new teaching strategies and their measurement tools should be developed in high schools in Turkey. In addition, these improvements will not be taken into account as long as university entrance conditions depend on only three hours examination not to the school achievement. For this purpose, our education system in state schools should be restructured. In that respect, the improvements have begun in 9^{th} class curriculum. Another problem that can be faced with during the application of new teaching method is the teachers' practical habits that they want to continue. Since they are accustomed to teach lessons based on traditional methods, they may feel the need of explaining everything in detail. They may think that they are the only knowledgeable and competent person in the class so they may not allow students to construct their own knowledge. Moreover, teachers' and students' lack of familiarity with case-based learning method can be a problem for the implementation of it in classes. For instance, students' familiarity to classroom activities such as group work can be an important factor for the effective implementation of case method of learning. For the disadvantage of case-based learning, Woods (1994) stated teaching habits might cause a persistent notion to accept change. Moreover, Gallucci (2007) claimed that instructors' enthusiasm using case-method is an important factor on the effectiveness of this method. Besides, one concern about case study method can be its over contextualization. In this case, one case or scenario may not be enough for students' understanding of concepts therefore multiple cases can be used for learning the same concept but sometimes this may be time-consuming or more complex cases can be used in order to deal with multiple concepts (NRC, as cited in Gallucci, 2007).

To sum up, case-based learning as a student-centered method requires more time and effort compared to traditional method. However, it is a teaching strategy in which students are actively engaged in learning process promoting students' conceptual understanding of concepts. Therefore, it is adviced to use case-based instruction to support meaningful learning.

6.2 Implications

This study has several important implications for science teachers, educators, and researchers:

Gas concepts have an important place daily life so there are many conceptions about gases in students' mind before instruction. While some of them are true, some of them conflict with scientifically true knowledge and they distort their learning severely. Therefore, during the instruction of case-based learning, students' existing knowledge related to the concepts of gases should be taken into account otherwise; it is difficult to accommodate new knowledge with the existing one meaningfully. The concepts connected with daily life facilitate learning and provide connection between the prior knowledge and the new information. The results of the study indicated that even well designed teaching strategies could not eliminate all the misconceptions related to a subject matter. Consequently, teachers should take in consideration misconceptions while designing their lessons. On the other hand, sometimes teachers can be the one of the sources of the misconceptions. In faculties, more courses should be opened that are dealing with the misconceptions and these courses should include strategies helping teachers to remedy them in their subject area. In addition, experts should give seminars or workshops organized by the ministry of national education to primary or secondary school teachers about new teaching techniques. Teachers should be trained about how to write and implement the cases in their routine classes. They should also be encouraged to use new teaching techniques like case-based instruction in order to enrich their lessons.

Teacher training programs in universities should include this method of learning and present examples about the implementation of cases. Researchers from different fields of science such as chemistry, biology, physics, and mathematics should investigate the effectiveness of this method in elementary and secondary school programs with respect to their subject area.

Students' attitude and motivation have an impact on students' learning. Therefore, teachers should take into account students' attitudes and motivation toward chemistry while developing instructional strategies. In the present study, case-based learning improved students' motivation and attitude toward chemistry positively in Anatolian high school. As in Anatolian high school, students' attitude and motivation in public high schools can be enhanced with decrease in class size. Teachers and also students thought that small class size facilitates personal interaction and relationship with students. In classes with small class size, students feel themselves confident and they are more likely to ask questions as being included in the learning activities. On the other hand, large classes seem to be problematic due to additional workload as well as reducing the quality of the relationship between the students and the teacher (Eames & Stewart, 2008).

During the implementation of case-based learning, some difficulties may arise and learning may be distorted due to classroom environment, overloaded curriculum, adaptation problems or inexperienced teachers. Regular classrooms were not appropriate for group work to implement the case-based instruction so application of this method in the class with larger class size occurred in the school laboratory, which provided suitable environment having individual chairs and tables for face-to-face group work as well as saving time. In addition, implementation of this method needs more time for reading, discussing, analyzing and evaluating of the given scenarios. However, time limitation, limited class hours and the overloaded curriculum affected the effectiveness of the case-based learning negatively. Therefore, class hours in chemistry course should be increased and classes suitable for group discussion providing face-to-face interaction should be designed.

6.3 Recommendations

Based on the results of this study, the researcher recommends that:

1. Similar studies can be conducted at different grade levels with different sample sizes.

2. Similar studies can be conducted in a larger sample and different types of schools in order to increase the generalizability of the study.

3. Studies can be conducted to investigate the effectiveness of case-based learning on students' understanding of chemical concepts other than gas topic in chemistry as well as in other disciplines such as physics, mathematics and biology.

4. Studies can be conducted to investigate the effect of case-based learning on pre-service students' understanding of gas concepts or other concepts in chemistry as well as other fields of science concepts.

5. Studies can be conducted in order to evaluate the long terms effects of case-based learning via longitudinal studies.

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APPENDIX A

INSTRUCTIONAL OBJECTIVES

1. To discover direction of the atmospheric pressure.
2. To explain pressure of gas in an enclosed space based on kinetic theory.
3. To explain how air pressure changes with change in altitude.
4. To conclude the homogeneous distribution of gas particles in any enclosed space.
5. To identify the relationship between molecular velocity and temperature of gases.
6. To comprehend the conservation of mass for reactions involving gaseous reactants or products.
7. To explain how the diffusion rate of gases changes depending on molecular weight and temperature of gases.
8. To explain the concept of partial pressure in mixtures of gases.
9. To comprehend gases have mass like solids and liquids.
10. To examine the effects of atmospheric pressure.
11. To establish the relationships between the pressure, volume, quantity and the temperature of a gas.
12. To explain cooling of a gas at molecular level.
13. To explain heating of a gas at molecular level.
14. To use ideal gas law to solve a problem.
15. To draw the partial pressure of a gas in a mixture.
16. To draw the distribution of gases in an enclosed space at different teamperatures.
17. To use gas laws in other science areas.

APPENDIX B

GAZ KAVRAM TESTİ

Adı Soyadı:

Sınıf:

Okul:

Cinsiyet: Kız ☐ Erkek ☐

Yaş:

Açıklama: Aşağıdaki çoktan seçmeli testte 26 soru bulunmaktadır. Her sorunun 5 seçeneği vardır. Doğru olduğunu düşündüğünüz bir seçeneği işaretleyiniz.

1. Gazlarla ilgili aşağıdakilerden hangisi <u>doğrudur</u>?

A) Gaz basıncı aşağı doğrudur.

B) Gaz halden sıvı ya da katı hale geçerken tanecikler küçülürler.

C) Gaz tanecikleri arasında yok denecek kadar az çekim kuvveti vardır.

D) Gazlar molekül ağırlıklarına göre farklı hacimler kaplarlar.

E) Gaz basıncı, gaz taneciklerinin içerdiği atom sayısına ve cinsine bağlıdır.

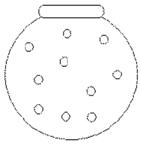
2. Kapalı bir kapta, gaz hâlde bulunan bir madde ile ilgili aşağıdakilerden hangisi <u>doğru değildir</u>?

A) Birim zamanda kap yüzeyinin her santimetrekaresine çarpan tanecik sayısı aynıdır.
B) Gazın yaptığı basınç kabın çeperlerinin her yerinde aynıdır.
C) Kap içinde herhangi bir noktada ölçülen basınç, bu gazın basıncıdır.
D) Kap içindeki gazın tabana yaptığı basınç yan yüzeylere yaptığı basınçtan daha fazladır.
E) Taneciklerin birbirleriyle yaptıkları toplam çarpma sayısı çeperlere yaptıkları toplam çarpma sayısına eşittir.

3. Üflenerek biraz şişirilip ağzı iple bağlanmış bir balon, bulunduğu ortamdan alınarak, aşağıdaki ortamlardan hangisine konulursa balonun hacminin <u>azalması beklenir</u>?

A) Aynı basınçta, daha soğuk
B) Aynı basınçta, daha sıcak
C) Aynı sıcaklıkta, yükseltisi daha fazla
D) Aynı sıcaklıkta, havası boşaltılmış
E) Aynı yükseltide, daha sıcak

4.Yandaki kapalı kapta hidrojen gazının 25 ^oC ve 1 atm basınçtaki dağılımı verilmiştir. (Yuvarlaklar (o) hidrojen gazının moleküllerini temsil etmektedir.). Aşağıdakilerden hangisi sıcaklık **-15 ^{o}C ye düşürüldüğünde gaz moleküllerinin dağılımını gösterir?**



A) 

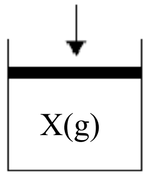
B) 

C) 

D) 

E) 

5. Sabit sıcaklıkta, ideal davranıştaki X gazı pistonlu bir kabın içine konuluyor ve piston itilerek sıkıştırılıyor. **Sıkıştırma işlemi sonunda bu gaz ile ilgili aşağıdaki yargılardan hangisi <u>yanlıştır</u>?**

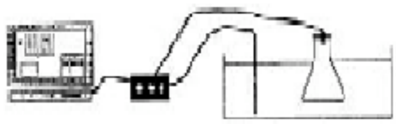


A) Basıncı artar.
B) Tanecikler arası uzaklık azalır.
C) Birim hacimdeki tanecik sayısı artar.
D) Taneciklerin ortalama hızı azalır.
E) Taneciklerin sayısı değişmez.

6. Gaz hâldeki bir madde ile dolu kapalı bir kap ısıtıldığında kap içindeki basıncın arttığı gözleniyor. **Aşağıdakilerden hangisinde bu olayın sebebi <u>en doğru</u> şekilde açıklanmıştır?**

A) Gaz hâldeki maddenin taneciklerinin büyümesi
B) Gaz hâldeki maddenin taneciklerinin ısındıkça sayısının artması
C) Isı alan gaz hâldeki maddenin ağırlaşması
D) Isı alan gaz hâldeki maddenin taneciklerinin çarpma sayısının artması
E) Isı alan gaz hâldeki maddenin taneciklerinin kabın çeperlerinde yoğunlaşması

7, 8 ve 9. soruları aşağıda verilen açıklamaya göre cevaplandırınız.



Hava içeren kapalı bir kap şekilde gösterildiği gibi su banyosunun içine yerleştirilmiştir ve bilgisayara bağlanmıştır. Sıcaklık değişimleri kaba yerleştirilen termometre ile takip edilmektedir. Ayrıca kap basıncı ölçen bir alete de bağlanmıştır ve basınç bilgisayarda okunabilmektedir. Su banyosunun sıcaklığı 25 °C ve basıncı 1 atm'dir.

7. 25 °C'de havayı oluşturan taneciklerin kap içerisindeki dağılımını <u>en iyi</u> gösteren şekil hangisidir?

A) B) C) D) E)

8. Su banyosuna buz ilave edilerek kaptaki sıcaklık 0°C'ye kadar düşürülmektedir. **Sıcaklık değişiminin havayı oluşturan tanecikleri etkileyecek kadar bekledikten sonra taneciklerin kap içindeki dağılımını <u>en iyi</u> gösteren şekil hangisidir?**

A) B) C) D) E)

9. Isıtıcı yardımıyla su banyosundaki su ısıtılarak gazı içeren kabın sıcaklığı 60°C'ye yükseltilmektedir. **Bu durumda taneciklerin kap içerisindeki dağılımını <u>en iyi</u> gösteren şekil hangisidir?**

A) B) C) D) E)

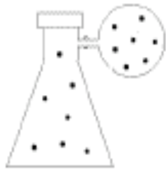
10. Hava ile dolu bir kaba şekildeki gibi bir balon bağlanmaktadır. Aradaki musluğu

açıp kabı ısıttığımızda balonun şiştiği gözlemlenmektedir. **Hangi şekil balon şiştikten sonra havayı oluşturan taneciklerin dağılımını en iyi açıklar?** (Noktalar (.) havayı oluşturan tanecikleri temsil etmektedir.)

A)

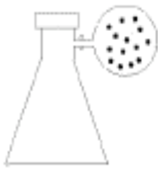
B)

C)

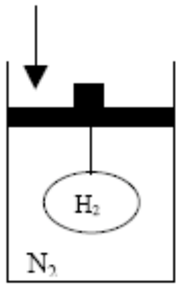


D)

E)



11. Sabit sıcaklıkta, şekildeki pistonlu kapın içerisinde azot gazı bulunmaktadır. Pistona çelik iple bağlı elastik balonun içinde ise hidrojen gazı bulunmaktadır.



Elastik balon kabın hiçbir yüzeyine değmeyecek şekilde, piston aşağı doğru bir miktar itilirse balonun şeklinde ne gibi bir değişiklik olur?

A) Balon patlar.

B) Balon sadece yanlardan büzülür.

C) Balonun sadece üst kısmı büzülür.

D) Balonun sadece alt kısmı büzülür.

E) Balon her yerden büzülür.

12. Bir gazı oluşturan taneciklerin arasında ne bulunur?

A) Hava

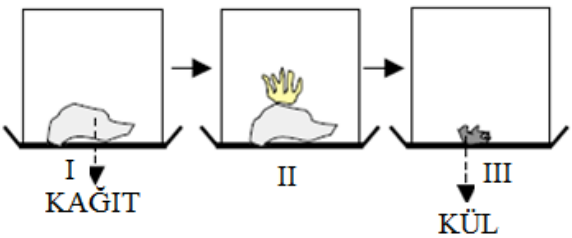
B) Su buharı

C) Başka gazlar

D) Hiçbir şey yoktur.

E) Yabancı maddeler (toz, kir vs.)

13. Aşağıda verilen şekillerde Durum I'de bir parça kâğıt cam fanusun içine konulmaktadır. Durum II'de kâğıt yanmakta ve Durum III'de küller oluşmaktadır. Her üç durumda da cam fanuslar tartılmıştır**. Buna göre aşağıdakilerden hangisi doğrudur?**



A) Durum I en büyük kütleye sahiptir.

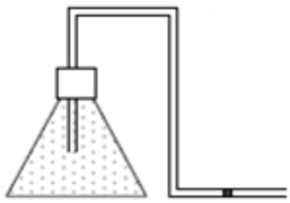
B) Durum II en büyük kütleye sahiptir.

C) Durum III en büyük kütleye sahiptir.

D) I ve II aynı kütleye sahiptir ve III' ten daha fazladır.

E) Hepsi de aynı kütleye sahiptir.

14. Şekilde verilen sistemde cam borunun içinde bir damla civa bulunmaktadır. Kabın içindeki basınç ve sıcaklık değişimine bağlı olarak civa damlası sağa ya da sola hareket etmektedir. **Eğer düzenek sıcaklığı 25 ^oC oda sıcaklığından 5 ^oC sıcaklığındaki bir ortama götürülürse civanın hareketi ile ilgili aşağıdakilerden hangisi doğru olur?**



A) Hareketsiz kalır, çünkü açık hava basıncı sabittir.

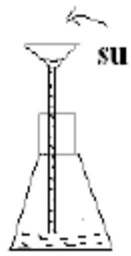
B) Önce sola sonra sağa hareket eder.

C) Sola hareket eder, sıcaklık düşünce erlendeki basınç da azalır.

D) Sağa hareket eder, sıcaklık düşünce kabın içindeki basınç azalır ve hacim artar.

E) Sağa hareket eder, sıcaklık düşünce hacim azalır ve erlendeki basınç da artar.

15. Şekildeki kap, huniye bağlı bir tıpa ile sıkıca kapatılmıştır. Kaba su döktüğümüzde kolayca girmektedir. Fakat kaptaki su seviyesi huninin alt kısmına ulaşınca su ilavesi zorlaşmaktadır. **Bunun sebebi aşağıdakilerden hangisi olabilir?**



A) Kaptaki su, girişi kapatmaktadır ve su giremez.

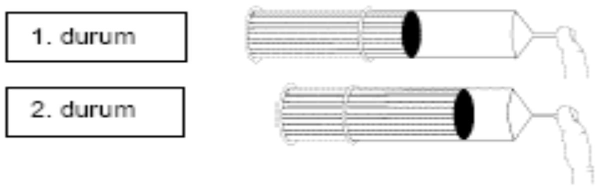
B) Kap daha büyük olsaydı daha fazla su alırdı.

C) Kaptaki iç basıncın artması su girişini engeller.

D) Kaptaki su yukarıya doğru itme kuvveti uygulamaktadır ve su giremez.

E) Kaptaki suyun kaldırma kuvveti, daha fazla su ilavesini kaldıramaz duruma gelmiştir.

16.



Sabit sıcaklık ve basınçta, içinde hava bulunan 1.durumdaki şırınganın pistonu bir miktar itilerek içindeki hava sıkıştırılıp 2.duruma getirilmektedir. **Sıkıştırma sonucunda havayı oluşturan tanecikler için aşağıdaki ifadelerden hangisi <u>doğrudur</u>?**

A) Tanecikler birbirine yapışır.
B) Taneciklerin hepsi şırınganın ucuna toplanır.
C) Tanecikler küçülür.
D) Tanecikler arasındaki mesafe azalır.
E) Tanecikler yüksek basınçtan dolayı patlar.

17. Sabit sıcaklıkta, bir maddenin katı hâlden sıvı hâle, sıvı hâlden gaz hâle geçtikçe, taneciklerinin aşağıda verilen özelliklerinden hangisi ya da hangileri <u>değişir</u>?

I. Büyüklüğü
II. Kinetik enerjileri
III. Tanecikler arasındaki uzaklık (mesafe)

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

18. Gazlarla ilgili verilen ifadelerden hangisi <u>yanlıştır</u>?

A) Tanecikli yapıya sahiptir.
B) Gazlar, bulundukları kabın her tarafına yayılırlar.
C) Gaz basıncı, birim hacimdeki tanecik sayısına bağlıdır.
D) Aynı sıcaklıkta, bütün gazların ortalama kinetik enerjileri aynıdır.
E) Aynı sıcaklıkta, gazların molekül ağırlığı arttıkça difüzyon hızı artar.

19. Soğuk ve sıcak havanın özellikleri ile ilgili verilen yargılardan hangisi doğrudur?

A) Sıcak hava soğuk havadan hafiftir.
B) Sıcak hava soğuk havadan daha ağırdır.
C) Havanın kütlesi de hacmi de yoktur, sıcak ya da soğuk fark etmez.
D) Sıcak hava ile soğuk hava farklı hacimlere fakat aynı kütleye sahiptirler.
E) Sıcak havanın tanecikleri genleşir, soğuk havanınkiler ise büzülür.

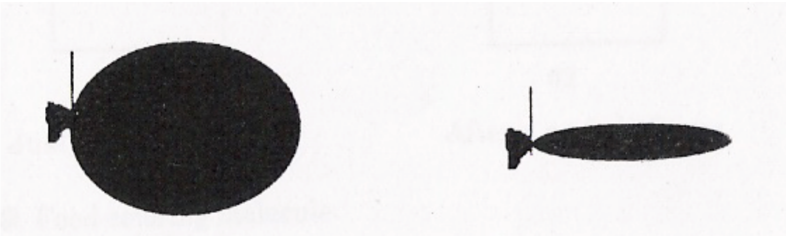
20. Atmosfer basıncının Patm olduğu bir ortamda hava ile dolu bir balonun basıncı Pdolu olarak ölçülmektedir. Balonun ağzı açılıp sönmesi beklenmektedir ve sönmüş balonun basıncı Psönmüş olarak ölçülmektedir. **Aşağıdakilerden hangisinde Patm, Pdolu ve Psönmüş basınçlarının ilişkisi doğru olarak verilmiştir?**

A) Psönmüş < Patm < Pdolu
B) Psönmüş = Patm , Patm < Pdolu
C) Patm = Pdolu = Psönmüş
D) Patm > Pdolu , Psönmüş=0
E) Patm < Pdolu, Psönmüş=0

21. Gazların özellikleri ile ilgili aşağıdaki yargılardan hangisi yanlıştır?

A) Gazlar sıvılaştırılabilirler.
B) Gaz tanecikleri sürekli hareket halindedir.
C) Gazlar bir kaba konulduklarında sıvılar gibi kabın dibinde bulunurlar.
D) Gaz tanecikleri arasındaki bağlar yok denecek kadar zayıftır.
E) Gaz tanecikleri rastgele hareket ederler, belli bir hareket düzeni yoktur.

22. Kauçuk bir balon Hidrojen gazı ile doldurulduktan sonra ağzı sıkıca bağlanır. Ancak birkaç gün sonra balonun söndüğü görülmektedir. **Aşağıdakilerden hangisi durumu <u>en iyi</u> açıklamaktadır?**



A) Dış basınç artmış ve balonu küçültmüştür.

B) Moleküller çarpışa çarpışa küçülmüşlerdir.

C) Hava soğumuştur ve moleküller bir araya kümelenmiştir.

D) Zamanla moleküllerin enerjisi tükenir ve hareketleri durur.

E) Balonun gözeneklerinden gaz çıkışı olmuştur.

23. İdeal davranıştaki X_2 ve X_3 gazlarının sıcaklıkları, hacimleri ve molekül sayıları eşittir. **Bu gazlarla ilgili aşağıdaki karşılaştırmalardan hangisi <u>yanlıştır</u>?**

A) Basınçları farklıdır.

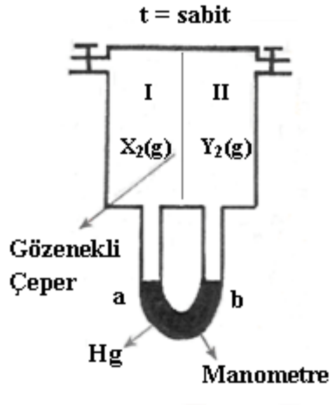
B) Özkütleleri farklıdır.

C) Kütleleri farklıdır.

D) Mol sayıları aynıdır.

E) Ortalama kinetik enerjileri aynıdır.

24. Şekilde görüldüğü gibi, bir kap gözenekli bir çeper ile I ve II bölmelerine ayrılarak manometreye bağlanıyor. Manometrenin kollarındaki civa seviyeleri aynı olacak şekilde kabın I.bölmesine X_2 gazı, II. bölmesine Y_2 gazı dolduruluyor. Aynı sıcaklıkta çok kısa bir süre sonra manometrenin a kolundaki civa seviyesinin yükseldiği gözleniyor.



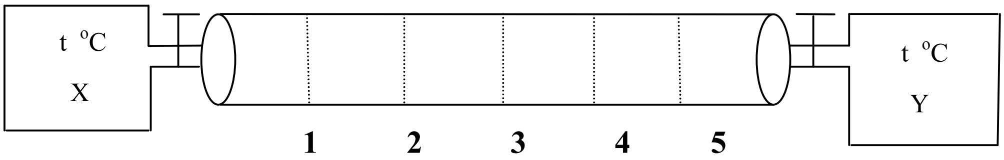
Bu gözleme göre, X_2 ve Y_2 gazları ile ilgili,

I. X_2 molekülleri Y_2 moleküllerinden hızlıdır.
II. Y_2 nin mol kütlesi X_2 ninkinden büyüktür.
III. Gözlem sırasında II. kabın toplam basıncı artmıştır.

Yargılarından hangileri doğrudur?

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

25.



Şekilde gördüğünüz X ve Y gazı aynı anda karşılıklı yayılmaya bırakıldığında, gazların ilk karşılaşmaları borunun 5. kesitinde gerçekleştiğine göre,

I. X'in yayılma hızı, Y'nin yayılma hızından büyüktür.

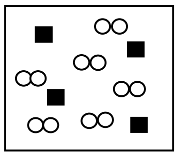
II. X'in molekül kütlesi, Y'nin molekül kütlesinden büyüktür.

III. Bu iki gazın borunun tam ortasında karşılaşmaları için, Y gazının bulunduğu kap ısıtılmalıdır.

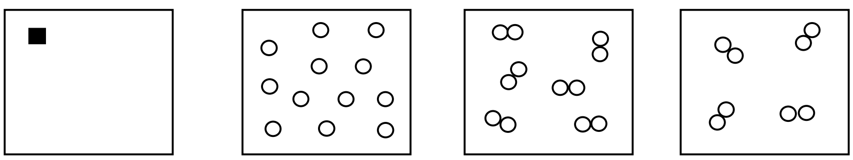
Yargılarından hangisi doğrudur?

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

26.Aşağıdaki kapalı kap, 25°C'ta şekilde gösterildiği gibi oksijen ( ) ve helyum ( ) gazlarından oluşan bir karışım içermektedir.



Aşağıdakilerden hangisi oksijen gazının kısmi basıncını göstermektedir?



A) B) C) D) E)

APPENDIX C

ÖGRENMEDE GÜDÜSEL STRATEJİLER ANKETİ

Değerli Öğrenci,

Bu ölçek <u>kimya dersine yönelik</u> öğrenme stratejilerini ve öğrenme güdülenmenizi belirlemek amacıyla hazırlanmıştır. Ölçekte yer alan sorulara verdiğiniz yanıtlar, kesinlikle **size not vermek** ya da sizi **eleştirmek** amacıyla **kullanılmayacaktır**. Bu soruların herkes için geçerli **doğru yanıtları bulunmamaktadır**. Bu nedenle lütfen aşağıda verilen tüm soruları dikkatle okuyarak yanıtınızı, ifadenin karşısındaki seçeneklerden sizin için en uygun olanı işaretleyerek belirtiniz.
Soruları yanıtlamak için aşağıdaki ölçütleri kullanın. Soruda geçen ifade sizin için **kesinlikle doğru ise (7)**'yi; sizinle ilgili **kesinlikle yanlışsa (1)**'i işaretleyin. Eğer ifadenin size göre doğruluğu bunlardan farklı ise sizin için en uygun düzeyi gösteren (1)'le (7) arasındaki rakamı işaretleyin.

Benim için Kesinlikle Yanlış.	**1 2 3 4 5 6 7**	**Benim için Kesinlikle Doğru.**

Soru No	**GÜDÜLENME (MOTİVASYON)**	
1	Kimya dersinde yeni bilgiler öğrenebilmek için büyük bir çabagerektiren sınıf çalışmalarını tercih ederim.	(1) (2) (3) (4) (5) (6) (7)
2	Eğer uygun şekilde çalışırsam,kimya dersindeki konuları öğrenebilirim.	(1) (2) (3) (4) (5) (6) (7)
3	Kimya sınavları sırasında, diğer arkadaşlarıma göre soruları ne kadar iyi yanıtlayıp yanıtlayamadığımı düşünürüm.	(1) (2) (3) (4) (5) (6) (7)
4	Kimya dersinde öğrendiklerimi başka derslerde de kullanabileceğimi düşünüyorum	(1) (2) (3) (4) (5) (6) (7)

5	Kimya dersinden çok iyi bir not alacağımı düşünüyorum.	(1) (2) (3) (4) (5) (6) (7)
6	Kimya dersi ile ilgili okumalarda yer alan en zor konuyu bile anlayabileceğimden eminim.	(1) (2) (3) (4) (5) (6) (7)
7	Benim için şu an kimya dersi ile ilgili en tatmin edici şey iyi bir not getirmektir.	(1) (2) (3) (4) (5) (6) (7)
8	Kimya sınavları sırasında bir soru Üzerinde uğraşırken, aklım sınavın diğer kısımlarında yer alan cevaplayamadığım sorularda olur.	(1) (2) (3) (4) (5) (6) (7)
9	Kimya dersindeki konuları **öğrenemezsem** bu benim hatamdır.	(1) (2) (3) (4) (5) (6) (7)
10	Kimya dersindeki konuları öğrenmek benim için önemlidir.	(1) (2) (3) (4) (5) (6) (7)
11	Genel not ortalamamı yükseltmek şu an benim için en önemli şeydir, bu nedenle kimya dersindeki temel amacım iyi bir not getirmektir.	(1) (2) (3) (4) (5) (6) (7)
12	Kimya dersinde öğretilen temel kavramları öğrenebileceğimden eminim.	(1) (2) (3) (4) (5) (6) (7)
13	Eğer başarabilirsem, kimya dersinde sınıftaki pek çok öğrenciden daha iyi bir not getirmek isterim.	(1) (2) (3) (4) (5) (6) (7)
14	Kimya sınavları sırasında bu dersten başarısız olmanın sonuçlarını aklımdan geçiririm.	(1) (2) (3) (4) (5) (6) (7)
15	Kimya dersinde, öğretmenin anlattığı en karmaşık konuyu anlayabileceğimden eminim.	(1) (2) (3) (4) (5) (6) (7)
16	Kimya derslerinde öğrenmesi zor olsa bile, bende merak uyandıran sınıf çalışmalarını tercih ederim.	(1) (2) (3) (4) (5) (6) (7)
17	Kimya dersinin kapsamında yer alan konular çok ilgimi çekiyor.	(1) (2) (3) (4) (5) (6) (7)
18	Yeterince sıkı çalışırsam kimya dersinde başarılı olurum.	(1) (2) (3) (4) (5) (6) (7)
19	Kimya sınavlarında kendimi mutsuz ve huzursuz hissederim.	(1) (2) (3) (4) (5) (6) (7)
20	Kimya dersinde verilen sınav ve ödevleri en iyi şekilde yapabileceğimden eminim.	(1) (2) (3) (4) (5) (6) (7)
21	Kimya dersinde çok başarılı olacağımı umuyorum.	(1) (2) (3) (4) (5) (6) (7)
22	Kimya dersinde beni en çok tatmin eden şey, konuları mümkün olduğunca iyi öğrenmeye çalışmaktır.	(1) (2) (3) (4) (5) (6) (7)
23	Kimya dersinde öğrendiklerimin	(1) (2) (3) (4) (5) (6) (7)

	benim için faydalı olduğunu düşünüyorum.	
24	Kimya dersinde, iyi bir not getireceğimden emin **olmasam** bile öğrenmeme olanak sağlayacak ödevleri seçerim.	(1) (2) (3) (4) (5) (6) (7)
25	Kimya dersinde bir konuyu **anlayamazsam** bu yeterince sıkı çalışmadığım içindir.	(1) (2) (3) (4) (5) (6) (7)
26	Kimya dersindeki konulardan hoşlanıyorum.	(1) (2) (3) (4) (5) (6) (7)
27	Kimya dersindeki konuları anlamak benim için önemlidir.	(1) (2) (3) (4) (5) (6) (7)
28	Kimya sınavlarında kalbimin hızla attığını hissederim.	(1) (2) (3) (4) (5) (6) (7)
29	Kimya dersinde öğretilen becerileri iyice öğrenebileceğimden eminim.	(1) (2) (3) (4) (5) (6) (7)
30	Kimya dersinde başarılı olmak istiyorum çünkü yeteneğimi aileme, arkadaşlarıma göstermek benim için önemlidir.	(1) (2) (3) (4) (5) (6) (7)
31	Dersin zorluğu, öğretmen ve benim becerilerim göz önüne alındığında, kimya dersinde başarılı olacağımı düşünüyorum.	(1) (2) (3) (4) (5) (6) (7)

Demografik Bilgiler

Adınız, Soyadınız :____________________

Yaşınız :____________________

Arastırma sonuçlarının gönderilmesini istiyorsanız e-posta adresiniz: ____________________

I would like to thank Assoc.Prof.Semra Sungur for permitting me to use the MSLQ.

APPENDIX D

KİMYA DERSİ TUTUM ÖLÇEĞİ

AÇIKLAMA: Bu ölçekte, kimya dersine ilişkin tutum cümleleri ile her cümlenin karşısında "Tamamen Katılıyorum", "Katılıyorum", "Karasızım", "Katılmıyorum" , "Hiç Katılmıyorum" olmak üzere beş seçenek verilmiştir. Her cümleyi dikkatle okuduktan sonra kendinize uygun seçeneği işaretleyiniz.

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyoru m	Hiç Katılmıyoru
1.Kimya çok sevdiğim bir alandır.	O	O	O	O	O
2.Kimya ile ilgili kitapları okumaktan hoşlanırım.	O	O	O	O	O
3.Kimyanın günlük yaşantıda çok önemli yeri yoktur.	O	O	O	O	O
4.Kimya ile ilgili ders problemlerini çözmekten hoşlanırım.	O	O	O	O	O
5.Kimya konularıyla ilgili daha çok şey öğrenmek isterim.	O	O	O	O	O
6.Kimya dersine girerken sıkıntı duyarım.	O	O	O	O	O
7.Kimya derslerine zevkle girerim.	O	O	O	O	O
8.Kimya derslerine ayrılan ders saatinin daha fazla olmasını isterim.	O	O	O	O	O
9.Kimya dersini çalışırken canım sıkılır.	O	O	O	O	O
10.Kimya konularını ilgilendiren günlük olaylar hakkında daha fazla bilgi edinmek isterim.	O	O	O	O	O
11.Düşünce sistemimizi geliştirmede kimya öğrenimi önemlidir.	O	O	O	O	O
12.Kimya, çevremizdeki doğal olayların daha	O	O	O	O	O

iyi anlaşılmasında önemlidir.					
13.Dersler içinde Kimya dersi sevimsiz gelir.	O	O	O	O	O
14.Kimya konularıyla ilgili tartışmaya katılmak bana cazip gelmez.	O	O	O	O	O
15.Çalışma zamanımın önemli bir kısmını kimya dersine ayırmak isterim.	O	O	O	O	O

I would like to thank Prof.Dr.Ömer Geban for permitting me to use the Attitude Scale Toward Chemistry.

APPENDIX E

ÖRNEK OLAYA DAYALI ÖĞRENME MODELİ

GERİ BİLDİRİM FORMU

Adı Soyadı:
Sınıf:
Okul:

Açıklama: Aşağıda verilen sorular Örnek Olaya Dayalı Öğrenme Modeline ilişkin görüşlerinizi belirlemek için hazırlanmıştır. Bu nedenle verdiğiniz cevaplar örnek olaya dayalı öğrenme modelinin ileride etkili bir şekilde uygulanabilmesi için büyük önem taşımaktadır. Lütfen her soruyu dikkatlice okuyarak, görüşlerinizi içtenlikle belirtiniz. Teşekkürler.

1. Örnek olaya dayalı öğrenme modeli gazlar konusunu öğrenmede etkili bir yöntem midir? Neden?

2. Örnek Olaya Dayalı Öğrenme Modelinde en çok hoşunuza giden özellik ya da özellikler nelerdir?

3. Örnek Olaya Dayalı Öğrenme Modelinde hangi özelliği ya da özellikleri kesinlikle değiştirmek isterdiniz?

4. Ders sırasında işlenen örnek olaylar hakkındaki görüşleriniz nelerdir?

5. Örnek Olaya Dayalı Öğrenme Modelinin uygulanması sırasında herhangi bir zorlukla karşılaştınız mı?

APPENDIX F

TREATMENT VERIFICATION CHECKLIST

Explanation: This scale includes fifteen items related to the implementation of case-based learning. For the first two items select "YES" or "NO". For the rest of the items (3 to 15), the alternatives of "Rarely", "Never", "Frequently", "Usually", and "Always" are given. After reading the items carefully, mark the option you think is correct.

Quest. No		**YES**	**NO**
1	Students work in small groups.	O	O
2	The groups are heterogeneous in terms of gender, chemistry achievement and attitude.	O	O

		Rarely	**Never**	**Frequently**	**Usually**	**Always**
3	Teacher hands out the case activities at the appropriate times.	O	O	O	O	O
4	Students generate ideas about given case scenarios and the related questions.	O	O	O	O	O
5	Each of the group participants joins a learning activity and makes a contribution.	O	O	O	O	O
6	Students respect the others ideas/opinions and listen each other while declaring.	O	O	O	O	O
7	Students share the information and help each other to understand during a group activity.	O	O	O	O	O
8	Teacher establishes a relaxing, comfortable environment.	O	O	O	O	O
9	Teacher ensures equal participation.	O	O	O	O	O
10	Teacher asks discrepant questions to create a	O	O	O	O	O

10	Teacher asks discrepant questions to create a dilemma by moving around the groups in the class.	O	O	O	O	O
11	Teacher encourages the students to think critically about the given case scenario.	O	O	O	O	O
12	Teacher makes directive explanations to keep the group focus on the goal.	O	O	O	O	O
13	Teacher asks open-ended and non-directive questions.	O	O	O	O	O
14	Teacher gives feedback to students about the case-based activities.	O	O	O	O	O
15	The students presenting the group ideas or	O	O	O	O	O

APPENDIX G

PERCENTAGES OF STUDENTS' RESPONSES ON POST-GAS CONCEPT TEST

Table G.1 Percentages of students' responses on GCT

		Response Percentage (%)	
Item Number	**Alternative**	**Experimental Group**	**Control Group**
1	A	1.5	0.0
	B	4.6	4.8
	*C	86.2	73.0
	D	3.1	11.1
	E	4.6	11.1
2	A	1.6	3.2
	B	3.1	1.6
	C	4.7	7.9
	*D	84.4	84.1
	E	6.3	3.2
3	*A	76.9	79.0
	B	10.8	16.1
	C	6.2	0.0
	D	1.5	1.6
	E	4.6	3.2
	*A	9.5	58.1
	B	27.0	25.8

4	C	4.8	3.2
	D	15.9	4.8
	E	42.9	8.1
5	A	1.6	3.2
	B	7.8	6.3
	C	28.1	25.4
	*D	45.3	65.1
	E	17.2	0.0
6	A	3.1	7.9
	B	6.3	1.6
	C	4.7	3.2
	*D	60.9	84.1
	E	25.0	3.2
7	A	1.5	3.2
	B	15.4	1.6
	C	1.5	3.2
	*D	80.0	92.1
	E	1.5	0.0
8	A	0.0	0.0
	B	0.0	5.0
	C	52.3	16.1
	*D	10.8	66.1
	E	36.9	9.7
9	A	42.2	9.7
	B	28.1	17.7
	C	0.0	1.6
	*D	28.1	71.0
	E	1.6	0.0
10	A	4.7	1.6
	B	14.1	9.5
	*C	64.1	81.0
	D	14.1	3.2

	E	3.1	4.8
11	A	34.9	40.3
	B	11.1	3.2
	C	6.3	3.2
	D	12.7	1.6
	*E	34.9	51.6
12	A	55.4	12.9
	B	4.6	3.2
	C	21.5	8.1
	*D	16.9	74.2
	E	1.5	1.6
13	A	10.9	1.6
	B	25.0	6.5
	C	12.5	1.6
	D	3.1	8.1
	*E	48.4	82.3
14	A	6.6	9.8
	B	6.6	1.6
	*C	62.3	42.6
	D	4.9	41.0
	E	19.7	4.9
15	A	12.7	9.8
	B	4.8	4.9
	*C	44.4	54.1
	D	36.5	29.5
	E	1.6	1.6
16	A	4.8	1.6
	B	12.7	3.2
	C	3.2	0.0
	*D	71.4	93.7
	E	7.9	1.6
	A	1.6	1.6

17	B	1.6	4.8
	*C	31.3	56.5
	D	15.6	0.0
	E	50.0	37.1
18	A	3.3	1.6
	B	0.0	0.0
	C	8.3	11.3
	D	20.0	24.2
	*E	68.3	62.9
19	A	28.1	30.6
	B	12.5	1.6
	C	4.7	3.2
	*D	6.3	54.8
	E	48.4	9.7
20	A	27.4	30.5
	B	22.6	16.9
	*C	22.6	20.3
	D	21.0	28.8
	E	6.5	3.4
21	A	4.7	4.8
	B	0.0	1.6
	*C	90.6	82.5
	D	3.1	6.3
	E	1.6	4.8
22	A	25.0	29.5
	B	1.6	0.0
	C	26.6	18.0
	D	12.5	6.6
	*E	34.4	45.9
23	*A	22.6	35.5
	B	16.1	41.9
	C	6.5	9.7

	D	37.1	6.5
	E	17.7	6.5
24	A	5.2	1.7
	B	25.9	5.1
	C	13.8	16.9
	D	39.7	32.2
	*E	15.5	44.1
25	A	12.3	3.2
	B	10.8	6.3
	*C	52.3	84.1
	D	1.5	6.3
	E	23.1	0.0
26	A	31.1	17.7
	B	23.0	4.8
	C	11.5	4.8
	*D	32.8	71.0
	E	1.6	1.6

APPENDIX H

SAMPLE LESSON IMPLEMENTED BY CASE BASED LEARNING BASED ON CONCEPTUAL CHANGE CONDITIONS

CASE: Bicycle Tire

Students were presented a case about the event that everyone may have experience while cycling. Starting a lesson with a real life phenomenon took the students' attention to the topic and saved the lesson from monotony. By means of this case, it was aimed to make students understand homogeneous distribution of gases through a daily life occurrence in which a person feels the same pressure of the bicycle tire even after blow outing, compare the motion of gas particles and the pressure of the bicycle tire before and after blow outing, compare the pressures of a gas applied to the sides and to the bottom inside the deflated tire, and draw the distribution of gases before and after blowing out to concretize this event.

Misconceptions were tried to be remedied considering Posner's (1982) conceptual change conditions. The theory of Posner specifies four conditions in order to provide conceptual change; *dissatisfaction*, *intelligibility*, *plausibility*, and *fruitfulness*.

A case of bicycle tire was presented to the small group of students with four to five students which was arranged at the beginning of the study. After distributing the case to the organized groups, teacher read aloud the presented case to the students. Then, students were given enough time to read the case if they needed and to solve the related study questions. The case of bicycle tire was used to take students to the subject and reveal the the misconceptions. By this way, disequilibrium or dilemma was intended to be created with the help of the misconceptions related to the subject. For example, students were asked what can be said for the movement of gas particles inside the biycle tire when the biycle tire is blown out regarding the common misconception of changing gas motion with changing the volume of it. However, students interpreted the gas motion as the direction of gas particles while blowing out of bicycle tire. Teacher reasked the question by emphasizing whether gas motion changes with the change of the volume of the tire or amount of gas particles. Therefore, students were given extra time for rethinking. Students answers were usually about increasing or decreasing of the motion of gas particles rather than the common conception of using up the energy of molecules in time and ceasing of their their movements. In addition, students were asked to compare the pressures of bicycle tire before and after blowing out based on the misconception found in literature as "*Deflated bike tire or balloon has less pressure inside than outside*". Likewise, they were asked whether the tire of bicycle exert the same pressure to the base and sides of the tire due to the reason of common misconception that "*Gases does not exert the same pressure in different directions*". Furthermore, students were asked to draw the distribution of gas particles before and after blowing out. Students' drawings indicated that some groups of students thought that gas particles are accumulated in the certain areas of the deflated tire like. After all groups drawings were shown on the board, teacher gave the groups an opportunity to defend their ideas by selecting a student randomly from the groups. If groups' ideas contradict each other, they were asked to think of different ideas and persuade each other. For example, some groups of students said gases do not accumulate like liquids in the deflated tire if they were so, they should have accumulated when the bicycle tire is inflated. In this case, they could not feel the same pressure when they touch the bicycle tire. And finally, in order to stimulate the common misconception of *"Matter, especially air, exists between the particles of a gas"*, it was asked what exists among the particles of gases that fill the bicycle tire. Therefore, these misconceptions were expected to create *dissatisfaction* on the minds of students. In addition to misconceptions, the probable contradiction(s) among the group members were also intended to strengthen the conceptual *dissatisfaction* of students. During small group discussions, teacher moved among the groups and assisted them when they have difficulty in understanding cases or related questions. The group and whole class discussion continued until intelligible and plausible answer(s) were found by the students to the case questions. Therefore, students constructed their own knowledge. After all groups explained their answers to the questions, teacher summarized the correct answers. If students had questions, teacher responded them. Thus the conceptual change conditions of *intelligibility* and *plausibility* were tried to be provided. One of the disadvantages of this study could be that students might be unconvinced after class discussion so if they have misconception(s), they will remain unchanged or other relevant misconceptions could also be developed after discussions. And lastly, teacher asked students to give similar examples to this situation to provide the fruitfulness (or usefulness) stage of the conceptual change. Students gave usually the examples of deflation or blowing out of balloon and gas evacuation from cylindrical container with movable frictionless piston.

APPENDIX I

CASES

CASE 1

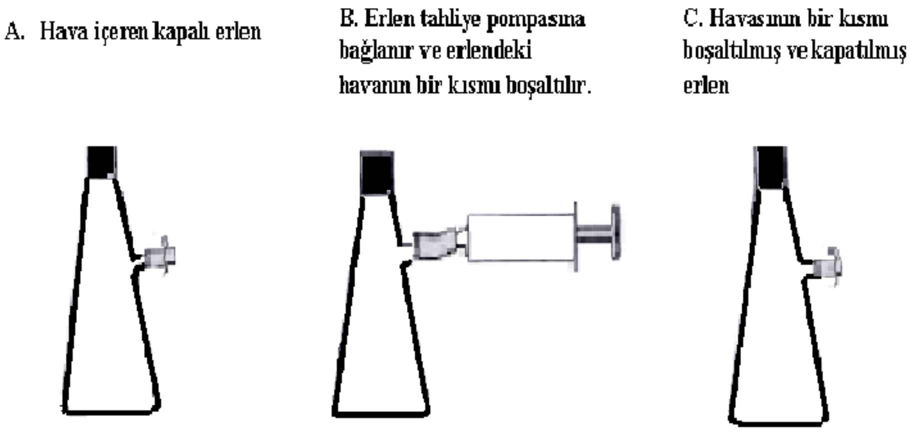
Ahmet hafta sonları babasıyla birlikte dalmaya gitmektedir. Babasıyla birlikte suya girmeden önce gerekli hazırlıkları yapıp içinde sıvılaştırılmış hava (azot-oksijen) bulunan tüpleri takarlar. Bir süre dalış yaptıktan sonra yorulan Ahmet teknede dinlenmeye karar verir. Denizin derinliklerinden deniz yüzeyine doğru çıkarken ağız kısmlarından çıkan hava kabarcıkların yukarı doğru yükseldiğini görür. Ardından bu kabarcıkların yükselirken hacimlerinin giderek arttığını ve denizin üst kısmında, ilk çıkış noktasındaki hacimlerinin birkaç kat fazlasına ulaştığını fark eder. Yükselme esnasında kabarcıkların içindeki madde ya da maddelerin kimyasal yapısında herhangi bir değişme olmamıştır dolayısıyla bu kabarcıkların hacimlerindeki değişmenin sebebi ne ya da neler olabilir? (Deniz suyunun sıcaklığını her noktada aynı kabul ediniz.)

Yükselen gaz taneciklerinin hareketi hakkında ne söylenebilir? Neden?

Bu etkinlikteki değişkenler nelerdir? Bu değişkenlerden hangileri değişti, hangileri sabit kaldı? (Basınç, hacim, mol sayısı, sıcaklık)

CASE 2

Tuğba kimya bölümünde araştırma görevlisidir. Biyomalzemeler üzerine çalışmalar yapan Tuğba'nın mikroptan arınmış steril ortamda deney yapması gerekmektedir. Bu nedenle kontaminasyon riskini azaltmak için öncelikle tüm deney malzemelerini sterilize eden Tuğba, ardından tahliye pompasını kullanarak içinde deney yapacağı erlenin içindeki havayı boşaltacaktır. Bunun için ilk olarak Şekil A'daki gibi tahliye pompasının erlene bağlar. Şekil B'de erlen tahliye pompasına bağlanmış ve içerisindeki havanın bir kısmı tahliye pompasına sıkıştırılmıştır. Bir süre sonra da Şekil C'deki gösterildiği gibi tahliye işlemini tamamlayıp erlenin ağzını sıkıca kapatmıştır. Tuğba gaz taneciklerini gözle göremediğinden dolayı tahliye işlemini çıplak gözle gözlemleyememiştir bu nedenle kabın içindeki havanın tamamen boşaltılıp boşaltılmadığından emin olamamaktadır. Sizce, tahliye işlemi öncesinde, sırasında ve sonrasında erlenin içerisindeki gazın dağılımı nasıl olur? Gazların dağılımını aşağıdaki şekilde verilen erlenlerin içine çizerek gösteriniz.



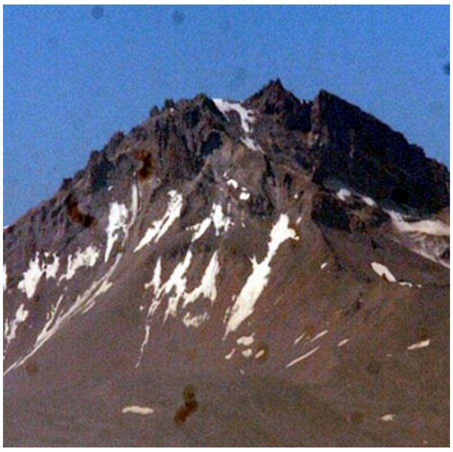
Şekil B'de tahliye pompasına sıkıştırılan havayı oluşturan taneciklere ne olur?

Şekil B'de erlendeki havanın bir kısmı tahliye pompasına sıkıştırıldığında gaz taneciklerinin hareketi hakkında ne söylenebilir?

Tahliye pompasına sıkıştırılan gazın hareketi azalmış olabilir mi? Neden?

Erlen yukarıdaki her üç durumda da bir miktar ısıtılsaydı, kaplardaki gazların dağılımı nasıl olurdu, açıklayınız.

CASE 3



Bir grup arkadaş boş zamanlarında dağa tırmanmaktan zevk alırlar. Yine bir dağ tırmanışı için gerekli hazırlıkları yapıp yola koyulurlar. Dağ yolu çok taşlı ve engebeli olduğundan yolculukları oldukça uzun sürecektir bu nedenle yanlarına yeterince erzak almayı ihmal etmemişlerdir. Tırmanmaktan yorulduklarında uygun bir kamp yeri bularak yemek ve çay yapıp günün yorgunluğunu atarlar. Zirveye ulaşana kadar bu şekilde dağın eteklerinde kamp yapmaya devam ederler. Uzun bir dağ tırmanışının ardından zirveye çok yaklaşırlar ve son kamp yerlerinden birini kurarlar. Yemek ve çay yapma sırası gelen kamp elemanı kaynaması için ateşe koyduğu suyun öncekilere oranla daha çabuk kaynadığını fark eder. Dağcı aynı malzemeleri ve suyu kullanmasına rağmen suyun daha çabuk kaynamasına anlam veremez ve değişikliğin sebebini merak edip durumu arkadaşlarıyla paylaşır.

Sizce deniz seviyesinden yükseklere çıkıldıkça su neden çabuk kaynar?

Dağcılar dağ tırmanışı sırasında neden belli yüksekliklerde kamp yaparlar? (Burunları kanar!!)

Yaylalarda, deniz seviyesinde yaşayan insanların neden yanakları al aldır?

Futbolcular neden deniz seviyesinden yüksek yerlere kampa giderler?

CASE 4

Bir bisiklet tutkunu olan Onur, her yıl düzenlenen bisiklet turnuvalarını kaçırmamaktadır. Bu seneki turnuvaya uzun süre hazırlanan Onur çalışmalarını tamamlar ve bisikletinin gerekli bakımını da yaptırdıktan sonra turnuva gününü heyecanla bekler. Turnuva uluslararası çapta olacağından dolayı katılım yüksek olacak ve birçok zorlu rakibi olacaktır. Nihayet beklediği turnuva günü gelir ve start verilir. Turnuva zorlu etaplardan oluşmaktadır. Yarış başladıktan birkaç kilometre sonra ormanlık alandan geçerken Onur'un bisikletinin lastiği patlar. Bu talihsizlik sonucu yarışma şansını kaybeden Onur, patlayan lastiğini şişirip yarışmadan ayrılacaktır. Onur lastiğine bir noktadan hava pompalamasına rağmen lastiğin her noktasındaki şişlik aynı olmuştur. Sizce bunun nedeni gazların hangi özelliğinden kaynaklanmaktadır?

Patlamış bisiklet lastiği içindeki gaz taneciklerinin hareketi/durumu için ne söylenebilir?

Patlamış bisiklet lastiğinin basıncını dış basınçla kıyaslayınız.

Patlamış bisiklet lastiğinin tabana yaptığı basınç ile yan yüzeylere yaptığı basıncı kıyaslayınız, nedenini belirtiniz.

Bisiklet lastiği, gaz taneciklerinin enerjisinin tükenmesi ve gaz hareketinin durmasından dolayı patlamış olabilir mi? Neden?

Patlamamış ve patlamış bisiklet lastiğinin içindeki gaz taneciklerinin dağılımını çizerek gösteriniz.

Bisiklet lastiği içindeki gaz tanecikleri arasında ne vardır?

APPENDIX J

INTERVIEW DIALOGUES

Properties of Gases-Volume versus molecular weight of the gases

Students were asked whether gases occupy different volumes or not according to their molecular weights

EG.HA.23: The first thing that comes to my mind was that they have different masses, when the masses are different, the pressures at the same volume would be different.

EG.MA.19: It is incorrect that the gases occupy different volumes related to their molecular weights.

EG.MA.01: Gases do not occupy different volumes related to their molecular weight. Actually it is about the volume, since the molecules of gas are lighter, they can be found in anywhere in the container. If the molecules were heavier, they would sink to the bottom. It was something like that.

EG.LA.16: Gases do not occupy different volumes but I did not make much interpretation to this.

CG.MA.03: I had no idea about this subject.

CG.MA.17: The volume of each element is different…it changes…I am not sure about that also.

CG.LA.08: I know that gases do not occupy different volumes according to their molecular weights; I know that their volumes are equal.

CG.HA.20: No, they do not occupy. They take the volume of the container in any way. Molecular weight is influential in diffusion rate. When using the formula of PV=nRT, volume has no relation with the molecular weight.

CG.HA.17: No, it is the same whether the gases put in this room or another room.

CG.MA.18: I think since the gases occupy the volume of the container, molecular weight does not affect.

CG.LA.42: I think it has nothing to do with the molecular weight.

CG.MA.08: Do not occupy….(Hesitating...) I think it does not have any relation to molecular weight. I do not think that molecular weight affects the volume of the gases.

EG.LA.22: Yes, I think since the molecular weights are different from each other, they occupy different volumes.

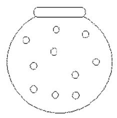
EG.MA.11: It does not depend on... (Hesitating...).

EG.HA.02: I said correct because the number of moles changes according to molecular weights, and I think the volumes change by depending on it.

EG.MA.04: Maybe true, I am not sure.

Properties of Gases - The distribution and the size of gas particles in a container at low temperature

The distribution of hydrogen gas molecules in a closed container at 25°C and 1 atm pressure was given in the next. Students were asked to select the correct distribution of H_2 molecules when the temperature of the container is lowered to -15 ^oC and it is mentioned that at -15 ^oC hydrogen is still gas.



EG.HA.23: In this question, the gas has been taken to a cold environment. I thought that it was dispersed homogeneously and the size of the molecules does not change.

EG.MA.19: The distribution of gas particles remain the same even if the temperature of the gas is lowered.

EG.MA.01: In atmosphere, warm air rises and cold air sinks to the bottom. But, in a closed container nothing is changed, gas particles diffuse homogeneously within the container.

EG.LA.16: I thought there would be an expansion and the particles are getting larger and the distance between the particles decrease. I am not sure whether the gas particles accumulate in bottom when they are cooled.

CG.MA.03: The size of the particles must be the same. I thought when gas particles are cooled down, they sink to the bottom.

CG.MA.17: When the temperature is decreased, gas particles move down. I thought that they should be accumulated at the bottom of the container. The particles which probably could have been solid become larger then it is supposed to take the shape of the container.

CG.LA.08: The gas particles sink to the bottom and the particles size remains the same.

CG.HA.20: I thought since the volume decreases, the distance between the particles may decrease. Moreover, I thought that the molecules slow down and come closer to each other and the particle size does not change.

CG.HA.17: When the temperature is decreased, the gas slows down. The particles should become larger and move down because they become more ordered.

CG.MA.18: I thought if the gases are in the state of gas at 25 ºC, they would be solid at -15 ºC. Therefore, I thought when the temperature is cooled down, the molecules of gas sink to the bottom. The correct answer might be alternative E (same particle size and sink to bottom) but D is (becoming larger and sink to bottom) is more logical because the sizes of the particles increase since they come close to each other. When the temperature decreases, small particles form the big ones while changing to solid state, and then they sink to the bottom.

CG.LA.42: Gas particles distribute homogeneously and only their molecules become smaller.

CG.MA.08: I think when the gases are cooled down; molecules of gases come close to each other and become smaller.

EG.LA.22: The particles are getting smaller and distribute homogeneously but they may shrink toward the middle. In addition, homogeneous distribution and smaller particle size is also logical.

EG.MA.11: Gas particles are getting larger when they are cooled down. I only know when the temperature drops, the volume decreases. The size of the particles might not change also.

EG.HA.02: I thought they distribute homogeneously whatever the temperature is.

EG.MA.04: I think the particles are getting smaller but there will be no change in their distribution.

Gas properties - The distribution of air molecules at room temperature (25 °C), 0 °C, and 60 °C

Students were asked to choose the diagrams that show the distribution of air molecules at 25 °C, 0 °C, and 60 °C implying that at these temperatures air is still gas (Please see questions 7, 8 and 9 in GCT).

EG.HA.23: Gases are distributed homogeneously either it is cooled or heated.

EG.MA.19: I thought that they are distributed homogeneously at 25°C. Gas molecules come close to the mouth of the container since they want to go out of the container when the temperature is lowered to 0 °C, they may sink to the bottom due to the increase in their weight. When the temperature increases, the gas particles need to go upward.

EG.MA.01: 25 °C is a room temperature, the gases are distributed equally within the container. At 0°C, they are dispersed homogeneously everywhere. When the gas is cooled down, the pressure must decrease but their distribution should not change. The pressure exerted on the walls of the container decreases, the speed of particles decreases.

EG.LA.16: The particles might accumulate in the middle and the space between the particles should be less at 25°C. When the gas is heated, it moves upward. When the gas is cooled down, the gas particles move towards the upper part of the container since the upper part remains warm, the particles move towards upward. When the temperature decreases, gas particles condense on the walls of the container but they might be distributed homogeneously.

CG.MA.03: When the temperature is lowered, the particles move towards the bottom. The gas particles condense on the walls of the container when the gases are heated because the middle part of the container will be firstly affected from the heat since the heat is given from below. Hence, the rate of collision of particles onto walls increases.

CG.MA.17: Gas particles are distributed homogeneously within the container since the temperature is equal in everywhere at 25°C. If they are heated, they accumulate at the upper part of the vessel. If they are cooled down, they would sink to the bottom.

CG.LA.08: As a whole, air is distributed to everywhere. I think that when the temperature decreases, it sinks to the bottom. When it is cooled, it must sink to the bottom. I thought that the gas particles move to the borders of the container when heated.

CG.HA.20: At room temperature (25°C), gas particles are distributed homogeneously and make equal pressure in the container, not accumulating in a place. When the gas is cooled down, I thought that the particles come closer to each other due to the interaction among them. With heating, gas particles might move upward first..I am not exactly sure about this question.

CG.HA.17: The distribution of gases at 25 °C is homogeneous because gas particles collide faster. When the temperature is decreased, the movement of gas particles slows down and they accumulate in the middle, not in the bottom unless the temperature is lowered to minus degrees of centigrade. At 60°C, the pressure would increase and it will apply directly to the walls.

CG.MA.18: At 25°C, distribution of the gas particles is homogeneous. When the temperature is lowered to 0 °C, gas particles move to the bottom. At 60°C, since they are so close to evaporation point, the boiling of water is 100°C, I think the particles start to move upward.

CG.LA.42: Gas particles are homogeneously distributed at 25°C. When the temperature is lowered, they accumulate in the middle, not at the bottom because temperature is not cold enough. Pressure increases with increasing temperature, and if they are on the walls of the container, they make more pressure.

CG.MA.08: At 25 °C ,gas particles are homogeneously distributed in the container. When the temperature is lowered to 0 °C, they accumulate in the middle not in the bottom because gravitational force has no effect on them. When the temperature is increased to 60 °C, it means that temperature is too high, the speed of gas molecules increases and they make more pressure towards the walls of the container.

EG.LA.22: They have distance among them and are distributed homogeneously at 25 °C. When the temperature decreases, there would be shrinking in the volume but I am not sure whether it occurs in the size of the particles or not. When the gas is heated, the particles of it distribute homogeneously to the surface.

EG.MA.11: At 25 °C, gas particles are distributed homogeneously. When the temperature is lowered, they accumulate at the bottom; they do not shrink in the middle. The movement is towards the sides of the container when heated. When the gas is heated, particles may be pushed towards the sides. The number of collisions increases and so they are seen on the walls of the container more frequently.

EG.HA.02: Gases are not gathered in one place, since we do not see gases we cannot imagine their distribution but I think whatever the temperature is, they are homogenously distributed.

EG.MA.04: In the room temperature, all the gases are dispersed homogeneously. They come close to each other at 0 ºC. Actually, cool air shrinks, because of this, they may accumulate. The particles condense on the walls of the container because the particles should move away from each other with heating.

Properties of Gases - The distribution of the air in a constant volume container

A constant-volume container filled with air is bonded to a balloon as shown in the figure. When the tap of the container is opened and the container is heated, it is observed that balloon is inflated. Students were asked to predict the distribution of air after inflating the balloon. (Dots (.) represent the molecules within air.)

EG.HA.23: There will be homogeneous distribution also.

EG.MA.19: Gases are homogeneously distributed throughout the container and the balloon.

EG.MA.01: After opening the tap of the container, gases are homogeneously distributed both in the container and in the balloon.

EG.LA.16: I thought that since the container is heated, the pressure of the gas increases and the gas particles in the container move upward or stay above due to high temperature however, the gas particles within the balloon are homogeneously distributed since we do not change its temperature.

CG.MA.03: The number of gas particles would be the same in proportion. They need to be equal, need not it...I do not know I am not sure.

CG.MA.17: It is absurd that all air molecules pass to the balloon. I think they are homogeneously distributed. The gas particles may go up when heated, but I am not sure.

CG.LA.08: Since the gas particles are heated, they inflate the balloon distributing into it. Gas particles gather on the walls of the balloon, because pressure increases inside the container with increasing temperature. The accumulation occurs on the walls of the balloon since gas particles are pushed towards it.

CG.HA.20: When the tap is opened, both sides should be balanced. I chose the option that both sides have the same number of particles.

CG.HA.17: Though the tap is opened and a little heat is given, homogeneous distribution should be throughout the containers.

CG.MA.18: When the system is opened, gas is homogeneously distributed. For example, in the figure in alternative there are 14 particles within it, 7 of them are in the container, and 7 of them are in the balloon. They must be distributed homogeneously to the container.

CG.LA.42: I think that the gas particles completely touch to the sides due to increase in size.

CG.MA.08: I think that gas particles are homogeneously distributed in the container because they are not affected from the heat so much. When the temperature is too high, gas particles might gather at the sides.

EG.LA.22: The particles enter into the balloon and the volume of it increases so I thought that gas particles gather around the walls of the balloon.

EG.MA.11: Again, the gas particles accumulate on the walls of the container when heated.

EG.HA.02: Distributes homogeneously.

EG.MA.04: The particles expand when heated up since they will move more so I said that they are homogeneously distributed.

Properties of Gases - What is present among the particles of a gas Students were asked what is found among the particles of a gas.

EG.HA.23: Nothing is found and I have said that there are negligible intermolecular forces among the particles.

EG.MA.19: Air is found. Maybe other gases and foreign substances are found.

EG.MA.01: We are talking about a gas and there is nothing among the molecules of a gas other than its own molecules.

EG.LA.16: Air is found between the particles of a gas because it moves freely in the room. There are certain percentages of oxygen, nitrogen and many other gases in the air. Thus, while breathing oxygen, we breathe also nitrogen.

CG.MA.03: I said nothing is found among the particles because if there were other gases, the collisions between particles would be impossible. I mean other gases affect the speeds of the gas particles.

CG.MA.17: There are no other gases inside particles of a gas. There is space among them and air fills that space.

CG.LA.08: Air is found.

CG.HA.20: I thought it by reasoning the air or atmosphere. I do not think that nothing is found, there are absolutely other gases among the particles of a gas. I am not sure about the foreign substances...

CG.HA.17: I thought the atmosphere, how can I say, there might be other things in gases.

CG.MA.18: Air must be found among the gas particles since it is available in everywhere.

CG.LA.42: There might be air because it is available in everywhere. However, it depends on under which condition and place it exists, isn't it?

CG.MA.08: Air is found because it is available in everywhere. There is nothing found choice makes sense also.

EG.LA.22: I think there is nothing among the particles of a gas because the particles belong to one kind of matter. Since they are only one kind of matter, there is nothing between them.

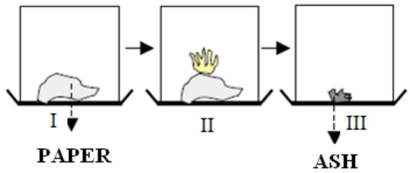
EG.MA.11: Nothing is found but I cannot explain the reason of this.

EG.HA.02: Nothing is found between the particles of a gas. If there were something else between them, we would have learnt it in the class. Foreign substances like dirt may also be found but nothing else.

EG.MA.04: Nothing, there is only space.

Properties of Gases - Whether the gases have mass or not

As shown in the following figure, a piece of paper is put in a glass container in condition I. In condition II paper is burning and in condition III ash is formed. In all three cases, glass container is weighted. Students were asked to compare the mass of the containers.



EG.HA.23: All of them have the equal mass because in any way gas exchange is not observed.

EG.MA.02: I said all of them have equal mass because mass is the constant quantity of substance. Total mass becomes equal; reducing the amount of solid increases the amount of gas.

EG.MA.01: All of them have equal mass due to the law of conservation of mass in chemical reactions. In this situation, there is a burning reaction, the mass of paper decreases in time but the gas is released and since the reaction occurs in the closed container, the total mass is conserved.

EG.LA.16: Water and ice have equal mass. Likewise, we did an activity in the lesson that a ton of cotton and a ton of iron have equal mass. I think when something is burned in nature; its mass does not change.

CG.MA.03: They have equal mass because as I know when it is burned, CO_2 gas is released in the same proportion, nothing is changed in a closed container. I do not know whether the gases have mass or not.

CG.MA.17: In condition III, the container is the heaviest due to the fact that it contains gas. Paper is not a heavy substance, and when it is in gas state it accumulates, so it is likely to make an effect on the pressure. The pressure would affect the mass of the container, but we cannot measure the pressure within the container and I think the mass of the container increased.

CG.LA.08: III has the biggest weight since molecules are compressed. I mean solid weight is less due to the compression.

CG.HA.20: In chemical reactions, there is a law of conservation of mass and total mass is constant. Hence, I thought that all of them have equal mass.

CG.HA.17: Total mass is not affected from decrease in solid mass. CO_2 is released generally from the burning reactions but I do not know whether the gases have mass or not.

CG.MA.18: I think in condition III, it has the biggest mass because before burning the weight of the paper is normal. In II, it starts to burn and it has also pressure due to temperature so it is slightly heavier. The event of burning is done in condition III and it has biggest mass since the gases are released after burning, they mix and make the container heavier.

CG.LA.42: If the mass of the paper reduces while burning, the mass of the container decreases also. I think I and II have the same weight but III is less.

CG.MA.08: Condition II has the biggest mass since paper reacts with O_2. In condition I, there are only air and paper, but in condition II there are air, paper and oxygen. Gases have mass but probably it is very small.

EG.LA.22: I and II have equal volume (volume of paper), since it becomes ash in III, I believe that its mass is less than the others. Gases are lighter than the solids. Therefore, total mass is reduced in any way.

EG.MA.11: All of them are equal. As I learned in chemistry, mass is conserved.

EG.HA.02: All of them are equal because of the law of conservation of mass.

EG.MA.04: In condition I, the mass of the solid is bigger, in II there is both mass of solid and CO_2 and in III there is only the mass of CO_2. Therefore, I thought that I and II have equal mass and they are bigger than III.

Properties of Gases - Hot and Cold Air

Students were asked to compare the size, volume and the mass of the hot and cold air.

EG.HA.23: Hot air is not lighter than cold air. Hot and cold air may have different volumes but they have equal masses. The size of the particles does not change.

EG.MA.19: Hot air is lighter than cold air because the mass decreases as the temperature increases, hot air becomes lighter. In fact, I thought that in summer electric wires are loose in summer but stretch in winter. I think it is more meaningful that volumes of hot and cold air are different but they have the same mass.

EG.MA.01: Hot air is lighter than cold air. It is something ordinary in daily life that warm air or hot air rises and pushes cold air downward. Of course, this is valid for the atmosphere. In a closed container, it does not rise, doesn't it.

EG.LA.16: Gases have both mass and volume. Hot air is lighter than cold air because when the hot air is heated, it becomes vapor.

CG.MA.03: I think that hot air is heavier than cold air. I think from the example that foots of the mountain are hotter, we feel the cold air more as getting upper and at the top it is seen that snow does not melt easily in any way therefore at the lowers there is hot air, at uppers there is cold air. Hot air is at the lower part because hot air is heavier than cold air.

CG.MA.17: Hot air is lighter than cold air because water vapor changes into gas state in hot air and this affects its lightness.

CG.LA.08: Hot air is lighter than cold air because there will be no compression between molecules and it is lighter because it spreads.

CG.HA.20: I used the formula m=d.V, as the temperature increases, volume increases and mass increases also. Therefore, it seems that hot air is heavier than cold air. Gas particles of hot air may expand while particles of cold air may shrink but I am not sure.

CG.HA.17: Hot air is lighter than cold air because speed of gases increase with increasing temperature. In order to be faster, hot air molecules must be lighter and smaller than the molecules of cold air. The gas particles may expand or shrink but I am not sure about this.

CG.MA.18: Cold air might be lighter than hot air, since the interactions in cold air are less than the hot air. Kinetic energy increases in hot air and the hot air might be heavier than cold air. It is true that hot air particles expand while cold air particles shrink. Since air is a matter, it has both mass and volume.

CG.LA.42: Hot air particles expand, cold air particles shrink. Hot air might be lighter since it affects every part of the ball but cold air particles are gathered in a place so maybe it becomes heavier. I do not know whether air has both volume and the mass.

CG.MA.08: I think that hot air is heavier than cold air. Since hot air is heavier than cold air, its pressure is higher than that of cold air. Air has mass but it is too small but actually it has no volume, no matter it is hot or cold. I am not sure that hot air particles expand, and cold air particles shrink.

EG.LA.22: Hot air is heavier than cold air because electric wires become straight in winter while they are looser in summer from this point I think hot air is heavier than cold air. In addition, hot air particles may expand and cold air particles may shrink.

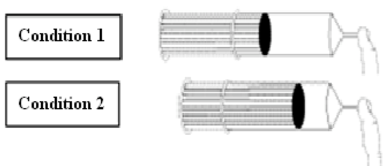
EG.MA.11: When the closed container is heated, particles expand so hot air is heavier than cold air. Hot air particles expand while cold air particles shrink. Hot and cold air has both mass.

EG.HA.02: Hot and cold air may have different volumes but they have equal masses. The volume of the hot air is more than cold air. The mass of the air is almost none but probably it has. The size of the particles does not change.

EG.MA.04: "Hot air is lighter than cold air", I remember this from geography lesson. Hot air particles rise and they are lighter than the ones in cold air, since they are distant from each other. Cold air particles shrink and go down and they are heavier than hot air. There will be no change in the size of the particles.

Pressure of Gases – The effect of gas pressure on the particles of a gas

At constant temperature and pressure, the piston of the syringe containing an amount of air (condition 1) is pushed a bit and the air inside is compressed (condition 2). Students were asked to find the truth about the gas particles forming air after compression.



EG.HA.23: The distance between the particles decreases with compression.

EG.MA.19: I am not sure that whether the size of the particles decrease or not. However, since the volume decreases, the distance between the particles decreases. The particles may explode.

EG.MA.01: Particles do not stick to each other but the distance between them decreases. Gas particles do not explode due to high pressure.

EG.LA.16: The size of the particles remains the same but some of the particles stick to each other with compression, not all of them. The distance between them decreases.

CG.MA.03: Only the distance between the particles decreases.

CG.MA.17: The distance between the gas particles decreases with compression; the particles are getting closer to each other. We cannot exactly say whether the particles stick to each other or not, it depends on the amount of the gas. The gas particles may explode depending on the type of the gas.

CG.LA.08: I think they stick to each other, since the distance between the particles decreases.

CG.HA.20: Since the volume decreases, they come close to each other a little more so the distance between the particles decreases. If the applied pressure is very high, the particles may explode.

CG.HA.17: No matter how great pressure is applied; the size of the particles does not change because the temperature is constant.

CG.MA.18: The gas particles do not stick exactly to each other but the area decreases. The size of the particles does not change but interaction of particles increase with the decrease in the volume.

CG.LA.42: If all the particles are gathered at the mouth of the syringe, they will also stick to each other. I do not know whether they stick to each other or not. There is no relation between the size of the particles and the volume because only the place of the particles is changed. I do not know whether they may explode or not. The distance between them decreases.

CG.MA.08: The particles neither stick to each other nor decrease in size. Actually, they do not explode but the distance between them decreases.

EG.LA.22: The size of the particles does not change since there is no relation between the applied pressure and the particles. I think that the particles do not stick to each other but the distance between them decreases. I am not sure whether the particles explode.

EG.MA.11: The particles do no stick to each other but the distance between them decreases. They may explode also. Definitely, the size of the particles decreases.

EG.HA.02: Particles do not stick to each other, if they stuck to each other, they would become liquid. The distance between them decreases.

EG.MA.04: Since the volume decreases, the distance between the particles decreases.

Pressure of Gases - Gas pressure in a constant volume container

Students were asked whether the gas pressure is equal all over the container or not.

EG.HA.23: The pressure of gas is the same all over the wall of the container. The pressure of the gas in the base of the container is more than the pressure on the sides of the container.

EG.MA.01: Gas makes the same pressure in a closed container.

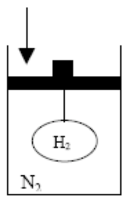
EG.LA.16: The temperature of the container may not be the same all over the container for instance if the heat comes from the bottom it means that the particles collide faster upward and so it makes the pressure more upward than the right and left sides of the container.

CG.MA.17: "The number of the particles striking to the surface of the container in each unit is the same" actually it can be true because it is meaningful if they are homogenously distributed in the container. Depending on the temperature, gases may condense at different points in the container. If the temperature is the same all over the container, the number of collisions becomes equal and so does pressure. If temperature is increased, gas accumulates at the top of the container and pressure increases upward.

CG.HA.20: Since the pressure is the same all over the container, the measured pressure becomes the same in everywhere.

CG.LA.42: Gases exert the same pressure to everywhere.

Pressure of Gases - Gas pressure in a non-constant volume container



As shown in the figure, nitrogen (N_2) gas is found in the cylindrical container with movable frictionless piston. Hydrogen (H_2) gas is found in the elastic balloon connected to cylinder by a steel rope. Cylinder is pushed downward without touch of elastic balloon to the surface of the vessel, students were asked to predict the shape of the balloon.

EG.HA.23: Balloon shrinks from everywhere because pressure is exerted from everywhere in the same way.

EG.MA.19: I thought that only the bottom of the balloon shrinks when the piston is pushed from above.

EG.MA.01: Balloon shrinks from everywhere because the pressure is equal in it.

EG.LA.16: The pressure increases with the compression in the vessel; balloon shrinks from everywhere since the pressure is equal in everywhere.

CG.MA.03: It is not possible of a balloon shrinking only from sides, from above or bottom.

CG.MA.17: Since we push the piston downward, only the bottom of the balloon may shrink, there will be no change on the sides.

CG.LA.08: I thought that the balloon explodes because the density of the hydrogen is probably more than the nitrogen because it makes a great pressure to the balloon.

CG.HA.20: Piston makes a pressure from upward and N_2 gas makes a pressure from downward, therefore the balloon gets inflated from sides.

CG.HA.17: Balloon shrinks not only from sides but also from the upper and the below parts.

CG.MA.18: The pressure is increased in the vessel as the piston is pushed, the balloon must shrink from all sides because the pressure is equal within the container.

CG.LA.42: I think only the bottom of the balloon shrinks because pressure will affect the balloon from bottom so the lower part of it will shrink.

CG.MA.08: Balloon explodes if the pressure of N_2 gas is more than H_2 gas; the balloon may explode because we compress it. It may also shrink from above only since pressure is exerted from above.

EG.LA.22: Since the pressure outside of the balloon increases, the balloon will begin to shrink from everywhere but H_2 gas will not be able to bear this and explode.

EG.MA.11: If the piston is pushed without touching the surface of the vessel, balloon explodes. However, if it is pushed less, the balloon may shrink from everywhere.

EG.HA.02: Since equal force is exerted to the balloon, it shrinks from everywhere.

EG.MA.04: Balloon may shrink from bottom and above, not from the sides since we are applying a pressure from that way. Maybe the balloon explodes.

Pressure of Gases - Gas pressure in a closed constant-volume container

Students were asked to explain the reason for increase in gas pressure in a closed constant-volume container with increase in temperature.

EG.HA.23: The size of the particles does not change. The number of the particles does not increase, only the speed of the particles increases. The correct answer is the increase in the number of collisions when the gas is heated.

EG.MA.19: I am not sure whether the number of gas particles increases when heated. The number of particles does not change and their speed does not increase. I think gases do not condense on the walls of the container, they distribute homogeneously.

EG.MA.01: Of course, the size of the particles stays the same. The number of gas particles does not increase. They do not become heavier but they get lighter in atmosphere while it stays the same in the same closed container. The number of the collisions increases since they are heated; the speed of particles increases more, also the number of collisions. Gas particles does not condense on the walls of the container, it is homogeneously distributed.

EG.LA.16: I did not think that the size of the particles change, particles remain the same, only the speed of the particles increases. When the gas is heated, gas particles do not become heavier because they do not change into liquid state with heating, I think it is impossible. The most logical answer is "Increase in the number of the collisions when the gas is heated". The pressure will increase and due to the pressure so does the number of collisions. I think the particles do not condense on the walls of the container, for example liquid vapor condenses in the upper part of the container. If we think of a pot, liquids condense on the walls of it; if it is gas, it does not condense.

CG.MA.03: The size of the particles does not change. I have no idea about the situation of gas becoming heavier when heated. By increasing temperature, the speed of particles increases therefore their number of collisions increases in parallel with this. They are homogeneously distributed thus they do not accumulate neither in the walls nor in the middle of the container.

CG.MA.17: The size of the particles does not increase on the contrary it decreases because of the enlargement of the empty space between the particles. I think the number of gas particles increases with heating because the number of gas particles is the least in solid, it increases more when the gas turns into liquid; it is the highest in the phase of the gas. I think the gas becomes heavier with heating for example cold air is heavier than hot air. Probably the number of collisions increases due to the increase in temperature. The empty space increases with heating, since the number of particles increases. They may move faster so the number of collisions increases. Gas particles might accumulate upward of the container.

CG.LA.08: Gas particles become heavier when heated. I mean, mass increases due to heat. The number of gas particles may increase with heating.

CG.HA.20: If the pressure of gas increases from the formula, $PV=nRT$, volume which is inversely proportional to the pressure must decrease, temperature or the number of mole must increase. When the gas is heated, the collisions become faster and the number of collisions increases since the particles speed up more.

CG.HA.17: Actually, the size of the particles decreases and their speed increases owing to heating. I find the explanation of increasing the number of collisions with heating most reasonable because of information given in the course. I am not sure that whether the particles condense on the walls of the container with heating.

CG.MA.18: When the container is heated, the speed of the particles does not increase unless there is no change in the volume. I think gases do not become heavier when heated; on the contrary they get lighter. Normally, when we heat a solid, it gets lighter. The particles may go upward with heating since after a while evaporation will occur.

CG.LA.42: With cooling, the size of the particles decreases, with heating it increases. I have no idea about how the number of particles changes with heating. If the gas is heated, it makes pressure only to the bottom. I do not know whether the gas particles condense on the walls of the container.

CG.MA.08: I think the speed of the particles increases and they make more pressure to the walls of the container so they condense on the walls of the container. I am in contradiction whether the size of the particles increases or decreases with heating but if the size of the particles increases, in parallel with this, pressure also increases. They may become heavier but I think it does not affect the pressure much. I am not sure whether the number of collisions increases or decreases.

EG.LA.22: If the gas is heated, the size of the particles increases and particles collide everywhere with the same speed and in order to condense they spread to corners equally.

EG.MA.11: When we give heat, there will be an increase in the volume and this causes an increase in the number of collisions. I am doubtful about becoming heavier of the gas particles but probably they do not become heavier. The gas particles condense when they are heated. However, the most accurate explanation is that "Increase in the number of the collisions when the gas is heated".

EG.HA.02: The number of collisions increases with heating, so does the pressure. The pressure is already equal to the number of collisions.

EG.MA.04: The size of the particles may increase due to increase in pressure. The particles do not become heavier with heating on the contrary they may get lighter. The gas particles may condense on the walls of the container but the most reasonable answer is that "Increase in the number of the collisions when the gas is heated".

Application of Charles's Law – Volume and Temperature Relationship

Students were asked that when the inflated balloon tied by rope was taken from its environment and placed in which environment, a decrease in the volume of it could be expected.

EG.HA.23: The same pressure and hotter, I did this by using the formula of PV=nTR. In a hotter environment, the volume of the balloon decreases because pressure and temperature are directly proportional. In this case, when the pressure increases, volume should decrease, they are inversely proportional.

EG.MA.19: The same pressure and colder. If the environment is colder, volume decreases. I think pressure decreases since the environment is cool. Consequently, it must be put at the same pressure but colder environment because I know that volume of the gases increases with increasing temperature.

EG.MA.01: In order to reduce the volume or to deflate the balloon, the balloon must be put in the environment which has higher atmospheric pressure or the place with the same pressure and colder because in cold place it also deflates. It deflates because the speed of molecules decreases, since the speed decreases balloon deflates.

EG.LA.16: I think shrinking occurs in a cold environment. Because when it is cooled down, it shrinks. Pressure is constant and temperature is changeable.

CG.MA.03: The same pressure and colder. From our childhood, I remember that balls and balloons deflate or shrink when they are put in cold areas like bathroom or balcony. This example came into my mind immediately. External pressure increases with the effect of temperature and the balloon gets smaller.

CG.MA.17: At the same pressure and in colder environment, gas accumulates in the middle of the balloon since its environment is cold; therefore, the volume of the balloon decreases.

CG.LA.08: When the environment is cool, its volume decreases due to it. It inflates in hot while it shrinks in cold. In hot environment, molecules are more distributed due to hotness and its volume increases.

CG.HA.20: Here, I think that gas particles expand with increase in temperature. Also, from PV=nRT, pressure and volume increase directly proportional to increase in temperature. Thus, I think that when the balloon is placed at the same pressure but a cooler environment, their volume decreases.

CG.HA.17: I know that volume and the pressure is inversely proportional to each other. If the pressure decreases, volume increases but in a cold environment since the gas pressure decreases, volume increases more because temperature is directly proportional to the pressure. When the gas is heated, the collision of particles increases, in this case pressure decreases and an increase in the volume is expected. In an evacuated environment, since there is no pressure, volume of gas is higher.

CG.MA.18: I think it should be taken to a warmer environment at the same altitude. For example, if something is heated like electric wires, it shrinks. In fact, not with heating but high temperatures, for example in summer 20 ºC or 30 ºC electric wires are loose. In a hot environment, interaction and the speed of the particles increase, the volume of the balloon decreases. In a cold environment, I think that volume will never change.

CG.LA.42: When I put the balloon on the balcony, its volume decreases. When the particles are taken to a cool environment, something occurs like diffusion as we learnt in biology. The air inside the balloon gets out or the molecules may be getting smaller. Gas molecules move slowly or since they move slowly, they may be getting smaller.

CG.MA.08: The same pressure and colder because I have done it at home and I saw the balloon shrinking. In fact, I do not know the reason.

EG.LA.22: If the balloon is put in a colder environment, it shrinks. If it is taken to a hotter environment, balloon inflates. I think if the external pressure is higher than the inner pressure, it shrinks.

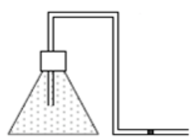
EG.MA.11: If the balloon is put in a colder environment, it shrinks. If the hot air is given, we can see the inflation of the balloon, volume increases, on the other hand if the cold air is given, it shrinks.

EG.HA.02: The same pressure and colder because when it is cooled, the kinetic energy of molecules decreases and so does the volume of the balloon.

EG.MA.04: Distance between particles increases, so the environment should be colder.

Application of Gay Lussac's Law –Temperature and Pressure Relationship

There is a drop of mercury in the glass container as shown in next. The mercury drop moves to the right or left depending on the pressure and temperature changing inside the glass container. The apparatus of the room temperature (25 ^{o}C) is put into environment 5 ^{o}C, students were asked to predict the direction of the movement of the drop of mercury.



EG.HA.23: It moves to the left because when the temperature decreases, the pressure inside the container decreases. I found this by this formula, PV=nRT.

EG.MA.19: It moves to the left because when the temperature decreases, the pressure inside the container decreases.

EG.MA.01: As the pressure decreases within the container with respect to the external pressure, the mercury droplet should move to the left.

EG.LA.16: It does not move because the air pressure is constant. I wonder whether the mercury droplet moves when the temperature is decreased. I think when mercury droplet moves to left, gases move towards the container, so the pressure decreases.

CG.MA.03: Mercury droplet stays the same because atmospheric pressure is constant.

CG.MA.17: I think that the mercury droplet moves to left because the temperature is lowered, the physical state of the gas may change and it may become solid with decreasing temperature.

CG.LA.08: When the temperature is lowered, the pressure inside the container is decreased because the gas particles move towards the container due to the decreased pressure.

CG.HA.20: I think it moves to left because the pressure decreases with decrease in temperature. In addition, temperature and pressure are directly proportional and I think that the volume will decrease due to the increase in pressure. With decrease in temperature, gas particles might be clustered in the container, so the pressure of the container decreases.

CG.HA.17: When the temperature is decreased, pressure and speed of the particles decrease so mercury droplet moves to the left.

CG.MA.18: The interaction between the particles and their average speed decrease, so their movement slows down. Therefore, mercury droplet moves to the left.

CG.LA.42: When the temperature is lowered, the pressure inside the container decreases. Gas particles might be getting smaller or clustered. Since the pressure decreases, the mercury moves to left.

CG.MA.08: When the container is cooled, gas molecules will be clustered and since nothing enters or gets out from the pipe, the mercury droplet remains the same, it does not move.

EG.LA.22: I think it moves to the left because when the temperature decreases, mercury droplet will move towards the particles due to the shrinkage. Mercury comes close to the gas.

EG.MA.11: I have no idea.

EG.HA.02: The pressure inside the container decreases with decrease in temperature, mercury droplet moves to the left. It is very clear.

EG.MA.04: I think the mercury droplet moves to the left because when the gas particles are cooled; they shrink so the applied pressure decreases and it moves to left.

Application of Avogadro's Law – The number of mole and Volume Relationship

The pressure of air-filled balloon is measured as P_{full} in an environment in which atmospheric pressure is P_{atm}, then the mouth of the balloon is opened and expected to deflate, and the deflated balloon's pressure is measured as $P_{deflated}$. Students were asked to find the relationship between among P_{atm}, P_{full} and $P_{deflated}$.

EG.HA.23: I think that all of them have equal pressure. If something does not cause the balloon to shrink when it is full, it means that the inner and outside pressures are equal to each other.

EG.MA.19: I thought that the inflated balloon's pressure is lower than the atmospheric pressure because as volume decreases, pressure increases, and the air-filled balloon has the highest pressure, $P_{full} > P_{deflated} > P_{atm}$.

EG.MA.01: I think $P_{deflated} = P_{atm}$, $P_{atm} < P_{full}$ because atmospheric pressure decreases the pressure of the balloon until their pressures are equal to each other.

EG.LA.16: I think the pressure of the deflated balloon may be equal to 0 because there is little air in the deflated balloon. I am in doubt that atmospheric pressure is higher than the pressure of air-filled balloon. However, the pressure of air-filled balloon and atmospheric pressure may be equal, I do not know.

CG.MA.03: $P_{deflated} = P_{atm}$, $P_{atm} < P_{full}$. The pressure of the inflated balloon is higher than the atmospheric pressure. When the mouth of the balloon is opened, air exchange occurs until the air is equalized and when the air exchange is complete, the pressure of the deflated balloon and atmospheric pressure become equal ($P_{deflated} = P_{atm}$).

CG.MA.17: The pressure of the deflated balloon is equal to the atmospheric pressure because there is no air inside it. I think the air-filled balloon has higher pressure.

CG.LA.08: I thought like $P_{deflated} < P_{atm} < P_{full}$. When the balloon is full, its pressure increases so pressure of air-filled balloon is higher than the atmospheric pressure. The pressure of deflated balloon is lowest because there are less gas molecules in it and they exert less pressure.

CG.HA.20: $P_{deflated} = P_{atm}$, $P_{atm} < P_{full}$. The atmospheric pressure is equal to the pressure of deflated balloon since the deflation is complete thus it is equal to the first condition of the balloon. The pressure of the air-filled balloon is higher than the atmospheric pressure because air is filled into it.

CG.HA.17: I think that the pressure of the deflated balloon is lower than the atmospheric pressure because while the balloon is deflating, it gives air to outside. Thus the relationship should be $P_{deflated} < P_{atm} < P_{full}$.

CG.MA.18: Cylindrical container examples are similar to balloons. The inner pressure of the balloon must be equal to the 1 atm pressure. Even the balloon is deflated, air also enters inside it therefore it does not matter whether the balloon is deflated or not, its pressure is equal to 1 atm.

CG.LA.42: Of course, the pressure of the deflated balloon is the least because its volume is the lowest. Deflated balloon has no pressure. The pressure of the atmospheric pressure, 76 cmHg, is higher than the pressure of the filled balloon.

CG.MA.08: The relationship among the pressures must be $P_{full} > P_{atm} > P_{deflated}$. P_{full} and $P_{deflated}$ cannot be equal to each other. When the mouth of the balloon is opened, the number of molecules decreases so it cannot be equal to the P_{full}. P_{full} is higher than the P_{atm} since the balloon is inflated.

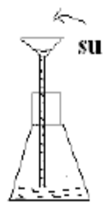
EG.LA.22: Atmospheric pressure is equal to the air-filled balloon ($P_{atm} = P_{full}$) because there is neither expansion nor contradiction in the air-filled balloon. $P_{deflated}$ is smaller than the other two pressures.

EG.MA.11: I do not know. I could not compare.

EG.HA.02: The inner and outside pressures are equal to each other. I am sure that $P_{atm}=P_{full}$. In addition, there is some gas in the inflated balloon so I think all of them are equal to each other.

EG.MA.04: Atmospheric pressure is always higher than the pressures of air-filled balloon and the deflated balloon. I think P_{full} and $P_{deflated}$ cannot be equal to each other since the particles in balloon collide to the walls of the container and make more pressure. In order to have the balloon deflated, the pressure of the deflated balloon must be equal to 1 atm. Therefore, the relationship between the pressure of the balloons, $P_{deflated} = P_{atm}$, $P_{atm} < P_{full}$.

Application of Boyle's Law – Pressure and Volume Relationship



According to the figure given on the right, the container connected to a funnel is closed with a stopper preventing the gas leak from the container. Water is easily entered when poured to the container but when the water level in the container is reached to the bottom of the funnel, water input is becoming difficult. Students were asked to explain the reason of this event.

EG.HA.23: Upward force of the water in the container applies a force so water cannot enter because the container is full in some ways.

EG.MA.19: I think upward force of the water in the container applies a force so water cannot enter.

EG.MA.01: As inner pressure is increasing, a repulsive force is generated to outside. Therefore, the entrance of water is not possible as long as an external pressure is not applied which is higher than the inner pressure.

EG.LA.16: I think increasing inner pressure prevents the entrance of water because the particles accumulate in the water entrance and the coming water cannot find the way to pass.

CG.MA.03: Upward force of the water in the container applies a force so water cannot enter.

CG.MA.17: Increasing inner pressure prevents water entrance because incoming water goes upward since the bottom of the funnel is closed. It must be like that since the water must flow somewhere; it cannot enter and stay there.

CG.LA.08: Water in the container closes water entry and the water cannot enter. In addition, other alternatives can be possible except for buoyancy of water.

CG.HA.20: I think that due to the increase in the inner pressure, no more water is let into the container.

CG.HA.17: I think that increasing inner pressure prevents water entry because amount of water increases. After a certain period, it cannot take any more water.

CG.MA.18: Upward force of the water in the container applies a force so water cannot enter. Let me give an example from daily life, for example, we drink cola with pipe easily but it is difficult to push it back since cola has a repelling force. After a while, it comes back. I thought that it is the repelling force of water.

CG.LA.42: I have no idea about this question. Maybe pressure affects and water cannot enter. Probably water entrance is closed by the water in the container.

CG.MA.08: I do not know, maybe increasing inner pressure prevents water entrance.

EG.LA.22: I think upward force of the water in the container applies a force so water cannot enter.

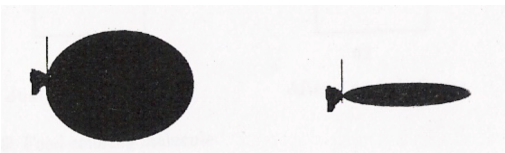
EG.MA.11: I think the best reason is the closing of the water entrance by the water in the container.

EG.HA.02: Since the water occupies some place, the gas inside the container is compressed. The inner pressure is increased because water is added to container.

EG.MA.04: The inner pressure may prevent the entrance of water to inside. It might be due to the compressed gas particles.

Effusion of Gases

A balloon made from rubber is filled with hydrogen gas and the mouth of it is tightly connected. However, after a few days later it is observed that balloon deflates. Students were asked to choose the best explanation for this situation.



EG.HA.23: The gas escaped from the pores of the balloon.

EG.MA.19: External pressure increases and the balloon gets smaller. Since the balloon is bonded, I do not think that the gas escaped from the pores of the balloon.

EG.MA.01: I think the most meaningful answer is the increase in the external pressure and causing the balloon get smaller. However, the environment is the same, so maybe there is gas releasing.

EG.LA.16: The gas escaped both from the pores and mouth of the balloon, due to the gas escape, balloon is inflated.

CG.MA.03: The most logical answer is the cooling of weather and clustering of molecules in the balloon.

CG.MA.17: I remembered from our childhood. When we put things on cold floor, it was deflated and gas molecules were accumulated or clustered in the middle. However, it may become smaller due to increase in external pressure.

CG.LA.08: External pressure increases and the balloon gets smaller otherwise balloon cannot deflate. Energy of molecules may be used up in time and their movements can stop. Nevertheless, increasing external pressure is more meaningful.

CG.HA.20: I think gas escaped from the pores of the balloon. It inflates until the inner pressure becomes equal with the external pressure.

CG.HA.17: I think external pressure may increase and this makes the balloon get smaller. Cooling of weather and clustering of molecules in the balloon are also possible. However, “The gas escaped from the pores of the balloon” explains the situation best.

CG.MA.18: The weather may be cool and the molecules in balloon may be clustered. The energy of molecules may slow down in time, it happens in the balcony of the homes also. I think the gas does not escape from the pores of the balloon, how can it be possible?

CG.LA.42: I think that energy of molecules is used up in time and their movements stop. External pressure may increase and the balloon gets smaller. The molecules inside the balloon may get smaller because of collisions. The gas cannot escape from the pores of the balloon because there is no hole in the balloon.

CG.MA.08: I think that the weather cools and the molecules clusters in balloon.

EG.LA.22: The most meaningful answer is the cooling of weather and clustering of molecules in the balloon. Energy of molecules may used up in time and their movements stop. I think gas escape cannot happen from the balloon because the mouth of it is tightly bonded.

EG.MA.11: The most meaningful explanation is the increase in the external pressure and causing the balloon get smaller. The weather may cool and the molecules may cluster in the balloon. Energy of molecules may be used up in time and their movements can stop. If the mouth of the balloon is not tightly bonded, the gas may escape from the pores of the balloon.

EG.HA.02: External pressure may have increased and maybe the balloon gets smaller, air may enter to environment in which it is placed. If the balloon is porous, the gas may escape from the pores of the balloon.

EG.MA.04: The weather may cool and the molecules in the balloon are clustered. The gas may also escape from the pores of the balloon.

Kinetic Energy and size of the gas particles during phase transition

Students were asked what features of the particles such as size, average kinetic energy, and distance between the particles, change during the transition of pure matter in the phase of solid to liquid or liquid to gas at the same temperature.

EG.HA.23: The size of the particles does not change. In addition, the kinetic energies of them do not change due to the constant temperature. The distance between the particles changes only.

EG.MA.19: The size of the particles may decrease from solid to liquid or liquid to gas. The average kinetic energies increase because in solid phase it moves slowly, in liquid phase it moves more quickly, it is the fastest in gas phase. The distance between them increases since they move independent from each other as the matter changes from solid to liquid or liquid to gas.

EG.MA.01: The size of the particles may change. The distance between the particles changes. Average kinetic energy is constant due to constant temperature.

EG.LA.16: I think that the size of the particles changes for instance I thought the size of the water and ice is not the same. The size of the particles may change during the phase change. The distance between particles also changes.

CG.MA.03: The size does not change. The distance between the gas particles decreases. When we consider the average kinetic energy, it does not change.

CG.MA.17: The size of the particles decreases while changing from solid to liquid or liquid to gas. Average kinetic energies increase gradually and the number of collisions increases. The distance between the particles increases also.

CG.LA.08: The size of the gas particles increases. Average kinetic energy does not change since the temperature is constant. The distance between the particles increases while changing from solid to liquid, liquid to gas.

CG.HA.20: I think the distance between the gas particles changes but the particle size does not change. Average kinetic energy changes when temperature changes. It has also formula $Ek=1/2mV^2$, it depends on both mass and the speed.

CG.HA.17: Average kinetic energy is associated with the temperature but it may not be the same in all. I think the size of the particles increases from solid to liquid or liquid to gas.

CG.MA.18: From solid to liquid, the size of the particles changes, it would get bigger. Average kinetic energy is constant since the temperature is constant. Of course, the distance between the particles increases.

CG.LA.42: The size changes but I do not know how the size of the particles changes. The distance between particles changes, it is the closest in solid and most remote in gases. Solids are more ordered and gases are more movable so average kinetic energy changes.

CG.MA.08: Actually, their sizes do not change. In gas phase molecules are further away in comparison to solid and liquid phase. Gases have the largest average kinetic energy and the distance between the particles increases.

EG.LA.22: From liquid to gas, the distance between the particles decreases but their size does not change. The average kinetic energy changes because their speed increases. Moreover, the gas particles move faster when they are getting closer to each other.

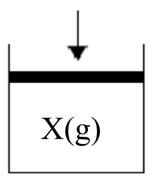
EG.MA.11: From liquid to gas, the size of the particles increases due to decrease in attractive force. I have no idea about the average kinetic energy. The distance between particles increases.

EG.HA.02: I am sure that the size does not change. The distance between the particles changes absolutely. Average kinetic energy was dependent on the gas temperature. If the temperature does not change, probably the average kinetic energy does not alter.

EG.MA.04: The size of the particles always remains the same. Actually, the average kinetic energy changes, it is the least in solids, the most in gases. The distance between the particles varies; it gets closer to each other in solids while it is more distant in gases.

The speed of the gas particles versus the volume of the container

At constant temperature, X gas, behaving ideally, is placed in a container and the container is compressed. Students were asked whether the speed of gas particles changes with changing the volume of the container.



EG.HA.23: The average speed of the particles decreases due to the decrease of the space between the particles. Ultimately, the area will be narrowed, and so their movement will be limited.

EG.MA.19: The average speed of the particles increases, since the volume decreases, the number of collisions increases and so does the speed of the particles.

EG.MA.01: The average speed of the particles decreases since they are compressed and come close to each other. This may be caused by the friction.

EG.LA.16: When the gases are compressed, their average speed increases.

CG.MA.03: Since they are in a smaller area, their speed does not increase.

CG.MA.17: I thought that the number of the collisions and speed of the particles decrease when the field is narrowed.

CG.LA.08: The average speed of the particles increases due to compression.

CG.HA.20: The speed of the gas particles depends on the temperature.

CG.HA.17: Yes, since they come close to each other, the number of collisions decreases. Therefore, I thought that their speed does not change too much but decreases a little bit.

CG.MA.18: Of course, the average speed is higher in a bigger container than that of a small container. In a small container, they collide more.

CG.LA.42: "Average speed of particles decreases" is wrong because their speed may increase in a smaller area.

CG.MA.08: Since the pressure increases, the volume decreases, their movement area will be narrowed and they would not move easily and so their average speed decreases.

EG.LA.22: The speed of the particles increases because they become faster due to increase in pressure.

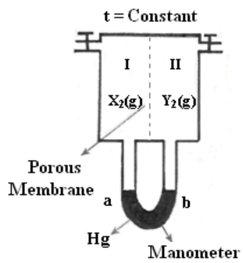
EG.MA.11: The average speed of particles increases since they will collide more with compression.

EG.HA.02: "Average speed of particles decreases" is wrong. Well, we did it in class, when the people were running, if the area is getting smaller, they run at the same rate, this does not change their rate.

EG.MA.04: On the contrary, the speed of particles increases because they collide more.

Diffusion of Gases

As seen from the figure, a container is separated into compartments I and II with a porous membrane and connected to a manometer. Being equal to the levels of mercury in the arms of the manometer, compartment I is filled with X_2 gas and compartment II is filled with Y_2 gas. At the same temperature, after a short period of time it is observed that the level of mercury in arm "a" increases. The reason of rising in arm "a" was asked to the students by presenting some alternatives about diffusion rate, molecular weight and pressure of these gases.



EG.HA.23: X_2 molecules are faster than Y_2 molecules since the level of mercury increased in arm a. Since X_2 is faster, its molecular weight is lower than Y_2. During the observation, total pressure of compartment II increased because there is an increase in the level of mercury in arm a. Thus, the answer is I, II and III.

EG.MA.19: If the level of mercury increases in the arm a, it makes a pressure from here (shows the compartment II) so X_2 molecules are faster than the Y_2 molecules. I think molecular weight of Y_2 is heavier than the X_2 since the pressure is higher here (compartment II). Total pressure of compartment II increases during the observation because it makes a pressure toward this side (compartment I).

EG.MA.01: X_2 molecules are faster than Y_2 molecules because they pass to compartment II faster, it exerts more pressure. The molecular weight of Y_2 may be higher than X_2 because Y_2 did not pass to the other region. During the observation, total pressure of compartment II increases.

EG.LA.16: X_2 molecules are not faster than Y_2 molecules. If they were faster, they would make a pressure toward the arm of the manometer and there would be increase in the level of mercury in arm b. The molecular weight of Y_2 is higher than X_2 since the level of mercury increases in arm a and both molecular weight and molecular rate of Y_2 are higher than X_2. The level of mercury increases in arm a since Y_2 molecules pass into the arm of the manometer. Thus, the number of particles decreases and the pressure decreases in compartment II.

CG.MA.03: If X_2 molecules were faster than Y_2 molecules, there would be an increase in the level of mercury in arm b. I think that the level of mercury in arm a increases since the arm b is affected.

CG.MA.17: If the mercury level is higher in arm a, X_2 molecules are faster than the molecules of Y_2. The molecular weight of Y_2 is higher than the X_2 because if the molecular weight of a gas increases, its pressure increases also.

CG.LA.08: The arm of the manometer is from b to a since the molecular weight of Y_2 is higher than the X_2. X_2 molecules are not faster than Y_2 molecules. The total pressure of compartment II increases.

CG.HA.20: If the pressure of region II increases, it exerts a pressure toward region I and the level of mercury increases in arm a. I think that molecular weight of Y_2 is higher than that of X_2 because high molecular weight causes high pressure at constant volume and temperature. If the molecular weight of Y_2 is higher, X_2 is faster than Y_2. The gas with low molecular weight is faster so all of the alternatives are correct.

CG.HA.17: The molecular weight of Y_2 might be lower than X_2 but I am not sure. I do not exactly understand the system.

CG.MA.18: Since the total pressure of compartment II increases, there is an increase in arm a. If the molecules of X_2 were faster than Y_2, they would make a pressure towards arm b because the pressure is directly proportional to the number of molecules. If the molar mass of Y_2 is more than that of X_2, it makes more pressure towards this side (shows arm b), so I think it is higher.

CG.LA.42: I think total pressure of compartment II increased during the observation. Presumably, X_2 molecules are faster than Y_2 molecules. I do not know whether the molecular weight causes a decrease or an increase in the pressure.

CG.MA.08: X_2 molecules cannot be faster than Y_2 molecules, if they were; they would make more pressure and increase the level of mercury in arm b. The molecular weight of Y_2 is higher than X_2. The total pressure of compartment II increases during the observation.

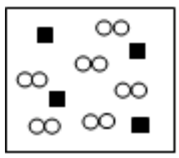
EG.LA.22: Y_2 molecules are faster than X_2 molecules because pressure is exerted by Y_2. The pressure of Y_2 is higher compared to X_2 because Y_2 pushes the mercury downward. I have no idea about the molecular weights. During the observation, total pressure of compartment II increases because pressure is exerted by Y_2.

EG.HA.02: Is there a transition from the porous membrane, it may or may not be. If they were, the arms of the manometer would always be in balance. X_2 exerts more pressure maybe due to the high number of molecules. At first they are the same but as X_2 passes to compartment II, Y_2 passes to other compartment. It is correct that the total pressure of compartment II increases during the observation.

EG.MA.04: Y_2 molecules must be faster than X_2 molecules since they collide more and there is an increase in arm a. The molecular weight of Y_2 might be higher than X_2. The pressure of compartment II increases.

Partial Pressure of Gases

The following closed container was presented containing a mixture of oxygen (○○) and helium (■) gases at 25 °C. Students were asked to select the picture that indicates the partial pressure of oxygen.



EG.HA.23: It is only the pressure of the oxygen. The number of the oxygen molecules should be equal and oxygen molecules should not be separated.

EG.MA.19: I selected alternative D since it only includes the oxygen gas. Since the partial pressure of oxygen is asked, there should be two oxygen atoms in its molecules. I selected this answer since it has 6 oxygen molecules and they were homogeneously distributed.

EG.MA.01: I chose the alternative D because it asks only the pressure of the oxygen and oxygen was found molecular in nature.

EG.LA.16: I do not know what the partial pressure is exactly. We have learnt this in class but I was absent.

CG.MA.03: I chose the option that there is a chemical reaction and its yield in the container.

CG.MA.17: I do not remember anything about the partial pressure. We have learnt it as a formula so I have no idea.

CG.LA.08: Since the partial pressure of oxygen is asked, it should not include helium. Picture C seems as if oxygen atoms distribute more homogeneously.

CG.HA.20: In fact, I did not put into play the helium since it mentions about the pressure of the oxygen. Oxygen molecules cannot be separated, they stay together and their number of molecules does not decrease.

CG.HA.17: I am not sure whether the gases react with each other or not. I only remember the formula related to partial pressure, PT/nT= Pg/ng.

CG.MA.18: There should be helium in the container because it has also partial pressure. The related formula should be something like that P_1/V_1 or n=PV but I do not remember very well.

CG.LA.42: I have no idea about the partial pressure. I think they react with each other since they are together in the container.

CG.MA.08: I think nothing is changed but they may react.

EG.LA.22: I think that it is mentioned about only oxygen. Oxygen should be neither separated from each other nor attached to each other, they distribute homogeneously.

EG.HA.02: Partial pressure is the exerted pressure by a particular gas in the container or its own pressure. Oxygen molecules cannot be separated or give a reaction with helium.

EG.MA.04: The oxygen atoms should not be separated from each other. Partial pressure is the particular pressure of the gases in a container so I did not include the helium. There should not be any change in the number of molecules.

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