THE RELATIONSHIP AMONG REASONING ABILITY, GENDER AND STUDENTS' UNDERSTANDING OF DIFFUSION AND OSMOSIS

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ABSTRACT

THE RELATIONSHIP AMONG REASONING ABILITY, GENDER, AND STUDENTS’ UNDERSTANDING OF DIFFUSION AND OSMOSIS

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This study investigated the 9th grade students' achievement regarding diffusion and osmosis in relation to reasoning ability, prior knowledge and gender. A total of 397 ninth grade students participated in the study. The Test of logical thinking (TOLT) and the Diffusion and Osmosis Diagnostic Test (DODT) were administered to determine students' reasoning ability and achievement in diffusion and osmosis, respectively. DODT results showed that the range of correct answers for the first tier was 41 % to 91%. When both tiers were combined, the correct responses were reduced to a range of 21% to 61%. This result reveals that students have enough content knowledge but they don’t know the underlying reason of their choice in diffusion and osmosis concepts. Pearson Product Moment correlations showed a statistically significant positive correlation between achievement and students' prior knowledge & reasoning ability. MRC Analysis was conducted to determine the contribution of prior knowledge, reasoning ability and gender to the achievement. Prior knowledge and reasoning ability, but not gender, made a statistically significant contribution to the variation on achievement. Prior knowledge and reasoning ability together predicted 37 % of the variation on achievement. Stepwise multiple regression analysis was computed to determine the variables were best predicting students' achievement. While prior knowledge explains 33 % of the variation in achievement, reasoning ability explains only 4 % of the variation in achievement. Results indicate that prior knowledge is a better predictor than reasoning ability in students' achievement.

Key words: Reasoning ability, gender, prior knowledge, diffusion, osmosis, misconception

ÖZ

ÖĞRENCİLERİN DİFÜZYON VE OSMOZ KAVRAMLARINDAKİ BAŞARILARI, MANTIKSAL DÜŞÜNME YETENEKLERİ VE CİNSİYETLERİ ARASINDAKİ İLİŞKİ

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Bu çalışmada Lise 1. sınıf öğrencilerinin difüzyon ve osmoz kavramlarındaki başarıları ile mantıksal düşünme yetenekleri, cinsiyet ve ön bilgi düzeyleri arasında ilişki olup olmadığı incelenmiştir. Toplam 397 Lise 1 öğrencisi bu çalışmaya katılmıştır. Öğrencilerin mantıksal düşünme yetenekleri Mantıksal Düşünme Yeteneği Testi (TOLT) ile, difüzyon ve osmoz konularındaki kavramsal bilgileri ise Difüzyon ve Osmoz Tanı Testi (DODT) ile ölçülmüştür. İki aşamalı tanı testi sonucunda öğrencilerin birinci aşama için % 41-91 oranında doğru cevaplar verdiği, ikinci aşama içinse % 21-61 oranında doğru cevap verdikleri tespit edilmiştir. Bu sonuçlar öğrencilerin difüzyon ve osmozla ilgili kavram sorularını yanıtlarken cevabın altında yatan nedeni tam olarak anlayamadıklarını açığa çıkarmıştır. Değişkenler arasındaki ilişkiler Pearson korelasyonu ile incelendiğinde öğrencilerin ön bilgi düzeyi ve mantıksal düşünme yeteneği ile difüzyon & osmoz' daki başarısı arasında pozitif korelasyon saptanmıştır. Çoklu regrasyon analizi ile öğrencilerin başarısına hangi değişkenin katkıda bulunduğu araştırılmıştır. Ön bilgi düzeyleri ile mantıksal düşünme yetenekleri başarıya katkıda bulunurken, cinsiyetin başarı üzerine bir katkısı bulunamamıştır. Ön bilgi düzeyi ve mantıksal düşünme yeteneği öğrencilerin Difüzyon & Osmoz Tanı Testi başarılarındaki farklılığın % 37' sini açıklamaktadır. Aşamalı çoklu regrasyon analizinde öğrencilerin başarılarını hangi değişkenin en iyi tahmin ettiği araştırılmıştır. Bu analiz sonucuna göre, ön bilgi düzeyi % 33, mantıksal düşünme yeteneği ise sadece % 4 oranında başarıdaki varyansı açıklamaktadır. Bu sonuçlar ön bilgi düzeyinin mantıksal düşünme yeteneğine göre öğrencilerin difüzyon ve osmoz başarılarını daha iyi tahmin ettiğini göstermektedir.

Anahtar Kelimeler: Mantıksal Düşünme Yeteneği, Cinsiyet, Ön bilgi düzeyi, Difüzyon, Osmoz, Kavram yanılgısı

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CHAPTER 1

INTRODUCTION

The effectiveness of present approach to science education has been questioned to meet the individual and societal needs that are changing very fast along with the rapid changes taking place in the science and technology. Most reports on science education have described the current science curriculum as obsolete (Hurd, 1991). Unfortunately, the traditional science pedagogy that is still common in most science classrooms represents science as a body of static knowledge that students perceive as absolute true. The resultant rote-learning process deters students from “doing or performing science” and hinders the progress toward becoming scientifically literate persons. A body of knowledge in science without the process skills very often does not become functional in helping a person to explore the nature objectively (DESE, Missouri 1996). In the future world, the ability to face the unknown would be much more useful than the ability to understand and repeat what is already known.

For many years, the need for education in science, mathematics, and technology areas will become even more important to each individual and to society as a whole in the twenty-first century (Lappan, 2000). Since the 1960's biology teaching in secondary schools has been transformed from a formal approach reflecting the structure of the discipline and mirroring the concerns of the scientific community to a broad-based approach reflecting the concerns of society as a whole. The aim of biology education today is to heighten awareness, improve students' self-image, understand the applications of biology in daily living, and promote participation in societal decision making in areas such as science policy and in other socially significant matters with a basis in biology.

Low achievement in biology is one of the main problems in Turkey. Özcan (2003) investigated the reasons underlying low biology achievement of students through the analysis of interviews conducted with biology teachers and 11th grade science students. Results revealed serious problems in current biology education. The first one is that students' perceptions are in the way that biology depends on memorization. Curriculum covering a high amount of topics and details is another reason causing low achievement in biology. In addition, class hour allocated to biology lesson and role of biology in university entrance exam (ÖSS) profoundly affects students' achievement and motivation in biology. Moreover, in the light of teacher interviews, students have difficulties in concepts due to the presence of many terms and Latin words in addition to the different words having same meanings. Most of the students find biology difficult even they have higher grades in biology. Tekkaya, Özkan and Sungur (2001) concluded that learning difficulties in biology rely on terminology, large number of foreign terms, insufficient teaching methods, and curriculum covering a quantity of subject matter, abstract and interdisciplinary nature of concepts and insufficient laboratory conditions and equipment. To date, many studies have investigated students' understanding of biological concepts: photosynthesis, genetics, ecology, respiration, classification, the circulatory system and the digestive system. Many of these topics about which students hold misconceptions are basic to biology knowledge and are interrelated.

Diffusion and osmosis are among such concepts. Studies focusing on students' understanding of diffusion and osmosis indicated that students had a considerable degree of misconceptions in various grade levels and these misconceptions are resistant to change by traditional teaching methods (Odom

& Kelly, 2001). For example, a study conducted by Friedler, Amir and Tamir (1987) indicated that high school students had difficulties in understanding dynamic equilibrium, osmotic relations in plants, solute-solvent and concentration-quantity relations. Furthermore, Odom and Barrow (1995) identified 20 misconceptions related to the particulate and random nature of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion and the process of osmosis among college biology students.

Some researchers have found the acquisition of new concepts may be related to student reasoning level. Lawson found the acquisition of domain-specific conceptual knowledge in high school biology and chemistry classes correlated with student reasoning levels. Age did not correlate with performance on the concept acquisition tasks. Smith (1986) found that reflective operational thought was neither a sufficient nor a necessary condition to successful genetics problem solving. Many investigators found that a student's developmental level correlated with achievement in college classes. The studies performed in the field of education showed significant relationship between reasoning abilities and biology achievement. For example, Johnson and Lawson (1998) investigated the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes. They found that reasoning ability explained a significant portion of variance in final examination score in both instructional methods. Moreover, Cavallo (1996) reported that reasoning ability best predicted students' achievement in solving genetics problems. Also, Ehindore (1979) mentioned that the brightness defined by students' performance on the biology tests is significantly related to the cognitive developmental precocity. Furthermore, Lawson and Thompson (1988) tested the hypothesis that formal reasoning ability is essential for 7th-grade students to successfully deal with prior misconceptions and develop scientifically acceptable biological conceptions concerning genetics and natural selection. The results showing that number of misconceptions is consistently and significantly related to the reasoning ability supported this hypothesis. Lawson (2000) found a significant relationship between conceptual knowledge and developmental level in college biology students. Odom (1994) reported that formal reasoning played a significant role in understanding diffusion and osmosis concepts. They found that formal high school students out performed preformal high school students on five out of seven concepts related to diffusion and osmosis. In addition, they found grade level to be an insignificant covariate, and in most cases formal 10th grade students out performed preformal 11th and 12th grade students. More recently, it is reported that there exist significant differences between levels of cognitive development and understanding of diffusion and osmosis in the favor of formal students (Odom and Kelly, 2001). Not only reasoning ability, but also prior knowledge plays a significant role in achievement and learning.

To what extend does the amount of prior knowledge on a topic affect student performance? Most college biology instructors assume that their students' prior knowledge plays an important role in their ability to acquire new concepts. Indeed, a common goal of the standard biology course is to provide students with the basic conceptual knowledge needed to enroll in advanced course work in a variety of areas such as genetics, ecology, and cell biology. Novak (1990) believed that storage of specifically relevant concepts is of primary importance. According to Novak, learners acquire a hierarchically organized framework of specific concepts, each of which permits them to make sense out of new experience. If these prior concepts are lacking, one cannot acquire new concepts. In support for this position, Yezierski (2003) found that for high school biology and chemistry students, previous science grade affected final examination performance. Moreover prior genetics knowledge, but not reasoning ability, significantly predicted performance on a genetics posttest. Johnson (1993) found that prior knowledge led to adoption of more effective study strategies, and therefore to better achievement in college physic and biology classes.

Diffusion and osmosis, keys to understand many important life processes, are widely taught in many secondary and college biology curricula. In Turkey, diffusion and osmosis concepts are taught at 9th grade level in 3 lesson hour. Diffusion and osmosis are the sub-topics of “Transport mechanisms across cell membrane” unit. This unit is learned in between “types of organic compounds” and “cell division”. Experiments related with this topic are carried out at 10th grade level during biology application lesson. These concepts are introduced into the initial stages of most biology courses in topics dealing with cellular structure and functioning. There are several reasons why we should focus on diffusion and osmosis concepts in biology. Diffusion is the primary method of short distance transport in a cell and cellular systems. Osmosis is key to understand water uptake by plants, water balance in aquatic creatures, turgor pressure in plants, and transport in living organisms. In addition, diffusion and osmosis are closely related to key concepts in physics and chemistry such as permeability and the particulate nature of matter. Because of the diversity of diffusion and osmosis concepts and their importance in understanding science and biological systems, an evaluation of students' understanding is needed so more effective teaching methods can be developed.

These studies indicated that students had difficulty in diffusion and osmosis concepts. Reasoning ability, gender and prior knowledge are seems to be underlying reasons of difficulty. Although there have been many studies concerning gender, reasoning ability and prior knowledge separately, no studies conducted investigating the relationship between gender reasoning ability, prior knowledge and the contribution of these variables on achievement.

1.1. Definition of Terms

The following terms were defined according to their use in this study:

1. Misconceptions were defined as students' incorrect beliefs, interpretations, or explanation about biological scientific principles. These beliefs were considered different from those accepted by scientists, and represented scientifically incorrect interpretations. In this study misconception was an alternative explanation constructed by a student in response to the students' prior knowledge and personal experience. Misconceptions were measured by using DODT (Diffusion and Osmosis Diagnostic Test) which was developed by Odom and Barrow (1995)

2. Conceptual Understanding was a level of understanding measured by the mean scores in DODT (Diffusion and Osmosis Diagnostic Test) items, where the content and the reason behind the content are comprehended by the learner.

3. Achievement was defined as students' general knowledge of basic biology principles pertaining to diffusion and osmosis. It was assessed by DODT (Diffusion and Osmosis Diagnostic Test) which was developed by Odom and Barrow (1995).

4. Prior Knowledge was defined as a students' biology background prior to participating in this study. This was determined by students' last semester school biology grades.

5. Formal Reasoning Ability was the ability to realize many operations as the followings:

a) Relationship between two variables remains constant despite their changing in value
b) Isolating individual factors and possible recombination of factors that may figure into new solutions
c) Interpreting observations that show unpredictable variability and recognizing relationships among variables in spite of random fluctuations that mask them
d) Realizing the necessity of an experimental design that controls all variables but the one being investigated

1.2. Problems of the study

The purpose of this study is to investigate 9th grade students' achievement regarding diffusion and osmosis in relation to reasoning ability, prior knowledge and gender.

1.2.1 Main problems of the study

1. What conceptions related to diffusion and osmosis do 9th grade students hold?

2. What are the best predictors of achievement in diffusion and osmosis concepts?

1.2.2 Sub Problems of the Study

Based on the main problem, the specific research questions to be addressed in this study are as follows:

1. Is there a relationship among reasoning ability, prior knowledge and students’ achievement in Diffusion and Osmosis?

2. Is there a statistically significant contribution of reasoning ability, prior knowledge and gender to the variation in Diffusion and Osmosis?
3. Is there a statistically significant contribution of reasoning ability to the variation in Diffusion and Osmosis Diagnostic Test scores when prior knowledge and gender were controlled?
4. Is there a statistically significant contribution of prior knowledge to the variation in Diffusion and Osmosis Diagnostic Test scores when reasoning ability and gender were controlled?
5. Is there a statistically significant contribution of gender to the variation in Diffusion and Osmosis Diagnostic Test scores when reasoning ability and prior knowledge were controlled?

1.3. Hypotheses of the study

The main and sub problems given above were tested with the following null hypotheses.

Null Hypothesis of Sub-problem 1 (H_0l): There is no statistically significant relationship between students' prior knowledge, reasoning ability and achievement.

Null Hypothesis of Sub-problem 2 ($H_0$2): There is no statistically significant contribution of reasoning ability, prior knowledge and gender to the variation in DODT achievement scores

Null Hypothesis of Sub-problem 3 ($H_0$3): There is no statistically significant contribution of reasoning ability on student understanding of diffusion and osmosis concepts, when their prior knowledge and gender were controlled

Null Hypothesis of Sub-problem 4 (H_04): There is no statistically significant contribution of prior knowledge on student understanding of diffusion and osmosis concepts, when their reasoning ability and gender were controlled

Null Hypothesis of Sub-problem 5 (H_05): There is no statistically significant contribution of gender on student understanding of diffusion and osmosis concepts, when their prior knowledge and reasoning ability were controlled

1.4. Significance of the Study

To date, many studies have been done in order to increase the biology achievement in Turkey. Most of them were related with the methods used in teaching a specific topic or the identification of misconceptions. However, in order to increase achievement, firstly it has to be revealed which biology topics are prerequisite in order to understand other topics. Besides, the importance of students' cognitive stages was discussed by many researches. It was mentioned that reasoning skills such as controlling variables, proportional, probabilistic, correlation and combinational reasoning were identified on emotional abilities for success in learning science. It is stated that prior knowledge and reasoning ability to be the factors that can predict academic achievement, depending on the instructional procedure used. It is suggested that reasoning ability may lit the academic achievement of biology college students, instructed either expository or inquiry methods.

The controversy continues as to whether a students’ prior knowledge or his or her reasoning level have the greater impact on his or her ability to acquire new concepts. In this study, formal reasoning ability of high school students is measured. Also, misconceptions in diffusion and osmosis unit are prevailed and students’ understanding level of diffusion and osmosis concepts are evaluated. Gender, prior knowledge, reasoning ability and achievement relationships are revealed in this study. Consequently, these findings will provide baseline information for predicting student achievement in biology courses. The relationship between the reasoning ability of the students and understanding of diffusion and osmosis concepts may provide teachers with knowledge needed to help students develop higher cognitive abilities, and to guide their students toward attaining more sound understanding of science. The findings of the study will give some information to science teachers, particularly biology teachers about how students understand diffusion and osmosis concepts. The findings can help to prepare a better class-hour time for biology teachers. Furthermore, teaching methods, e.g. laboratory activities, might be applied based on the findings of the study. Finally, two- tier multiple choice test can be a valuable tool that can aid teachers in assessing both their teaching methodologies and students’ understanding and reasoning about diffusion and osmosis. If these steps could be taken, interest of students to the lesson would increase and thus their achievement would improve.

CHAPTER 2

REVIEW OF LITERATURE

This study tries to find out what conceptions related to diffusion and osmosis do the 9th grade students hold in Turkey? Secondly, it seeks to answer the following question: What is the contribution of prior knowledge, reasoning ability and gender to the understanding of diffusion and osmosis? Finally, it aims to identify the best predictors of achievement in the concepts of diffusion and osmosis.

The purpose of this chapter is to examine the studies related to difficulties in biology, conceptual understanding of diffusion and osmosis, and the importance of reasoning ability, prior knowledge and gender in students' achievement. Although many research has been done on biology education, only few of them focused these questions in Turkey. So the examples from worldwide researches on this topic needed to be taken into consideration.

2.1. Research Related with Difficulties in Learning Biology

Students' difficulties in understanding biology concepts have been investigated by many researchers. For example, Johnstone and Mahmoud (1980) did the fundamental research on the issue on 167 university students, 166 high school biology students and 50 biology teachers in Scotland. The instruments in the study were questionnaire, examiners' reports, teachers' questionnaires, and conversations with inspectors and lecturers. From the data of high school and university students obtained from questionnaire, water transport in organisms including osmosis, water potential and water balance, energy conversions in photosynthesis, respiration, ATP and ADP, genetics and mechanism of evolution were found to be difficult topics. The responses of teachers were osmosis, water potential, and control of water in organisms, chemical energy, ATP, ADP, chemistry of photosynthesis and respiration, mechanism of evolution and genes. Their results revealed that all the university and high school students and teachers classified the same topics as difficult. Additionally, Scottish Examination Board publishes a report (years 1970-1978) on each of their examinations account on the strengths and weaknesses exhibited by candidates. Students had difficulty in basic plant and animal anatomy, ecosystems, genetics, water relations in organisms, enzymes, photosynthesis, respiration, energy storage and conservation and mechanism of evolution. According to the opinions of inspectors and lecturers, students had most trouble with water relationships in organisms and energy considerations in the building and breakdown of foods.

Marek (1986) made an investigation to identify fundamental concepts in high school biology and measure high school students' misunderstandings of these concepts. The subjects were 10th grade biology students attending an urban high school in Oklahoma. Two classes of approximately 30 students were identified as representative and typical biology classes which met daily for 50-minute periods. From the numerous topics comprising all biology courses, two basic concepts were identified for this research with conceptualization: the cell and the process of diffusion. The cell and diffusion, fundamental and universal concepts essential to the understanding of biological systems, were selected from a sample of biology concepts including food chain, ecosystem, producers, decomposers, circulation, respiration, digestion and mitosis. Approximately 30 percent of class time was spent in laboratory work conducting experiments from a laboratory manual. During the remainder 70 percent class time, students listened to lectures, read from the textbook, watched films and completed written assignments.

The diffusion concept statement was as follows:

"A ten gallon glass container is full of clear water. Several drops of a dark dye are dropped on the surface of the water. The dye begins to swirl, and then spread throughout the water. Eventually the water changes from colorless to light blue. In a paragraph describe how the blue dye spread to change the color of the water to a uniform light blue."

The revised concept statements were administered to a research sample of 60 students, 29 males and 31 females, at the end of the school year. Responses for each concept statement were identified as no response (NR), partial understanding (PU), sound understanding (SU) or specific misunderstanding (SM). Evaluation scheme for the Diffusion statement was as the following table.

Table 2.1 Evaluation criteria for diffusion concept statement

DEGREE OF UNDERSTANDING	KEY IDEAS OF RESPONSES
NO RESPONSE	Blank or repeats questions I don't know I don't understand
PARTIAL UNDERSTANDING	Includes at least one: Use the term of diffusion; molecular movement; concentration gradient; definition without explanation
SOUND UNDERSTANDING	All of the above: Random movement of particles from a region of greater concentration to a region of lesser concentration
SPECIFIC MISUNDERSTANDING	Typical responses include: water molecules accept blue dye; water is universal solvent; water cells and dye cells pass through each other

Only 15.8 percent of the students in the study demonstrated sound understanding of the cell-a concept fundamental and pervasive in biology. Even fewer, 1.8 percent of the sample demonstrated and sound understanding of the diffusion concept. Fifty percent of the sample showed specific misunderstanding in diffusion concept. Fewer than half of the students in this study demonstrated any degree of understanding of the cell or diffusion. The results (high degree of misunderstandings) of this research are consistent with other studies (Gilbert 1977; Gilbert and Watts, 1983).

Bahar, Johnstone and Hansell (1999) determined the difficulties of Scottish students in biology, which was previously determined by Johnstone and Mahmoud in 1980. The aim of this study was to revisit the topics perceived as difficult by students and to see what changes in student perception, if any, had occurred in the intervening period. The sample was composed of 207 first year university students who were studying biology, but not necessarily planning a career in biology. Students were asked to indicate their view of difficulty of each topic headings by using 4 point likert scale. They found monohybrid crosses, dihybrid crosses and linkages, genetic engineering, genetic control of development and metabolic processes, meiosis, central nervous system, sense organs and coordination, gametes, alleles and genes as the most difficult topics. On the other hand, diffusion and osmosis, obtaining food in animals and plants, enzymes, active transport, secretion of materials and defense mechanisms in plants had been chosen as easiest topics. It was also interesting those topics in the general area of transport (diffusion, osmosis, active transport) were rated as difficult in the past. Considerable changes were made in the Scottish syllabuses which have resulted in those difficult topics becoming accessible to student.

In another study, Tekkaya, Özkan and Sungur (2001) investigated the students' difficulties in biology. In their study, students recognized hormones as the most difficult topic in the curriculum. It was interesting that students fail to relate the hormones to other systems due to the perception of hormones as separate system. They also argued that it requires rote memorization. Rote learning could make subsequent learning of science increasingly difficult and may deter many from continuing to take science courses or pursing scientific careers. Also, genes and chromosomes were found as difficult, because they are abstract concepts and there are many confusing terms. As well, mitosis and meiosis were labeled as difficult, because of the complexity during differentiation of phases. Lastly, the nervous system was perceived as difficult, because of rote memorization. On the other hand, students rated the concept of ecology, cell and organelles as easy, because they have been taught these topics since elementary school. In addition, students have been taught teachers used different teaching strategies such as analogy and demonstration in the above topics. In this study, gender differences were also investigated and it was concluded that boys perceive biological concepts easier than girls due to socialization factors and classroom experiences leading to low self-esteem and passive dependent behavior among girls.

In a recent study, Kablan (2004) analyzed Turkish high school students learning difficulties in biology. A total of 397 grade 11 students and 16 biology teachers participated in the study. Students and teachers perceptions of difficult and important to learn concepts were determined through a questionnaire. Moreover, semi-structured interviews were conducted with students and teachers to determine the intrinsic difficulties and sources of difficulties. Descriptive statistics was used to determine frequencies of difficult, moderate and easy biology concepts as perceived by students and teachers. Biotechnology and genetic engineering, hormones, photosynthesis, genes, Mendelian genetics and cellular respiration were found to be difficult concepts for students to learn. On the other hand, the students identified producers, consumers and decomposers, active transport, diffusion and osmosis as easy topic. In addition, cell, enzyme, cell division, respiratory system in vertebrates, protein synthesis, and reproduction in animals are selected as important topics to be learned. On the contrary, body systems in invertebrates and animal tissues are found to be less important topics to be learned by the students.

Özcan (2003) carried out a study aimed to explore students' and teachers' perceptions with respect to biology education at high school level in order to reveal the reasons of students' low achievement in biology as indicated by the university entrance examinations between the years 1996-2002. She conducted interviews with 45 eleventh grade high school students and 45 biology teachers. This study reported that reasons of low achievement in biology as follows. Students are not actively involved in the lessons and they expected the lesson be enjoyable and integrated into daily life. Another problem was insufficient time allocated to biology lessons compared to other science lessons. Moreover, students tend to memorize the concepts without thinking the reason behind them. As a result of rote memorization, they couldn't make any connection between the concepts. So they show a wide range of difficulties in understanding the basic biological concepts.

To sum up; many researchers investigated the students difficulties in learning biology. Whatever the topic, the main reason that students are faced is generally coming from memorization, lack of interest, abstract and confusing terms, lack of enough conceptual knowledge, etc. Students tend to memorize the concepts without thinking the reason behind them. Since each new concept is closely related to others, they couldn't make meaningful connection between the concepts.

2.2. Research Related with Students' Conceptual Understanding of Diffusion and Osmosis

It is generally accepted that students come to class with well established but not scientific preconceptions. These different conceptions generated by students have been called "alternative conceptions" (Arnaudin and Mintzes, 1985) or "misconceptions" (Fisher, 1985). Fisher (1985) summarized the characteristics of the misconceptions as pervasive, stable and often resistant to change through traditional teaching method. Understanding and identification of misconceptions in diffusion and osmosis concepts have been studied by Johnstone and Mahmoud (1980); Friedler, Amir and Tamir, (1987); Zuckerman (1994); Simpson and Marek (1988); Westbrook & Marek (1991); Odom and Barrow (1995); Odom and Kelly (1999).

Johnstone and Mahmoud (1980) discovered that "osmosis and water potential" were regarded by students and teachers as the most difficult of fifteen major biological concepts. Why should be the osmosis topic prove to be so difficult? Several reasons were written as follows:

- Its understanding requires formal reasoning
- It requires a high level of reasoning as well as an understanding of the relationship between macro- and micro- systems in phenomena such as concentration, membranes, direction of molecular movement.
- The student has to learn and use several underlying new concepts such as diffusion, plasmolysis, turgor, selective membrane.
- Some of the prerequisite concepts require knowledge of physics and chemistry, e.g., solutions, solubility, solute, concentration, dilution, particulate nature of matter which was found by Johnstone and Mahmoud to be difficult, especially for biology students.
- The confusing use of terms by textbooks and teachers, e.g., diffusion pressure deficiency and water potential.
- Confusion is caused by the difference between the everyday meaning and the scientific meaning of concepts, e.g., pressure concentration – quantity.
- The tendency of teachers and students to use teleological explanations, e.g., 'the water moves out in order to balance the concentrations'.

Friedler et al., (1987) investigated high school students' difficulties in understanding osmosis in Jarusalem. In this study, the relative difficulty of selected concepts related to osmosis, differences in understanding osmosis and related concepts between students in different grade levels, and how students' difficulties and the reason of misunderstandings are expressed. Five hundred secondary students in years 9-12 were studied through the use of five different kinds of instruments: prior learning inventory, self- report knowledge inventory, true/false test, definitions and clinical interviews. Some of the major findings were:

- The most frequent explanation offered to osmosis is 'a desire or drive towards equalizing concentrations'.
- Hardly any student uses the concept 'water concentration' as the reason to the question "why did the water move from one region to another?"
- Most student fail to realize that in dynamic equilibrium water molecules keep moving indefinitely even through the net concentration difference is zero.
- Students have special difficulty in understanding osmotic relations in plants because of additional items such as cell vacuole and cell wall which make the system more complex. Hence, phenomena like plasmolysis are often misconceived.
- Many students have difficulty in grasping solute-solvent and concentration-quantity relations.
- Students may perform laboratory experiments without really understanding the underlying principles.

Zuckerman (1993) identified 12 accurate & 8 inaccurate conceptions about osmosis held by high school science students. It was reported that misconceptions about osmosis blocked problem solving of osmosis-related questions. Two alternative conceptions were specifically linked with blocking meaningful problem solving: The rate of osmosis is constant, and the concentration of water across the membrane must be equal at osmotic equilibrium. Of the 12 accurate conceptions, two were especially important in enabling problem solvers to generate correct answers: Increasing the height of a column of the solution increases hydrostatic pressure on the membrane; and when a solution and water are separated by a selectively permeable membrane, pressure against the solution side of the membrane opposes osmosis.

Zuckerman (1994) perform another study in USA to identify the conceptual knowledge of high school students who solved a significant problem about osmosis. The problem selected for her study is significant for both instruction and research in the domain of osmosis. A funnel involving dilute sugar solution is covered by an inelastic membrane permeable only to water has been put in a beaker in an inverted position. The funnel was surrounded by pure water. The problem asks to make a graph to show how the solution level in the funnel changes with time. Teachers recommended students who were outstanding in science for both their overall conceptual knowledge and interest in problem solving. Presumably their conceptual knowledge about osmosis could be useful for the majority of students to know. Sixteen outstanding science students participated in this study. The investigative procedure for each participant began with an individual clinical interview. The purpose of the interview was to explore the participant’s conceptions, both accurate and inaccurate, about osmosis. Presumably the participant would use these conceptions to solve the problem. A think-aloud solving of the problem and retrospective report of the solving course immediately followed each clinical interview. She used records of these events to determine whether the solving course was scientifically meaningful. Each think aloud solving also generated a pencil-paper answer. She assessed this answer for correctness against a graph that served as the model answer. Of the 16 outstanding science students who participated in this study, only two solved the problem. That is, this study is a report of the conceptual knowledge they displayed during their presolving clinical interviews. She therefore concluded that most science students lack the necessary conceptual knowledge to interpret these conditions correctly.

Simpson and Marek (1988) examined differences in conceptual understanding of diffusion between students in large and small schools. Concept Evaluation Statement was used to measure conceptual understanding for diffusion. They found that approximately 50 % of the students sampled had no understanding of (or gave no response) the diffusion concept. Marek examined 8th and 10th grade students for their understanding of diffusion concept. Only 1 of 252 eight grade students and 2 of 60 tenth grade students showed sound understanding of the diffusion concept. Almost 90 % of the 8th grade students and over 50 % of the 10th grade students indicated no understanding of the diffusion concept. The differences between the large and small school samples at each level of understanding were significant ($p<0.05$) for the concept of diffusion. Based upon chi-square calculations, a relationship exists between the concept-diffusion- and the size of school they attend. Students attending large high schools developed more instances of understanding for the concept of diffusion while students attending small schools showed more instances of misunderstandings or no understanding of diffusion. The intellectual developmental level of students can affect how students understand a concept. Also, concept taught above the developmental stage at which a student is capable of functioning could lead to misunderstandings about that concept. A greater percentage of students in larger schools function at formal operations as compared to students in small schools.

Westbrook & Marek (1991) conducted a cross-age study of student understanding on the concept of diffusion. Cross- age study provide an opportunity to observe the shifts in concept development that occur as students mature, increase in intellectual development ,and experience additional coursework. This study examined 7th-grade life science students, 10th-grade biology students and college zoology students. The purpose of this project was to examine the understanding of the concept of diffusion among students. The occurrence of misconceptions at each of the grade levels and patterns of student understanding across the grade levels were examined. Responses from 100 students from each grade level were randomly selected for data analysis. Each student responded to a test packet consisting of a biographical questionnaire, two Piagetian-like developmental tasks, and a Concept Evaluation Statement (CES). The CESs was used to measure the understandings of the concept of diffusion. None of the 300 Students levels exhibited complete understanding of the diffusion concept. Over 60 % of the 10th grade and college students sampled exhibited misconceptions concerning the process of diffusion. Fifty five percent of the responses of the 7th grade students displayed misconceptions. The fewer number of misconceptions among 7th graders can be attributed to the fact that irrelevant issues (such as density and surface tension) did not occur in the responses. Most of the 7th grade responses indicating partial understanding can be presented by this example:

> "…It (the dye) will mix with water and turn the water blue."

Misconceptions were evident when the students attempted to include other information, as exhibited in this response by a 10th grade student:

> "…The dye…scatters its molecules throughout the water and soon fills up every atom or molecule in the water to give it a bluish tint."

A student from college sample wrote:

> "… According to the principle of entropy, it (dye) will spread out as much as it possibly can."

Irrelevant factor such as surface tension, cohesive and adhesive forces, and chemical potential were often noted in the responses the college sample. One student combined the concept of dissolving, diffusion and density to arrive at this response;

> "…If the dye is soluble it will dissolve in water to give a blue, clear solution. However, if the dye is not water soluble it will diffuse through the liquid and either sinks to the bottom, stay in the middle, or stay in the top, depending on its density."

There was no appreciable difference among the grade levels in sound or partial understanding, misconceptions, or no understanding. An analysis of the misconceptions exhibited by the college sample showed that many of the misconceptions could be traced to a misapplication of scientific terminology.

Regardless of the age of the student or the level of schooling, misconceptions of the diffusion concept were prevalent. The responses of the college students appeared to be more sophisticated –included more scientific terminology- than those of the 7th grade and 10th grade students. Although the college students had been exposed to more information, the increased exposure to the concept and vocabulary apparently did not lead to increased understanding. Prior knowledge and chemistry coursework did not enhance the students' abilities to correctly reply to the question.

Odom and Barrow (1993) carried out another study to determine if male and female freshman college biology majors differ in their understanding of diffusion and osmosis concept after adjusting for placement in math upon entering college. The data for this study were obtained from a sample of 117 biology majors enrolled in an introductory biology course. The composition of the sample was 51 male and 66 female students. The major findings were:

- There was no significant difference in scores of male and female students.
- Math placement was a significant variant when assessing understanding using the Diffusion and Osmosis Test
- Major misconceptions were detected in three areas: the particulate and random motion of matter, the process of diffusion and the process of osmosis.

Odom and Barrow (1995) developed and applied a two-tier diagnostic test to measure college biology student's understanding of Diffusion and Osmosis after a course of instruction. Misconception data were collected from interviews and multiple-choice questions with free response answers. The data were used to develop 12 two-tier multiple-choice items in which the first tier examined content knowledge and the second examined understanding of that knowledge. The diagnostic instrument was administered to 240 students (123 non-biology majors and 11 biology majors) enrolled in a college freshman biology laboratory course. The students had completed a unit on diffusion and osmosis. The content taught was carefully defined by propositional knowledge statements, and was the same content that defined the content boundaries of the test. The split-half reliability was 0.74. Difficulty indices ranged from 0.23 to 0.95 and discrimination indices ranged from 0.21 to 0.65. Twenty misconceptions (Table 2.2) were identified through analysis of items on the Diffusion and Osmosis Test. They are grouped under the headings of particulate nature and random motion of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion and the process of osmosis.

Table 2. 2 Specific Misconceptions Detected by the Diffusion and Osmosis Diagnostic Test

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The particulate and random nature of matter

1. Particles move from high to low concentration because
a. They tend to move until the two areas are isotonic and then the particles stop moving
b. There are too many particles crowded into one area, therefore they move to an area with more room.

2. As the difference in concentration increases between two areas, rate of diffusion:
a. increases because the molecules want to spread out.
b. decreases because if the concentration is high enough, the particles will spread less and the rate will be slowed.

3. When a drop of dye is placed in a container of clear water the:
a. dye molecules continue to move around because if dye molecules stopped, they would settle to
the bottom of the container
b. dye molecules continue to move around because this is a liquid; if it were solid the molecules would stop moving

Concentration and tonicity

1. A glucose solution can be made more concentrated by adding more glucose because the more water there is, the more glucose it will take to saturate the solution

2. Side 1 is 10% salt solution and side 2 (15% salt solution).
a. Side I is hypotonic to side 2 because water moves from high to low concentration
b. Side I is hypertonic to side 2 because the water moves from high to low concentration

Influence of life forces on diffusion and osmosis

1. If a plant cell is killed and placed in a salt solution, diffusion and osmosis will not occur because the cell will stop functioning

Process of diffusion

1. The process responsible for a drop of blue dye becoming evenly distributed throughout a container of clear water is:
a. diffusion because the dye separates into small particles and mixes with water.
b. osmosis because there is movement of particles between regions of different concentrations.

2. When sugar is added to water, after a very long period of time the sugar will be more concentrated on the bottom of the container because:
a. There will be more time for settling

Table 2.2 continued

b. The sugar is heavier than water and will sink.
c. Sugar dissolves poorly or not at all in water.

Process of osmosis

1. Two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water; side 2 contains pure water. After 2 hours, the water level in side 1

a. will be higher because water will move from the hypertonic to the hypotonic solution
b. will be higher because water moves from low to high concentrations
c. will be lower because water will move from the hypertonic to hypotonic solutions
d. will be the same because water will became isotonic.

2. If a freshwater plant cell were placed in a beaker of 25% saltwater solution, the central vacuole would decrease in size because salt absorbs the water from the central vacuole.

Odom & Barrow claimed that The Diffusion and Osmosis Test was appeared to provide a feasible approach for evaluating students' understanding and for identifying alternative conceptions of diffusion and osmosis concepts.

Odom and Kelly (2001) investigated the effect of concept mapping and learning cycles in teaching diffusion and osmosis concepts to high school biology students. This study explores the effectiveness of concept mapping, the learning cycle, expository instruction, and a combination of concept mapping / learning cycle in promoting conceptual understanding of diffusion and osmosis. Four high school biology classes were taught diffusion and osmosis concepts with the aforementioned treatments. A total of 108 secondary students enrolled in four different sections of college preparatory biology, formed the sample for the study. Each of four sections randomly assigned to a treatment group. The same teacher taught each of the four classes. Conceptual understanding was assessed immediately and seven weeks after instruction with the Diffusion and Osmosis Diagnostic Test. The independent variable was instructional treatment. Scores on the Logical Reasoning Test were the covariate. After adjustment by the logical reasoning covariate, DODT scores were not statistically significant among treatment groups the day after instruction. The scores were statistically significant seven weeks after instruction. The results reflected a moderate to good association between treatments and adjusted DODT scores seven weeks after instruction. The results also indicated the concept mapping/learning cycle and concept mapping treatment groups significantly outperformed the expository treatment group in conceptual understanding of diffusion and osmosis. No significant difference was found among the learning cycle group and other treatments.

Christianson and Fisher (1999) compared student learning about diffusion and osmosis in constructivist and traditional classrooms. The study is carried out in three non-major biology courses at three different universities. The first two courses follow a traditional pattern of instruction, with lectures given in large lecture halls to all of the students enrolled in the course and laboratory experiences occurring in multiple smaller sections (up to 24 students). The third is an integrated laboratory/discussion class that employs many facets of inquiry teaching and discovery based, constructivist learning. The instrument was the DODT developed by Odom and Barrow. The greatest differences in performance between Lecture course and Lab/Discussion course occurred on three content items involving complex reasoning. Students in the two lecture courses performed less well on the combined content plus reason questions than they did on the content items alone. In contrast, students in Lab/Discussion course demonstrated good understanding of the reasoning on most items. A chi-square analysis comparing student performance in Lecture course and Lab/Discussion course indicates a significant difference between the two courses. These results provide a good indicator of student understanding of diffusion and osmosis because they include the reasoning component. Certain aspects of diffusion and osmosis, e.g. the random motion of molecules, the effect of temperature on molecular motion, and semi-permeability of cell membranes, are clearly easier for students to answer. These are correctly answered by 65-100% of students. More difficult material (correctly answered by 10 - 82 % of students) includes correct use of terminology, and concepts, e.g. concentration, consequences of the continual motion of matter and the physical, non-life requiring nature of diffusion and osmosis. Two apparent failures in student understanding (answered correctly by only 15-36% of students) occurred in item 2 and 3, which deal with the movement of molecules from regions of higher to lower concentration, and the effect of concentration on the rate of this movement.

Recently, Sanger, Brecheisen and Hynek (2001) examined whether viewing computer animations depicting the molecular processes of diffusion and osmosis would affect students' conceptions of these topics. Students' conceptions of diffusion and osmosis topics were measured using the Diffusion and Osmosis Diagnostic Test. This study was performed using 149 students enrolled in a secondary semester introductory college biology course at a small Midwestern University. All of these students attended the same lecture section. Each student was also enrolled in one of six different laboratory sections. This research study was performed in the laboratory sections after the students had received instruction on diffusion and osmosis in the lecture section. The laboratory sections were randomly assigned to either the control or experimental group. Students in the experimental group received instruction using two computer animations to explain molecular behaviors associated with the process of diffusion. Both groups performed several experiment including the diffusion of potassium permanganate in water, the osmosis of water and glucose (but not starch) through cellulose dialysis tubing, and the effect on the cells of an Elodea leaf after being placed in hypotonic, isotonic and hypertonic solutions. The major difference between the two groups is that the experimental group viewed two animations before performing these experiments while the control group did not. The first animation depicted the molecular processes occurring when perfume particles diffuse through the air. The second animation starts with a drawing of a thistle tube experiment that the students had seen and discussed in lecture. It starts with a thistle tube covered by a semi permeable membrane and filled with syrup that has been placed in a beaker of water. After performing the laboratory experiments, both sets of students were asked to respond to the DODT. To determine the effects of viewing computer animations, responses to the questions on the DODT were compared from students who viewed the animations and from those who did not. In the results, the most striking difference is that students who viewed animations were less likely to choose responses suggesting that particle motion stops after equilibrium is reached (misconception). While 8 % of the students in the control group believed that dye and water molecules stop moving once they are mixed because otherwise the container would be different shades of blue, none of the students who viewed the animation chose this response. Similarly, more students in the control group believed that particles move until they are isotonic and then stop moving than in the experimental group (36% versus 19%). In general, it appears that these animations were successful in helping students understand the dynamic nature of equilibrium processes, which is a common and persistent misconception exhibited by students in chemistry classes as well. Although the students who viewed the animations were less likely to believe that the particles stop moving once they reach equilibrium, they were more likely to exhibit a misconception about why these particles do not stop moving. While only 3% of the students in the control group believed that dye and water molecules keep moving once they are mixed because otherwise they would settle to the bottom of the container, 14% of the students in the experimental group chose this response. It appears that although the animations convinced students that the particles do not stop moving once they reach equilibrium, it was not completely effective at convincing them why they don't stop moving (random motion). On the other hand, students who viewed the animations were less likely to attribute molecular motions to anthropomorphic "desires" of the molecules. More students in the control group believed that as the difference in concentration increases between two areas, the rate of diffusion increases because the molecules want to spread out than in the experimental group (47% versus 32%). Although the animations had a positive effect on students' conceptions about the particulate nature and random motion of matter, the animation appeared to convince students that sugar does not dissolve in water. While only 3% of the students in the control group believed that sugar does not dissolve well in water, 11 % of the students who viewed the animations chose this response. Discussions with students revealed that they interpreted the brown circles surrounded with water molecules in the second animation as suggesting that the sugar and water particles did not completely mix with each other and that these sugar particles did not dissolve in water. This difficulty stems from students trying to apply rules that work at the macroscopic level, like "if you can see the particles, the compound has not dissolved in water," to pictures at the molecular level.

More recently, Panizzon (2003) investigated students' understandings of diffusion through the application of a cognitive structural perspective provided by the Structure of the Observed Learning Outcome (SOLO) model devised by Biggs and Collis. In his study, 60 senior secondary school and 120 first-year university science students were presented with two extended response questions regarding diffusion. Four months after the completion of the questionnaires, 30 students were interviewed. The responses obtained from the students were interpreted using the Structure of the Observed Learning Outcome model. In terms of an overall perspective from the questionnaires, the largest majority of students (76 % for Q1 and 79 % for Q2) responded within the concrete symbolic mode. A smaller number of students (8% for Q1 and 5% for Q2) responded within the formal mode. The results from the study provided strong evidence of a pathway of conceptual understanding of diffusion from simple intuitive ideas about movement to highly abstract views in which students explained the random motion of molecules in terms of kinetic theory. These results were consistent for both the high school and university students. In addition, the pathway provided a means of interpreting previous research results and practical ways of improving instruction in the future.

As a summary, the Diffusion and Osmosis Diagnostic Test appears to provide a feasible approach for evaluating students' understanding and for identifying alternative conceptions of diffusion and osmosis concepts. It is obvious that there are many misconceptions in diffusion and osmosis in the literature. Generally students trying to apply rules that work at the macroscopic level, like "if you can see the particles, the compound has not dissolved in water," to pictures at the molecular level. There was no significant difference in scores of male and female students in conceptual understanding of diffusion and osmosis. The results also indicated the concept mapping/learning cycle and concept mapping treatment groups significantly outperformed the expository treatment group in conceptual understanding of diffusion and osmosis.

2.3. Research Related with Reasoning Ability and Achievement in Biology

Piaget's theory, about the concepts of formal reasoning ability and formal thought, has been tested extensively. The majority of the studies tested the ability of students to practice formal thought, the best methods to develop and utilize it, and defined how it is linked to success in the science classroom (Lawson, 1978; Lawson 1982; Lawson, 2000; Valanides, 1996; Gerber, Cavallo and Marek, 1997).

Lawson (1982) studied the intercorrelations among three measures of formal reasoning measures of achievement in four academic areas for a sample of 72 ninth-grade students selected from English classes of a high school in an upper –middle class community in the San Francisco Bay area. The formal reasoning measures were the Lawson Classroom Test of Formal Reasoning and two clinical interview tasks, the bending rods and the balance beam. Achievement in reading, language arts, mathematics, social studies, and science was measured by the Iowa Tests of Educational Development. The coefficients among the formal reasoning measures and achievement in the various areas are all substantial (r=0.42 to 0.72) and generally similar for all areas of achievement. That is they are not substantially higher for science and mathematics than for say social studies. If the measures of formal reasoning are essentially science and mathematics tasks (as some person believes) then the measures should correlate more highly with science and mathematics achievement than with achievement in the non-science areas. The fact that the classroom test correlated as well as with social studies achievement (r= 0.72) as with science or mathematics achievement (r= 0.69 and 0.70 respectively) demonstrates clearly that this is not the case. This is an important result because it demonstrates that formal reasoning is related to general achievement and not achievement in science and mathematics alone. This relation to general achievement would seem to be imperative if efforts to increase formal reasoning are to improve general achievement. Improvements in formal reasoning will cause improvements in general achievement. It should be noted that, although the descriptive data reported suggest a correlational relationship between formal reasoning and general achievement, they do not imply a causal relationship.

Lawson and Thompson (1988) carried out a study to test the following hypothesis: “Following instruction, formal operational students would hold significantly fewer misconceptions than their concrete operational classmates.” The sample is consisted of 131 seventh grade students. They were administered an essay test on principles of genetics and natural selection following instruction. Responses were categorized in terms of the number of misconceptions present. The number of misconceptions were compared to reasoning ability (concrete, transitional, formal), mental capacity, verbal intelligence (low, medium, high), and cognitive style (field dependent, intermediate, field independent). The only student variable consistently and significantly related to the number of misconception was reasoning ability; thus, support for the hypothesis of the study was obtained.

Mwamwenda (1993) examined the relationship between cognitive development, particularly on formal operations, and academic achievement among Canadian university students. The results showed a statistically significant relationship between cognitive development and academic achievement; students who had fully attained formal operations performed better than those who had not.

Besides, the study done by BouJaoude (1994) showed that prior knowledge, TOLT scores, and meaning orientation accounted for 32% of the variance on the final examination scores. In the study, the students' grades on an hour-long exam early in the semester were used as measures of the students' prior knowledge, while the semester cumulative final examination scores were used as measures of achievement in chemistry.

Valanides (1996) evaluated school children’s performance on the test of Logical Thinking (TOLT) to identify differences related to five reasoning modes among three grade school classes and between male and female students. Performance of 195 7th, 8th and 9th grade students on TOLT was used in this study. TOLT scores revealed substantial deficiencies in the development of student reasoning abilities, and only 9th grade students had significantly better performance than 7th grade students which was related to proportional reasoning problems. There were no significant differences between male and female students.

Cavallo (1996) performed a study to explore relationships among school students' (N = 189) meaningful learning orientation, reasoning ability and acquisition of meaningful understandings of genetics topics, and ability to solve genetics problems. This research first obtained measures of students' meaningful learning orientation (meaningful and rote) and reasoning ability (preformal and formal). Students were tested before and after laboratory-based learning cycle genetics instruction using a multiple choice assessment format and an open-ended assessment format (mental model). The assessment instruments were designed to measure students' interrelated understandings of genetics and their ability to solve and interpret problems using Punnett square diagrams. Regression analyses were conducted to examine the predictive influence of meaningful learning orientation, reasoning ability, and the interaction of these variables on students' performance on the different tests. Meaningful-learning-orientation best predicted students' understanding of genetic interrelationships, whereas reasoning ability best predicted their achievement in solving genetic problems. The interaction of meaningful learning orientation and reasoning ability did not significantly predict students' genetics understanding or problem solving. Meaningful learning orientation best predicted students' performance on all except one of the open-ended test questions. This research provides information for educators on students' acquisition of meaningful understandings of genetics.

Gerber, Marek & Cavallo (1997) investigated a study to find the relationships among informal learning environments, teaching procedures and scientific reasoning ability. This study of middle school and high school students (N ＝ 505) used the independent variables of informal learning environment (impoverished or enriched) and science classroom teaching procedure (non-inquiry and inquiry) to explore possible differences in the dependent variable of scientific reasoning ability. The results of two-way ANOVAs indicated that informal learning environments and classroom teaching procedures produced significant main effects on scientific reasoning abilities. Interactions revealed a tendency for scientific reasoning abilities to increase with enriched informal learning environments and inquiry teaching procedures. The results indicated unique relationship patterns in informal learning environments and teaching procedures among students within the different grade levels.

Valanides (1997) carried out a study about the cognitive abilities of 12th grade students. The study investigated the differences related to formal reasoning abilities among students attending different sections of the upper cycle of secondary schools in Cyprus. The subjects of the study were twelfth-grade students from 21 intact classes (227 boys and 242 girls). These classes were randomly selected among the 36 twelfth grade classes of four schools in a town of Cyprus. The sample of students represented the science section, the economic section and the unified section consisting of sections following common curricula in science and mathematics. Students' performance on a standardized test of Logical Thinking (TOLT) was used as a measure of their cognitive abilities. The students of the unified section had lower performance than the students of both the science and economic section on all cognitive measures, and female students had lower performance than male students on cognitive measures related to control of variables and probabilistic reasoning. Multiple regression analysis between performance on TOLT and gender, section of study, and measures of school achievement showed that gender, section of study, achievement in mathematics, and grade point average, but not achievement in science and Greek language, contributed significantly to predicting performance on TOLT. Observed differences related to measures of school achievement either among the subjects of the three sections or between male and female students did not correspond to differences related to cognitive measures. Factor analysis of performance on the ten TOLT items produced a two factor solution. There were also significant differences in students' performance between items related to same or different reasoning mode. The results of the study cast doubt on the appropriateness of the existing curricula or their implementation and indicate that different theoretical perspectives should be considered when evaluating cognitive development.

Johnson and Lawson (1998) explored the effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes. Subjects were 366 students enrolled in a non-majors biology course were pretested to determine reasoning ability and prior knowledge. The number of previous biology courses was also recorded as an indicator of prior knowledge. After a semester of either expository or inquiry (learning cycle) instruction, students took a comprehensive final examination. Reasoning ability but not prior knowledge or number of previous biology courses accounted for a significant amount of variance in final examination score in both instructional methods and with semester examination and quiz scores in inquiry classes. This suggest that reasoning ability limits achievement more than prior knowledge among these biology students, whether they are enrolled in expository or inquiry classes. Reasoning ability explained more of the variance in final examination scores for students enrolled in expository classes (18.8%) than in inquiry classes (7.2%). The reason for this is not clear, but significant improvements in reasoning were found in the inquiry but not in the expository classes. These improvements were accompanied by significant differences in achievement in the inquiry classes. Perhaps the reasoning improvement facilitated the better and more equal achievement for students in the inquiry classes, thus reducing the correlation between initial reasoning ability and final achievement.

Lawson, Alkhoury, Benford, Clark, and Falconer (2000) carried out a study related to concept construction and intellectual development in biology. Subjects were 663 undergraduate students enrolled in a course “The Living World” taught at a major Southwestern University during the fall semester of 1999. Because concept construction presumably depends in part on developmental level, students at different developmental levels were predicted to vary in the extent to which they succeeded on the concepts test. As predicted, a significant relationship ($p<0.001$) was found between conceptual knowledge and developmental level. This result provides additional support for the hypothesis that procedural knowledge skills associated with levels of intellectual development play an important role in declarative knowledge acquisition and in concept construction. The result also supports the hypothesis that intellectual development continues beyond the “formal” stage during the college years, at least for some students.

In a recent study, Sungur and Tekkaya (2003) investigated the effect of reasoning ability and gender on the human circulatory system concepts achievement and attitude toward biology. A total of 47 tenth grade students participated in the study. Group assessment of logical thinking (GALT), Attitude toward biology scale, and the human circulatory system concepts tests were administered to determine students’ reasoning ability, attitude toward biology, and achievement, respectively. Two–way multivariate analysis of variance (MANOVA) was used to analyze the data. The results revealed that although there was no statistically significant mean difference between boys and girls with respect to achievement and attitude toward biology, there was statistically significant mean difference between concrete and formal students with respect to achievement and attitude toward biology.

In another recent study, Kablan (2004) investigated whether there is a relationship between reasoning ability, gender, perceived difficulty and importance. Students’ reasoning ability was assessed by using Group Test of Logical Thinking (GALT). While a statistically significant negative correlation was found between reasoning ability and perceived difficulty ($r = -.115$, $p<.05$), no statistically significant relationship between gender and perceived difficulty was found. In other words, students having low reasoning ability perceive the topics in biology as difficult. Regarding students’ cognitive stages, findings of this study indicated that majority of high school students are not formal reasoners. Results of the study also showed that reasoning ability and importance level each made a statistically significant contribution to the variation in students' perceived difficulty.

Over the years, researchers in science education gave special interest to gender because of its assumed relationship with a variety of variables such as achievement and attitude (Adamson, Foster and Reed, 1998; Dimitrov, 1999; Jones and Howe, 2000; Soyibo, 1999). Differences in science achievement between males and females are non-existent until adolescence. The gender gap in science achievement tends to widen and favor males as students get older. The cause for the differences in science achievement among males and females is complex due to the array of possible genetic, environmental, and social factors. Concerning gender differences in the achievement of life sciences, some indicated no significant difference between boys and girls (Dimitrov, 1999), while others reported significant gender differences (Okeke and Ochuba, 1986; Soyibo, 1999; Young and Fraser, 1994). The study carried out by Dimitrov (1999) revealed that there was no significant difference between girls and boys with respect to achievement in life sciences. Moreover, Okeke and Ochuba (1986) reported no significant difference between boys and girls with respect to achievement in biology tests. On the other hand, Soyibo (1999) showed that girls significantly performed better on a test of errors in biological labeling. Furthermore, Erickson and Erickson (1984) indicated gender related differences in biology favoring male students. However, generally, in many of such studies the differences found to be statistically significant are not markedly large. The study carried out by Weinburgh and Englehar (1994) supported this idea suggesting that students' attitudes differ among science disciplines. They found that although the effect was small, girls appeared to have more positive attitude toward biology than did boys. Moreover, Jones (2000) reported that while more boys wanted to learn about planes, cars, computers, light, electricity, and new sources of energy, more girls wanted to learn about rainbows, healthy eating, and animal communication. In addition, the study conducted by Adamson (1998) revealed that boys are more likely to work on the projects in physical sciences and girls are more likely to work on the projects in life sciences. These findings, in general, suggested that boys show a more positive attitude toward physical sciences whereas girls show a more positive attitude toward life sciences.

To sum up, what factor (s) influence the likelihood a student will succeed in college biology is controversy. Some researchers have found the primary determinant to be the student's prior knowledge of biology, while others have found it to be reasoning ability. Additionally, influence of gender in predicting achievement was marked as important.

CHAPTER 3

METHOD

In the previous chapters, purpose, problems and hypothesis of the study was presented, the significance of the study was underlined and related literature was reviewed.

This chapter is composed of seven parts. In the first part, population and sampling procedure, in the second part instruments of the study will be explained. The following part includes variables and the fourth part includes procedure. In the fifth part, methods used to analyze data will be mentioned. At the end of the chapter, assumptions and limitations will be explained briefly.

3.1. Population and Sample

All 9th grade private high school students in Turkey were identified as the target population of this study. However, it is appropriate to define an accessible population since it is not easy to come into contact with this target population. The accessible population was determined as all 9th grade private school students in Ankara. This is the population which results of this study will be generalized. A sample of 397 students participated in the study. The sample consisted of 193 female and 204 male students. The students were enrolled in a course specifically designed to meet the general biology education science requirements for all 9th grade students. The students were taught by different high school biology teachers who have at least 4 years of experience.

3.2. Instruments

Data was collected by two means. These were the Diffusion and Osmosis Diagnostic Test (DODT) and the Test of Logical Thinking (TOLT).

3.2.1. Diffusion and Osmosis Diagnostic Test

Students' conceptual understanding of Diffusion and Osmosis was measured by the Diffusion and Osmosis Diagnostic Test, which has previously been determined to be a good indicator of student understanding of diffusion and osmosis (Christianson & Fisher, 1999; Odom & Barrow, 1995). The Diffusion and Osmosis Diagnostic Test was developed by Odom & Barrow in 1995. It is a 12 item test. Items for the diagnostic instrument are based on the two-tier, multiple-choice format. The first tier consists of a content question with two, three or four choices. The second tier consists of four possible reasons for the first part: three alternative reasons and one desired reason. The alternative reasons were based on misconceptions previously detected during a multiple-choice test with free response reason and interview sessions.

Content boundaries of the DODT were defined by a list of 22 propositional knowledge statements (figure 3.1).

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1. All particles are in constant motion.
2. Diffusion involves the movement of particles.
3. Diffusion results from the random motion and/or collisions of particles (ions or molecules).
4. Diffusion is the net movement of particles as a result of a concentration gradient.
5. Concentration is the number of particles per unit volume.
6. Concentration gradient is a difference in concentration of a substance across a space.
7. Diffusion is the net movement of particles from an area of high concentration to an area of low concentration.
8. Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved.
9. Diffusion rate increases as temperature increases.
10. Temperature increases motion and/or particle collisions.

11. Diffusion rate increases as the concentration gradient increases.
12. Increased concentration increases particle collisions.
13. Diffusion occurs in living and nonliving systems.
14. Osmosis is the diffusion of water across a semi permeable membrane.
15. Tonicity refers to the relative concentration of particles on either side of a semi permeable membrane.
16. A hypotonic solution has fewer dissolved particles relative to the other side of the membrane.
17. A hypertonic solution has more dissolved particles relative to the other side of the membrane.
18. An isotonic solution has an equal number of dissolved particles on both sides of the membrane.
19. Osmosis is the net movement of water (solvent) across a semi permeable membrane from a hypotonic solution to a hypertonic solution.
20. Osmosis occurs in living and nonliving systems.
21. A semi permeable membrane is a membrane that selectively allows the movement of some substances across the membrane while blocking the movement of others.
22. Cell membranes are semi permeable.

Figure 3.1 Propositional knowledge statements, determined by Odom & Barrrow, required for understanding diffusion and osmosis.

The conceptual areas covered by the test are: the particulate and random nature of matter, concentration and tonicity, the influences of life forces on diffusion and osmosis, the kinetic energy of matter, the process of diffusion, and the process of osmosis. An item was scored as correct on the DODT if both the desired content and reason answer were selected. Since 1 point can be obtained for each item, a total test score of 12 is possible. Items were evaluated for both correct and incorrect response combinations selected by the students. Table 3.1 shows a sample question from DODT that tests understanding of the particulate and random nature of matter.

Table 3.1 The percentage of 9th grade students selecting each response combination for item 3 on the Diffusion and Osmosis Diagnostic Test (DODT).

As the difference in concentration between two areas increases, the rate of diffusion:

(a) Decreases

(b) Increases

Reason

(a) There is less room for the particles to move.

(b) If the concentration is high enough, the particles will spread less and the rate will be slowed.

(c) The molecules want to spread out.

(d) The greater likelihood of random motion into other regions.

	Reason				
Choice on first tier	a	b	c	d	Total
a	5.8	12.3	3.8	3.5	25.4
b	9.3	8.6	28.5	28.2*	74.6

*Correct choice and reason

The desired content answer was selected by 75 % of the students, while only 28% selected the desired content answer and reason combination.

3.2.2. The Test of Logical Thinking

Students' reasoning abilities were measured by the Test of Logical Thinking developed by Tobin & Capie in 1981. The test has 10 items measuring five reasoning modes. The first two items measure proportional reasoning, the second two measure controlling variables, the third two measure probabilistic reasoning, the fourth two measure correlational reasoning and the last two combinatorial reasoning. In items 1-8 a subject needs to have both the answer and the reason correct to be awarded 1. For the combinatorial logic items, students must actually list all the possible combinations of several variables. Since 1 point can be obtained for each item, a total test score of 10 is possible. This test was translated and adapted into Turkish by Geban, Aşkar, and Özkan in 1992 (appendix A). Its reliability was found as .81.

Students' performance on the TOLT was used as a measure of formal reasoning abilities and as a means to categorize the subjects into stages of cognitive development based on Piagetian criteria and the proposals of the authors of TOLT. So test scores from 0-3, 4-7, and 8-10 were used as a basis for classifying the subjects as low, medium and high formal thought, respectively (Oliva, 2003).

3.3. Variables of the Study

This current study included 4 variables. Three of them were independent variables (IVs) and one of them was dependent variable (DV). One of the independent variables was determined as covariate. Characteristics of the variables have been shown in Table 3.2.

Table 3.2 Characteristics of the Variables

Type of Variable	Name	Type of Value	Type of Scale
DV	DODT	Continuous	Interval
IV	Prior knowledge	Continuous	Interval
IV	TOLT	Continuous	Interval
IV	Gender	Discrete	Nominal

3.3.1 Dependent Variables

In this study, the dependent variable was students' diffusion and osmosis concepts test scores (DODT). It was measured by the Diffusion and Osmosis Diagnostic Test.

3.3.2 Independent Variables

In this study, there were three independent variables: students' test of logical thinking scores (TOLT), students' biology grades of first semester, and gender. TOLT, and Prior knowledge were considered as continuous variables and they were measured on interval scale. Gender was considered as discrete variables and it was measured on nominal scale.

3.4. Procedure

No previous data was collected about students' understandings of diffusion and osmosis to cut down on potential test boredom, redundancy, and test learnedness. The researcher wanted to reduce the chance of students learning test items that could be recalled during instruction. He also wanted to reduce the chance of the teacher seeing the test and potentially teaching to specific items on the test. DODT was administered to students in a 45-minute class hour period after the completion of the unit on diffusion and osmosis at the second semester. The translated TOLT was administered to each of the selected classes. A 45-minute class hour period was allowed for students to answer TOLT problems. The problems were presented to the students in the same order. The proportional reasoning items were presented first and were followed by control of variables, probabilistic, correlational, and combinatorial reasoning items. At the beginning of the test the students were informed that the test consisted of problems involving strategies which are useful in a variety of everyday problems. The purpose of the test was to provide information about to measure formal reasoning abilities.

Students' first semester biology grades were taken from the school records at the end of first semester. They were used as a basis of students' prior knowledge in biology.

3.5. Data Analysis

The mean, median, mode and standard deviation of the variables were presented as descriptive statistics. A descriptions and frequencies of misconceptions are also presented in descriptive statistics.

For inferential statistics, Pearson correlation analysis, multiple regression correlation (MRC) analysis and stepwise multiple regression analysis were calculated. Total TOLT scores were used as a measure of reasoning ability. Students' grades in biology in previous semester were used as students' prior knowledge. Dependent variable was the achievement score measured by two-tier Diffusion and Osmosis Diagnostic Test (DODT). To see the relationship that might exist among students' reasoning ability, prior knowledge and achievement, Pearson correlation analysis was computed. Multiple Regression Correlation (MRC) analysis was used to explore contributions of students' reasoning ability, prior knowledge and gender to the understanding of the diffusion and osmosis concepts. A stepwise multiple regression analysis was applied to the data to determine the variables which were best predicting students' achievement on the DODT. Predictor variables were reasoning ability, prior knowledge, and gender.

3.6. Assumptions of the Study

At the beginning of the study, the researcher made the following assumptions:

- The administration of the instruments was under standard conditions.
- The sample is the good representative of the population
- The instructors demonstrated closely related teaching styles, interest, abilities, and conceptual understanding of the subject matter.
- Students responded honestly and thoughtfully to the selected instruments.

- One lesson period (45 minutes) was assumed to be enough for the completion of the each instrument.

- Learner characteristics (e.g., health, socio-economic status, demographic variables) did not affect performance of students during application of instruments.

3.7. Limitations of the Study

- The study is limited to 397 ninth grade students in a private school in Ankara

- The study was restricted to the key biological concepts (diffusion and osmosis)

CHAPTER 4

RESULTS

In this chapter, the results of the study were presented in four sections. In section one, the results of the descriptive statistics related to the students' understanding of Diffusion and Osmosis measured by Diffusion and Osmosis Diagnostic Test (DODT) and Test of Logical Thinking (TOLT) are given. In section two, student's understanding of diffusion and osmosis are explained and the misconceptions obtained in this study are presented. In section three, the results related to the inferential statistics of testing 4 null hypotheses are shown. A brief summary of the findings of the study are given in section four.

4.1. Descriptive Statistics

Descriptive statistics related to the students' diffusion and osmosis concepts test scores, test of logical thinking and their prior knowledge were shown in Table 4.1. This table provides the number, minimum & maximum range, standard deviation, mode and mean scores of each variable.

Table 4.1 Basic Descriptive Statistics Related To Diffusion and Osmosis Diagnostic Test , the Test of Logical Thinking , and Prior Knowledge

	N	Mean	Std.Dev	Possible Range	Actual range	Mode
DODT	397	4.71	2.48	0-12	0-12	4
TOLT	397	6.66	2.28	0-10	0-10	8
Prior Knowledge	397	3.73	1.17	0-5	1-5	5

Students' scores in Diffusion and Osmosis Test range from 0 to 12. The higher scores mean the greater achievement in diffusion and osmosis (Table 4.1). The relatively low mean score of 4.71 indicates students’ low level understanding of diffusion and osmosis. Most students understand 4 items out of 12 in the study.

Students' test of Logical Thinking scores range from 0 to 10. Higher scores represent higher formal thought. As shown in Table 4.1, the mean of TOLT is 6.66 which indicate relatively high reasoning ability. The mode of the TOLT score is 8. That is the fact that most students in the study make 8 items correctly out of ten items. As can be seen from the histograms in Figure 4.1, the distribution of DODT score is similar to the normal distribution. However, the distribution of TOLT score is rightly skewed, which means that more than half of the students in the study have medium or high reasoning abilities.

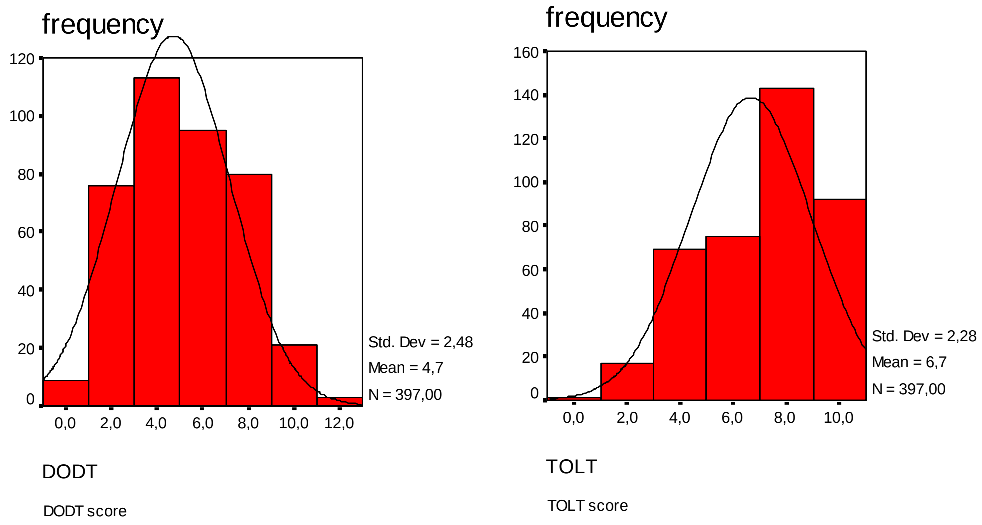

Figure 4.1 Histograms Related to DODT & TOLT scores

Prior knowledge, which was the first semester biology grades, has a range of scores from 1 to 5. The higher score implies high achievement in the biology exams during the semester. In Table 4.1, the mean of the prior knowledge 3.73 indicates moderate level of prior knowledge. The grade 5 is observed most frequently among students.

4.1.1 Descriptive Statistics Concerning DODT

In this part, descriptive statistics for DODT were given. According to Gilbert (1977), if a multiple-choice item has four to five distracters, understanding is considered satisfactory if more than 75% of the students answer the item correctly. The DODT results suggest that students did not acquire a satisfactory understanding of diffusion and osmosis concepts. Students scored 75.1 % on 1 out of 12 items, the item 7 measures the kinetic energy of matter. For the present study, the range of correct answers for the first tier of the test was 41 % to 91% for 9th grade students. When both tiers were combined, the correct responses were reduced to a range of 21% to 61 % (Table 4.2).

Table 4.2 Percentages of 9th grade students selecting the desired content choice and combination content choice and reason on DODT

Items	Content choice (%)	Combination (%)
1	55.4	39.0
2	91.2	30.7
3	74.6	28.0
4	79.9	48.4
5	43.1	27.5
6	66.8	30.0
7	84.4	75.1
8	54.7	20.9
9	57.7	39.0
10	62.5	38.8
11	41.1	32.7
12	82.4	61.2

Table 4.2 reveals that students had enough content knowledge but they did not know the reason behind their selections. Item related to particulate nature and random motion of water, 91 % of the students selected the desired choice but only 31% of the students selected the correct reason. Item 11 assessing students' understanding on influence of life forces on diffusion and osmosis appears to be a difficult item. Only 41% percent selected the correct content choice. In this item a plant cell was killed and placed in 25% saltwater; then the question asked whether diffusion and osmosis would continue. The desired response combination was that "diffusion and osmosis would continue" because "the cell does not have to be alive" (32.7%). Item measuring the process of osmosis appears to be most difficult because only 21% percent selected the correct combination choice.

Distribution of total DODT scores with respect to gender is demonstrated in Table 4.3. Mean scores of females (5.03) is greater than mean scores of males (4.41) in Diffusion and Osmosis Diagnostic Test. Girls seems to be more successful in conceptual understanding of diffusion and osmosis.

Table 4.3 Performance on total DODT with respect to Gender

Total DODT Score	Performance (%)	Gender (%)	
		F	M
0	2.2	2.0	3.4
1	6.8	7.0	6.6
2	12.3	9.6	15.0
3	12.0	10.0	14.0
4	16.4	14.2	18.6
5	14.9	16.2	13.6
6	9.0	9.0	9.0
7	11.3	12.6	10.0
8	8.8	10.6	7.0
9	2.2	2.4	2.0
10	3.2	4.0	2.4
11	0.3	0.6	0.0
12	0.5	0.0	1.0

4.1.2 Descriptive Statistics Concerning Reasoning Ability

Students' performance on the TOLT was used both as a measure of formal reasoning abilities and as a means to categorize the subjects into stages of cognitive development based on Piagetian criteria and the proposals of the authors of TOLT. In items 1-8 a subject needs to have both the answer and the reason correct to be awarded 1. For the combinatorial logic items, students must actually list all the possible combinations of several variables. Since 1 mark can be obtained for each item, a total test score of 10 is possible. Test scores between 0-3, 4-7, and 8-10 were used as a basis for classifying the subjects as low level, medium level and high level formal thought, respectively.

Analysis of each TOLT items was given in table 4.4. Item 9 which control combinatorial reasoning of students is the one which was scored over 75%. However, item 2 controlling proportional reasoning is solved by less than half of the students (43 %). Another interesting finding of the study was that female did well in item 3, 4, 9 and 10 which were the control of variables and combinatorial. In contrast, male did well in items 1, 2, 5, 6, 7 and 8 that were related with proportional, probabilistic and correlational mode of the reasoning ability.

Table 4.4 Performance on each TOLT items with respect to Gender

Reasoning mode	**Item number**	**Gender (%)**		**Total (%)**
		Male	**Female**	
Proportional	1	74.5	71.5	73.0
Proportional	2	44.6	42.0	43.3
Control variables	3	66.7	77.8	72.5
Control variables	4	68.6	80.3	74.3
Probabilistic	5	66.2	59.1	62.7
Probabilistic	6	63.7	57.0	60.5
Correlational	7	59.3	58.0	58.7
Correlational	8	64.2	62.2	63.2
Combinatorial	9	86.8	89.1	87.9
Combinatorial	10	67.6	71.5	69.5

Table 4.5 shows the total distribution of TOLT scores among the students. Total score 8 is the mode that is most students (18.9%) in the study solved 8 items out of ten. Total score 7 follows the mode. However, only 1 student (0.3 %) didn’t solve any item.

Table 4.5 Distribution of scores on TOLT

Score	Frequency	Percentage
0	1	0.3
1	8	2.0
2	9	2.3
3	20	5.0
4	49	12.3
5	27	6.8
6	48	12.1
7	68	17.1
8	75	18.9
9	56	14.1
10	36	9.1
Total	**397**	**100.0**

Table 4.6 shows the levels of formal reasoning thought with respect to gender and total sample. This table indicates 9.6 % of the students have low formal reasoning thought, 48.4 % of the students have medium formal reasoning thought and 42.1 % of the students have high formal reasoning thought. These mean that most of the students in the study were medium formal reasoning thought. In relation to gender, percentages of female students in medium and high formal reasoning thought are nearly same. Concerning gender difference, above half of the male students were medium formal reasoning thought (51.5 %). However, percentage of high formal females was greater than that of males.

Table 4.6 Descriptive statistics for total sample, the gender and reasoning ability with respect to thought of formal reasoning

Gender	**Formal Reasoning Thought**		
	Low (0-3)	**Medium (4-7)**	**High (8-10)**
Male (%)	9.3	51.5	39.2
Female (%)	9.8	45.1	45.1
Total	9.6	48.4	42.1

Descriptive statistics for the gender and reasoning ability with respect to achievement in DODT is summarized in Table 4.7. This table indicated that both males and females at the high formal reasoning thought outperformed on the diffusion and osmosis diagnostic test compared to the students at low and medium formal reasoning thought. As can be concluded from the table, the achievement of the students at the high formal reasoning thought was the highest; achievement of the students at the low formal reasoning thought was the lowest for both males and females. Mean achievement scores of females are higher than males in all formal reasoning thought.

Table 4.7 Descriptive statistics for the gender and reasoning ability with respect to DODT achievement

	Low (0-3)		**Medium (4-7)**		**High (8-10)**		**Total**	
Achievement	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
<u>Gender</u>								
Male	2.42	2.04	3.89	1.85	5.58	2.70	4.41	2.45
Female	3.16	1.98	4.26	2.12	6.21	2.36	5.03	2.47
Total	2.79	2.02	4.06	1.98	5.90	2.54	4.71	2.48

To find out whether high formal reasoning thought students have similar conceptual understanding to the medium or low formal reasoning thought students, students correct responses for each DODT items are tabulated with respect to their formal reasoning thought in table 4.8. Table shows the percentages of students giving correct responses for each DODT item with respect to their formal reasoning thought. Table reveals that increase in formal reasoning thought results in increase in conceptual understanding of diffusion and osmosis. High level students outperformed both low and medium thought students in all items. One can easily conclude that increase in formal reasoning thought increases DODT achievement.

Table 4.8 Performance on each DODT items with respect to formal reasoning thought

DODT item	Low (0-3)	Medium (4-7)	High (8-10)
1	15.8	34.4	50.9
2	28.6	31.6	32.9
3	7.9	17.2	45.5
4	21.1	46.4	56.9
5	21.1	22.9	31.1
6	26.6	36.8	33.5
7	55.3	70.3	84.4
8	17.7	21.1	24.6
9	15.8	30.7	54.5
10	15.8	30.7	53.3
11	5.3	24.5	49.1
12	28.9	56.8	74.3
Total	23.0	32.8	44.2

4.2. Students' Conceptual Understanding of Diffusion and Osmosis

Twenty-five misconceptions (Table 4.9) were identified through the analysis of items in Diffusion and Osmosis Diagnostic Test. They are grouped under the headings of the particulate nature and random motion of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion, the process of osmosis and membrane.

Table 4.9 Percentages of Responses by 9th Grade Students with Misconceptions Detected by the Diffusion and Osmosis Diagnostic Test

Misconceptions	Students Responses (%)	Item
The particulate and random nature of matter		
1. Particles move from high to low concentration because		
a. They tend to move until the two areas are isotonic and then the particles stop moving	31.2	2
b. There are too many particles crowded into one area, therefore they move to an area with more room.	26.7	2
2. As the difference in concentration increases between two areas, rate of diffusion:		
a. increases because the molecules want to spread out.	28.5	3
b. decreases because if the concentration is high enough, the particles will spread less and the rate will be slowed.	12.3	3
3. When a drop of dye is placed in a container of clear water the:		
a. dye molecules continue to move around because if dye molecules stopped, they would settle to the bottom of the container	17.1	6
b. dye molecules continue to move around because this is a liquid; if it were solid the molecules would stop moving	11.3	6
c. dye molecules have stop moving because if they were still moving, the container would be different shades of blue	20.9	6
Concentration and tonicity		
1. A glucose solution can be made more concentrated by adding more glucose because		
a. the more water there is, the more glucose it will take to saturate the solution	9.8	4
b. concentration means the dissolving of something.	17.4	4
2.Side 1 is 10% salt solution and side 2 (15% salt solution).		
a. Side I is hypotonic to side 2 because water moves from high to low concentration	13.9	9

Table 4.9. continued

Misconceptions	Students Responses (%)	Item
b. Side I is hypertonic to side 2 because the water moves from high to low concentration	9.1	9
c. Side I is hypertonic to side 2 because there are fewer dissolved particles on side 1	12.1	9
Influence of life forces on diffusion and osmosis		
1. If a plant cell is killed and placed in a salt solution, diffusion and osmosis will not occur because the cell will stop functioning	20.9	11
Process of diffusion		
1. The process responsible for a drop of blue dye becoming evenly distributed throughout a container of clear water is:		
a. diffusion because the dye separates into small particles and mixes with water	10.3	1
b. osmosis because there is movement of particles between regions of different concentrations.	6.8	1
c. a reaction between water and dye because the dye separates into small particles and mixes with water	19.1	1
2. When sugar is added to water, after a very long period of time the sugar will be more concentrated on the bottom of the container because:		
a. There will be more time for settling	5.8	5
b. The sugar is heavier than water and will sink.	22.9	5
c. Sugar dissolves poorly or not at all in water.	21.2	5
Process of osmosis		
1. Two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water; side 2 contains pure water. After 2 hours, the water level in side 1		
a. will be higher because water will move from the hypertonic to the hypotonic solution	17.6	8
b. will be higher because water moves from low to high concentrations	11.1	8
c. will be lower because water will move from the hypertonic to hypotonic solutions	10.8	8
d. will be the same because water will became isotonic.	8.6	8
2. If a freshwater plant cell were placed in a beaker of 25% saltwater Solution the central vacuole would decrease in size because salt absorbs the water from the central vacuole.	13.4	10

Table 4.9. continued

Misconceptions	Students Responses (%)	Item
Membrane		
1. All membranes are semi permeable because they allow some substance to enter, but they prevent any substance from leaving	13.9	12

4.2.1 Particulate Nature and Random Motion of Matter

Students are not able to comprehend that diffusion is a result of the random interaction of particles as measured by items 2, 3, and 6. For example, only about 30 % of the students selected the desired answer combination in item 2, which is related to the process of diffusion. In this item, the direction of movement of particles during the process of diffusion is asked. The most common response for this item may have been the result of a misunderstanding of the terminology. For example, many students selected “particles generally move from high to low concentration because particles tend to move until two areas are isotonic and then the particles stop moving”. Another common response was, “there are too many particles crowded into one area and therefore they move to an area with more room”. As suggested by Odom & Barrow, these students may have memorized the prefix iso, which means “the same”, and interpreted this item to mean that particles would continue to move until they are the same concentration throughout. The desired response combination was that “particles generally move from high to low concentration because particles in areas of greater concentration are more likely to bounce toward other areas”.

In item 3, students were asked to determine the rate of diffusion as the difference in concentrations between two areas increases. The most common response combination for this item was, “increases because the molecules want to spread out”. However the desired response combination was that “increases because there is greater likelihood of random motion into other regions.

For each of above selections, students may view matter as needing to move from one area to another.

4.2.2. Concentration and tonicity

Items 4 and 9 examined students' understanding of concentration and tonicity. In item 4, students were asked to choose the combination how a glucose solution can be made more concentrated. Students had difficulty in determining that increasing the concentration of a solution resulted in more dissolved particles. Only 48.4 % of the students selected the desired answer combination. The most common response was that "adding more glucose" would increase the concentration of the solution, because “concentration means the dissolving of something”. The desired response combination was “adding more glucose because it increases the number of dissolved particles”. Item 9 assessed students' understanding that tonicity refers to the relative number of dissolved particles restrained by a semi-permeable membrane. In this item, a diagram illustrated a two-sided container separated by a membrane. Side 1 contained 10 % saltwater and side 2 contained 15 % saltwater. Students had greater difficulty in selecting the desired answer combination (39 %). The question involves the prefixes *hypo-, hyper-,* and *iso-* and asks about the tonicity of side 1 relative to side 2. The most common response was that side I was "hypotonic" because "water moves from a high to a low concentration". “Side I was "hypotonic" because "the concentration of water molecules is less on side 1” was the correct combination. Students ascertained that tonicity refers to something other than the relative number of dissolved particles. Another common response was that “Side 1 is hypertonic to side 2 because there are fewer dissolved particles on side 1.” Students had difficulty in remembering the meanings of those prefixes.

4.2.3. Influence of life forces on diffusion and osmosis

This concept was examined through item 11. In this item a plant cell was killed and placed in 25% saltwater: then, the question asked whether diffusion and osmosis would continue. The desired response combination was that "diffusion and osmosis would continue" because "the cell does not have to be alive" (32.7%). Analysis of responses revealed numerous misconceptions. The most common response was that diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning. It is reasonable that students would compare a cell with a living organism such as a person. When a person dies, many observable physiologic functions stop, such as the heartbeat and breathing. At the macro-level, when an organism dies it stops functioning, but at the micro-level, processes may continue for hours or days.

4.2.4. Process of diffusion

This concept was examined through item 1and 5. In item 1, a drop of blue dye was placed in a container of clear water, and over time the dye became evenly distributed throughout the water. Only 39% of the students selected "the process responsible for blue dye becoming evenly distributed in the water is diffusion" because "there is movement of particles between regions of different concentrations." The most common misconception was that the process was " a reaction between water and dye because the dye separates into small particles and mixes with water. “The process was diffusion because the dye separates into small panicles and mixes with water” was the other misconception. When the "dye" was added to the water, students may have been using the word dye at a macro-level (a bottle of dye) instead of at the micro-level (dye molecules). In item 5, a small amount of sugar was added to a container of water and allowed to set for a very long period of time without stirring. The desired response combination was, "the sugar molecules will be evenly distributed throughout the container because there is movement of panicles from a high to low concentration.” A minority of students (about 28%) selected the desired answer combination. The most common responses were "the sugar molecules will be more concentrated on the bottom of the container" because "the sugar is heavier than water and will sink," and "there will be more time for settling. One interpretation of these results is that students integrated gravity concepts into solution chemistry. Students can see sugar granules sink to the bottom of the container. If students ignored the condition (that the sugar was allowed to set for a very long period of time), their response would describe what happens when sugar granules are first placed in the container.

4.2.5 Process of osmosis

This concept was assessed through items 8 and 10. Analysis of responses revealed numerous misconceptions. In each item students were asked to determine net direction of water movement through a membrane. In item 8, the two columns of water were separated by a semi-permeable membrane through which only water could pass. Side 1 contained water and dye, and side 2 water. About half of the students (55%) determined the correct net direction of water movement, but less than 21 % selected the correct reason that “after 2 hours the water level in side 1 will be higher than in side 2” because “the concentration of water molecules is less on side 1”. The most common response was that the water on side 1 would be higher because “water will move from the hypertonic to hypotonic solution”. It is likely that students had memorized the tonicity terms with little understanding of their meaning. Students may have recalled that there was a rule to determine the net direction of water movement. The correct rule is that water moves from hypotonic to hypertonic solutions; thus, students may have remembered the rule incorrectly. Another response for item 8 (as well as item 2) was that "water moves until it becomes isotonic.” Memorization of the term isotonic with little understanding of the process of osmosis could result in this misconception. Iso means "the same," and it is possible that students considered osmosis as continuing until the concentrations were the same on each side. Item 10 assessed the process of osmosis in a plant cell. This item showed a picture of a plant cell that lives in fresh water and was placed in 25% saltwater. Students determined what happened to the size of the central vacuole. The desired response was that "the central vacuole would decrease in size" because "water will move from the vacuole to the salt water solution." A majority of students determined the correct direction of water flow (63 %), whereas 39% of the students selected the desired reason. The most common response was "salt absorbs water from the central vacuole". The meaning of absorb may be different in a science context than in a nonscientific one. Common experiences in a non science context are that sponges and paper towels absorb water. If absorb is viewed as the taking away of water, then students may have believed that the saltwater solution absorbed the freshwater. In a scientific context, absorption is capillary action caused by adhesion. Salt solutions do not cause capillary action.

4.2.6 Kinetic Energy of Matter

This concept was assessed by item 7 which measures the effect of temperature on the rate of molecules. Seventy five percent of the 9th grade students selected the desired answer combination was that “A drop of green dye is added to beakers with equal amounts of clear water at two different temperatures (beaker 1, 25°C and beaker 2, 35°C). Beaker 2 became light green first” because “the dye molecules move faster at higher temperature.” Since 75% of the students selected the correct answer combination, therefore, we concluded that 9th grade students’ understanding the concept of kinetic energy of matter was satisfactory.

4.2.7 Membrane

The item 12 measures the ability of students to understand the structure of cell membrane. Sixty one percent of 9th grade selected the desired answer combination was that “all cell membranes are semi permeable” because “they allow some substances to pass.” Most common misconception was that “all cell membranes are semi permeable” because “they allow some substances to enter, but they prevent any substance from leaving” (13.9% of the students). Students remembered the selectively permeable membrane but they thought it as a gate opening in one direction.

To sum up, 9th grade students have difficulties in understanding diffusion and osmosis concepts. Almost 24 misconceptions are revealed in this study. The only difference with other studies may be the percentages of students’ answers. Approximately, all misconceptions in the questions are the same. All specific misconceptions are observed in the sample of our study. So the findings of this study are consistent with the previous studies.

4.3 Inferential Statistics

All hypotheses are tested at the significance level 0.01 by using SPSS. Pearson –Product Moment correlations were conduct to determine whether there was a relationship between students' prior knowledge, reasoning ability and achievement in Diffusion and Osmosis. Table 4.10 shows the correlation coefficients among variables.

To determine the contribution of variables to the achievement in Diffusion and Osmosis, Multiple Regression Correlation Analysis was conducted. The findings were represented in Table 4.11.

A stepwise multiple regression analysis was applied to the data to determine the variables were best predicting students’ performance on the

DODT. Predictor variables were reasoning ability, prior knowledge, and gender. Total TOLT scores were used as a measure of reasoning ability. Students' grades in biology in previous semester were used as students' prior knowledge. Dependent variable was the achievement score measured by two-tier Diffusion and Osmosis Diagnostic Test (DODT). The findings were represented in Table 4.12.

4.3.1. Analyses of Hypotheses

H_0 1:

The hypothesis 1 was stated as there is no statistically significant relationship between students' prior knowledge, reasoning ability and achievement.

Pearson–Product moment correlations were conduct to determine whether there was a relationship between students' prior knowledge, achievement and reasoning ability. The results presented in table 4.10 showed a statistically significant positive correlation between students' prior knowledge and reasoning ability (r=.590, p=.000) which means that students' having high formal reasoning ability also have higher prior knowledge. Also there was a statistically significant positive correlation between students' prior knowledge and achievement (r=.575, p=.000). It means that if the students have high prior knowledge, their achievement increases. Moreover, a statistically significant correlation was found between reasoning ability and achievement (r=.501, p=.000). So students having high formal reasoning ability have higher achievement in diffusion and osmosis. The results indicated the higher the reasoning ability, the higher the prior knowledge and the greater the achievement.

Table 4.10 Pearson Product Moment Correlation Coefficients among variables (n=397)

	Prior Knowledge	Reasoning Ability
Reasoning Ability	.590 *	-
Achievement	.575 *	.501*

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

H_0 2:

The hypothesis 2 was stated as there is no statistically significant contribution of reasoning ability, prior knowledge and gender to the variation on achievement scores.

Multiple Regression Correlation Analysis was conducted to determine the contribution of reasoning ability, prior knowledge and gender on achievement. According to table 4.11, reasoning ability and prior knowledge but not gender significantly effected the scores on achievement (F=78.243, p <.05). Prior knowledge and reasoning ability together predicted 37 % of the variation on achievement. So reasoning ability and prior knowledge but not gender, each made a statistically significant contribution to the variation on achievement

Table 4.11 Multiple Regression Correlation Analysis for reasoning ability, prior knowledge and gender on achievement

Independent Variables	B	Beta	*t*	*p*
Reasoning ability	.276	.254	5.108	.000
Prior knowledge	.881	.417	8.303	.000
Gender	.281	.057	1.401	.162

H_0 3:

The hypothesis 3 was stated as there is no statistically significant contribution of reasoning ability, prior knowledge and gender to the variation on achievement.

Table 4.12 Stepwise Multiple Regression Analysis

Model		Beta	*t*	*p*	variation (%)
1	Reasoning ability	.501	11.494	.000	4
2	Prior knowledge	.575	13.978	.000	33
3	Gender	.125	2.506	.130	
4	Reasoning ability	.247	4.995	.000	37
	Prior knowledge	.429	8.675	.000	
	Gender	.057	1.401	.162	

Stepwise multiple regression analysis was computed to determine the variables were best predicting students' achievement on the DODT. Analysis reveal that, while prior knowledge explains 33 % of the variation in the DODT achievement (F=195.397, p <.05), reasoning ability explains 4 % of the variation in the DODT achievement (F=132.115, p <.05). Results indicate that prior knowledge is a better predictor than reasoning ability in the DODT achievement. However, gender has no contribution to the variance on achievement.

4.4 Summary of the Results of the Study

This study was performed in order to understand the relation between reasoning ability, gender, prior knowledge and conceptual understanding of diffusion and osmosis among 397 ninth grade students. The distribution of DODT achievement scores could be seen similar to the normal distribution. The range of correct answers for the first tier of the test was 41 % to 91% in DODT. When both tiers were combined, the correct responses were reduced to a range of 21% to 61%. The DODT results suggest that students did not acquire a satisfactory understanding of diffusion and osmosis concepts. Results of DODT revealed that 9th grade students' have difficulties in understanding diffusion and osmosis concepts. Almost 24 misconceptions are observed in this study. Nearly, all alternative responses in the questions are the same with previous studies.

Pearson –Product moment correlations were conduct to determine whether there was a relationship between students' prior knowledge, reasoning ability and achievement. The results showed that prior knowledge significantly correlated with reasoning ability and achievement**.**

A Multiple Regression Correlation Analysis showed that both reasoning ability and prior knowledge made a significant contribution to the achievement on diffusion and osmosis.

A Stepwise Multiple Regression Analysis revealed that while reasoning ability one explains 4 % of the variation in achievement, prior knowledge explains 33% of the variation in the DODT achievement. This result implied that prior knowledge plays an important role to improve reasoning abilities of the students as well as their achievement.

CHAPTER 5

DISCUSSION

This study was conducted to investigate 9th grade students' achievement regarding diffusion and osmosis in relation to reasoning ability, prior knowledge and gender.

This chapter presents conclusions of the study, and discusses implications for practice and for further research.

5.1. Discussion

Results of the study showed that students have many misconceptions concerning the particulate nature and random motion of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion, the process of osmosis and membrane. Of a possible 12 correct response; the relatively low mean score of 4.71 was obtained in DODT. This indicates student's low level of understanding concerning diffusion and osmosis. These findings are in agreement with many of the finding reported in the literature (Westbrook & Marek, 1991; Zukerman, 1994; Odom & Barrow, 1995; Christianson & Fisher, 1999; Kelly & Odom, 1997; Odom & Kelly, 2001).

With regard to content choices, only one of the twelve items is responded correctly above 75 % of the students in DODT. Low understanding of diffusion and osmosis is especially critical in the ninth grade where curriculum goes around the human body systems and transport systems in plants in tenth grade. The curriculum of tenth grade is divided into nervous system, skeletal and muscle system, endocrine system, circulatory system, respiratory system, digestive system, and excretory system, all of which revolve around the idea of the movement of molecules due to differences in concentration. Students are expected to understand diffusion & osmosis concepts and apply these concepts to the broader perspective in transpiration, water uptake through roots, release of neurotransmitters, action potential, blood and tissue fluid, absorption of nutrients, transportation of gases, formation of urea, regulation of blood pressure and body temperature etc. All of these concepts are important in understanding biology.

Many researchers discussed the causes behind the misconceptions. Odom and Barrow (1995), for example, stated that most of the concepts in diffusion and osmosis are closely related to concepts present both in chemistry and in physics, such as solutions, particulate nature of matter, and permeability. Therefore understanding of these concepts requires the understanding and application of knowledge in physics and chemistry as well as biology. They stated that misconceptions were generally based on school experiences involving students' learning styles and instruction. These misconceptions are resistant to change by traditional teaching methods. Another reason might be the interrelationship among concepts. In addition, Friedler, Amir and Tamir (1987) emphasized that understanding of osmosis requires understanding of transportation in living organisms, water intake by plants, diffusion and water balance in land and aquatic creatures. However, teachers and textbook authors give less emphasis to and devote less time to challenging students' misconceptions. They mainly focus on topics related to the diffusion and osmosis that require less conceptual restructuring.

These misconceptions were found to be generally based on societal practices and school experiences involving students' learning styles and instruction. Odom & Barrow (1995) summarized the underlying reasons why students selected the incorrect answers as the following:

- Students may have memorized the prefix iso, which means "the same", and interpreted the item as particles would continue to move until they are the same concentration throughout.

- Students may view matter as needing to move from one area to another.

- Students ascertained that tonicity refers to something other than the relative number of dissolved particles.

- Students had difficulty in remembering the meanings of the prefixes "iso, hypo and hyper".

- Students thought diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning. It is reasonable that students would compare a cell with a living organism such as a person. When a person dies, many observable physiologic functions stop, such as the heartbeat and breathing. At the macro-level, when an organism dies it stops functioning, but at the micro-level, processes may continue for hours or days.

- Students may have been using the word dye at a macro-level (a bottle of dye) instead of at the micro-level (dye molecules).

- Students integrated gravity concepts into solution chemistry. Students can see sugar granules sink to the bottom of the container. If students ignored the condition (that the sugar was allowed to set for a very long period of time), their response would describe what happens when sugar granules are first placed in the container.

- It is likely that students had memorized the tonicity terms with little understanding of their meaning. Students may have recalled that there was a rule to determine the net direction of water movement. The correct rule is that water moves from hypotonic to hypertonic solutions; thus, students may have remembered the rule incorrectly.

- "Salt absorbs water from the central vacuole". The meaning of absorb may be different in a science context than in a nonscientific one. Common experiences in a non science context are that sponges and paper towels absorb water. If absorb is viewed as the taking away of water, then students may have believed that the saltwater solution absorbed the freshwater. In a scientific context, absorption is capillary action caused by adhesion. Salt solutions do not cause capillary action.

- Students remembered the selectively permeable membrane but they thought it as a gate opening on one direction.

In this study, Pearson – Product moment correlations were conduct to determine whether there was a relationship between students' prior knowledge, reasoning ability and achievement. The results showed a statistically significant positive correlation between each variable. Firstly, when the students' prior knowledge increases, reasoning ability of the students increases too (r=.590, p=.000). Secondly, if the students' prior knowledge increases, student achievement in diffusion and osmosis increases (r=.575, p=.000). Lastly, increase in student' achievement is related to the improvement in reasoning ability (r=.501, p=.000). The studies of Cavallo (1996), Ehindore (1979), Johnson and Lawson (1998), Christianson and Fisher (1999), Lawson, Benford and Clark (2000) supported the positive correlation between reasoning ability and achievement. Moreover, Panizzon (2003) found a significant relationship between conceptual knowledge and developmental level in college biology students. More recently Sungur and Tekkaya (2003) found a significant mean difference between concrete and formal students with respect to achievement and attitude toward biology. However, Johnson and Lawson (1998) did not found a significant relationship between prior knowledge and biology achievement. In support of this view, Westbrook and Marek (1991) determined no relationship between reasoning ability and understanding diffusion. In this regard, Anderson, Sheldon and Dubay (1986) found that amount of previous biology instruction did not improve college students' performance on a pretest or on a posttest concerning concepts of respiration and photosynthesis. McAdaragh (1981) found no significant difference in ninth graders' understanding of earth science concepts owing to background experience.

Multiple Regression Correlation (MRC) Analysis was conducted to determine the contribution of reasoning ability, prior knowledge and gender on achievement. Reasoning ability and prior knowledge, but not gender made a significant contribution to the achievement on diffusion and osmosis. To what extend do the reasoning ability and prior knowledge can be used to predict achievement? A stepwise multiple regression analysis was applied to the data. Reasoning ability alone explains 4 % of the variation on achievement while prior knowledge alone itself explains 33% of the variation on achievement. Stepwise analysis reveals that prior knowledge is a better predictor than reasoning ability on achievement. This finding was supported by many scientists. Blurton (1985) found that prior genetics knowledge, but not reasoning ability, significantly predicted performance on a genetic posttest. Gooding, Swift, Schell and Mc Croskery (1990) found that for high school biology and chemistry students, previous science grade affected final examination performance. Novak (1990) believed that storage of specifically relevant concepts is of primary importance. If prior concepts are lacking, one cannot acquire new concepts. Hegarty - Hazel and Prosser (1991) found that prior knowledge led to adoption of more effective study strategies, and therefore to better achievement in college physics and biology classes. However, Bitner (1991) showed that reasoning ability explained 62 % of the variance in high school grades. Johnson and Lawson (1998) suggest that reasoning ability but not prior knowledge, accounted for a significant amount of variance (18.8 %) in final examination score.

5.2. Implications for practice

Identification of misconceptions about diffusion and osmosis is vital to make meaningful problem solving accessible to more students. Furthermore, identification of misconceptions is needed to develop strategies to provide student with the accurate conceptual knowledge required for scientific problem solving. This study showed that there are many misconceptions concerning diffusion and osmosis that students bring to classroom resulting from their past school experiences and environment. Hence, teachers should be aware of them by giving in-service seminars or distribution of related journals. Consequently, when they identify misconceptions, it might be possible to help students effectively to acquire scientific conceptions by developing alternative teaching approaches that address students’ misconceptions. If misconceptions are realized by the students, the learning that comes on top of it will be meaningful and long term.

Based on the result of this study, biology teachers appear not to be teaching for comprehension of diffusion and osmosis concepts, but rather for emphasizing the acquisition of facts (although there were no direct observations of instruction). Further, the DODT can be a valuable tool that can be aid teachers in assessing both their teaching methodologies and students' understanding and reasoning about diffusion and osmosis.

Reasoning ability and prior knowledge appears to be a significant predictor of achievement in diffusion and osmosis among 9th grade students. High school biology instructors would be well advised to be more concerned with the development of their students' reasoning abilities than with making certain that they cover a wide range of specific biology concepts. Thus, present results imply that such students would be better instructed by courses that focus on the development of scientific reasoning and the acquisition of fewer concepts.

For students with a limited biological background, there is the need to provide experiences that enable them to gain a macroscopic view of the movement of particles. For example, two common ones include the movement of perfume or ammonium throughout a room and reference to the experiment in which potassium permanganate is dropped into a beaker of water and heated. While the dispersion in both instances is the result of convection, the concrete representations help students to develop an understanding of particle movement at a macroscopic scale. Students can grapple with the notion of concentration differences at this scale and, once conceptualized, are able to transfer their understanding to the cellular or microscopic level.

In implementing formal science curricula at the high school level, the hands-on activities necessary for the underlying understanding of the content matter cannot be ignored. Future studies on diffusion and formal thought need not only to investigate further relationship between formal reasoning and diffusion but to as well delve further exemplary curriculums that could help students make these formal connections.

5.3. Further Recommendations

To foster formal operations, teachers should pose problem to students and present them with questions and conflicting situations, and encourage them to analyze their own thinking either individually or in groups (Mwamwenda, 1993). Moreover, it is suggested that courses should be taught by learning cycle (Bitner, 1991) and inquiry (Johnson and Lawson, 1998) which foster scientific reasoning. This study showed that as the reasoning ability of students' increases, their understanding in diffusion and osmosis concepts increase.

Improving science achievement through the use of more effective instructional strategies, promoting the active role of the learner, and promoting the facilitative role of the teacher has long been an aspiration of science educators. To this end, two predominant teaching methods that have long histories of use remain widespread in the science education community: concept mapping and the learning cycle.

Repeating this study with a range of age levels may show the relationships not seen in this study. Also repeating this study in an experimental format may reveal if treatments that use experiments in laboratory or inquiry based learning might be more effective in helping students shed their misconceptions on diffusion and osmosis.

As national high school curriculum increasingly expects students to learn concepts that require formal thinking, the developmental ability of these students to integrate and understand science content must be addressed. Therefore, the methodologies used to implement science curriculum at the high school level becomes a key issue in how to best teach the high school student.

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APPENDIX A

MANTIKSAL DÜŞÜNME YETENEK TESTİ

AÇIKLAMA: Bu test, çeşitli alanlarda, özellikle Fen ve Matematik dallarında karşılaşabileceğiniz problemlerde neden-sonuç ilişkisini kurup, problem çözme stratejilerini ne derece kullanabileceğinizi göstermesi açısından yok faydalıdır. Bu test iyindeki sorular mantıksal ve bilimsel olarak düşünmeyi gösterecek cevaplan içermektedir.

NOT: Soru Kitapçığı üzerinde herhangi bir işlem yapmayınız ve cevaplarınızı yalnızca cevap kağıdına yazınız. CEVAP KAĞIDINI doldururken dikkat edilecek hususlardan binsi, 1 den 8 e kadar olan sorularda her soru için cevap kağıdında iki kutu bulunmaktadır. Soldaki ilk kutuya sizce sorunun uygun cevap şıkkını yazınız, ikinci kutucuğa yani AÇIKLAMASI yazılı kutucuğa ise o soruyla ilgili soru kitapçığındaki Açıklaması kısmındaki şıkları okuyarak sizce en uygun olanını seçiniz. Örneğin 12. ci sorunun cevabı sizce b ise ve Açıklaması kısmındaki en uygun açıklama ikinci şık ise cevap kağıdını aşağıdaki gibi doldurun:

12. $\boxed{b}$ AÇIKLAMASI $\boxed{2}$

09 ve 10 uncu sorulan ise soru kitapçığında bu sorularla ilgili kısımları okurken nasıl cevaplayacağınızı daha iyi anlayacaksınız.

SORU 1: Bir boyacı, aynı büyüklükteki altı odayı boyamak iyin dört kutu boya kullandığına göre sekiz kutu boya ile yine aynı büyüklükte kaç oda boyayabilir?

a. 7 oda

b. 8 oda

c. 9 oda

d. 10 oda

e. Hiçbiri

Açıklaması :

1. Oda sayısının boya kutusu sayısına oram daima 3/2 olacaktır.

2. Daha fazla boya kutusu ile fark azalabilir.

3. Oda sayısı ile boya kutusu sayısı arasındaki fark her zaman iki olacaktır.

4. Dört kutu boya ile fark iki olduğuna göre, altı kutu boya ile fark yine iki olacaktır.

5. Ne kadar çok boyaya ihtiyaç olduğunu tahmin etmek mümkün değildir.

SORU 2: On bir odayı boyamak için kaç kutu boya gerekir? (Birinci soruya bakınız)

a. 5 kutu

b. 7 kutu

c. 8 kutu

d. 9 kutu

e. Hiçbiri

Açıklaması:

1. Boya kutusu sayısının oda sayısına oram daima 2/3 dür.

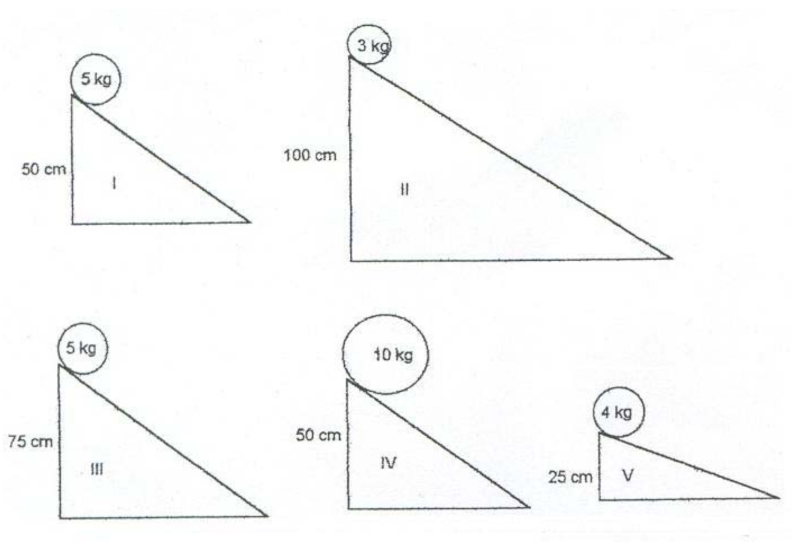
2. Eğer beş oda daha olsaydı, üç kutu boya daha gerekecekti

3. Oda sayısı ile boya kutusu arasındaki fark her zaman ikidir.

4. Boya kutusu sayısı oda sayısının yarısı olacaktır.

5. Boya miktarını tahmin etmek mümkün değildir.

SORU 3: Topun eğik bir düzlemden (rampa) aşağı yuvarlandıktan sonra katettiği mesafe ile eğik düzlemin yüksekliği arasındaki ilişkiyi bulmak için deney yapmak isterseniz, aşağıda gösterilen hangi eğik düzlem setlerini kullanırdınız?

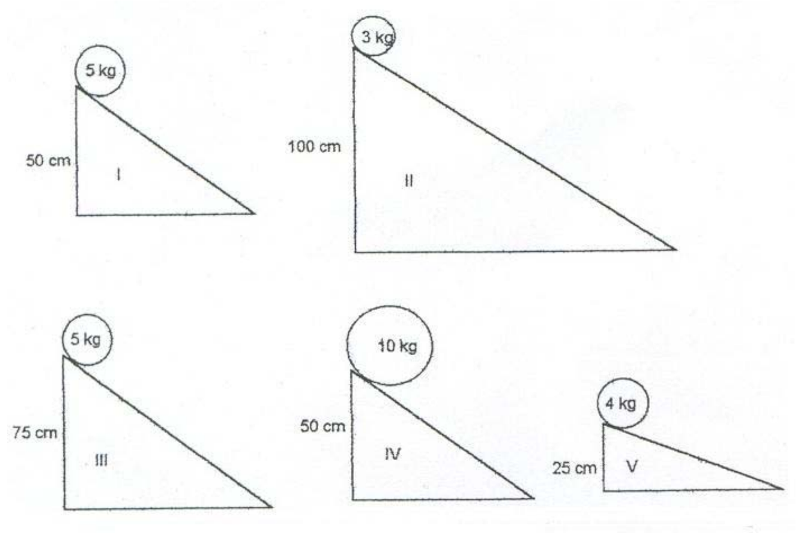


a. I ve IV
b. II ve IV
c. I ve III
d. II ve V
e. hepsi

Açıklaması:

1. En yüksek eğik düzlemle (rampa) karşı en alçak olan karşılaştırılmalıdır.
2. Tüm eğik düzlem setleri birbiriyle karşılaştırılmalıdır.
3. Yükseklik arttıkça topun ağırlığı azalmalıdır.
4. Yükseklikler aynı fakat top ağırlıkları farklı olmalıdır.
5. Yükseklikler farklı fakat top ağırlıkları aynı olmalıdır.

SORU 4: Tepeden yuvarlanan bir topun eğik düzlemden (rampa) aşağı yuvarlandıktan sonra katettiği mesafenin topun ağırlığıyla olan ilişkisini bulmak için bir deney yapmak isterseniz, aşağıda verilen hangi eğik düzlem setlerini kullanırdınız?



a. I ve IV

b. II ve IV

c. I ve III

d. II ve V

e. hepsi

Açıklaması:

1. En ağır olan top en hafif olanla kıyaslanmalıdır.

2. Tüm eğik düzlem setleri birbiriyle karşılaştırılmalıdır

3. Topun ağırlığı arttıkça, yükseklik azaltılmalıdır.

4. Ağırlıklar farklı fakat yükseklikler aynı olmalıdır.

5. Ağırlıklar aynı fakat yükseklikler farklı olmalıdır.

SORU 5: Bir Amerika'lı turist Şark Ekspresi'nde altı kişinin bulunduğu bir kompartımana girer. Bu kişilerden üçü yalnızca İngilizce ve diğer üçü ise yalnızca Fransızca bilmektedir. Amerika'lının kompartımana ilk girdiğinde İngilizce bilen biriyle konuşma olasılığı nedir?

a. 2 de 1

b. 3 de 1

c. 4 de 1

d. 6 da 1

e. 6 da 4

Açıklaması :

1. Ardarda üç Fransızca bilen kişi çıkabildiği için dört seçim yapılması gerekir.

2. Mevcut altı kişi arasından İngilizce bilen bir kişi seçilmelidir.

3. Toplam üç İngilizce bilen kişiden sadece birinin seçilmesi yeterlidir.

4. Kompartımandakilerin yarısı İngilizce konuşur.

5. Altı kişi arasından, bir İngilizce bilen kişinin yanı sıra, üç tanede Fransızca bilen kişi seçilebilir.

SORU 6: Üç altın, dört gümüş ve beş bakır para bir torbaya konulduktan sonra, dört altın, iki gümüş ve üç bakır yüzük de aynı torbaya konur. İlk denemede torbadan altın bir nesne çekme olasılığı nedir?

a. 2 de 1

b. 3 de 1

c. 7 de 1

d. 21 de 1

e. Yukarıdakilerden hiçbiri

Açıklaması :

1. Altın, gümüş ve bakırdan yapılan nesneler arasından bir altın nesne seçilmelidir.

2. Paraların1/4 ü ve yüzüklerin 4/9u altından yapılmıştır.

3. Torbadan çekilen nesnenin para veya yüzük olması önemli olmadığı için, toplam 7 altın nesneden bir tanesinin seçilmesi yeterlidir.

4. Toplam yirmi bir nesneden bir altın nesne seçilmelidir.

5. Torbadaki 21 nesnenin 7 si altından yapılmıştır.

SORU 7: Altı yaşındaki Ahmet'in şeker almak iyin 50 lirası vardır. Bakkaldaki kapalı iki şeker kutusundan birinde 30 adet kırmızı ve 50 adet sarı renkte şeker bulunmaktadır. İkinci bir kutuda ise 20 adet kırmızı ve 30 adet sarı şeker vardır. Ahmet kırmızı şekerleri sevmektedir. Ahmet'in ikinci kutudan kırmızı şeker çekme olasılığı birinci kutuya göre daha fazla mıdır?

a. Evet

b. Hayır

Açıklaması:

1. Birinci kutuda 30, ikincisinde ise yalnızca 20 kırmızı şeker vardır.

2. Birinci kutuda 20 tane daha fazla sarı şeker, ikincisinde ise yalnızca 10 tane daha fazla sarı şeker vardır.

3. Birinci kutuda 50, ikincisinde ise yalnızca 30 sarı şeker vardır.

4. İkinci kutudaki kırmızı şekerlerin oram daha fazladır.

5. Birinci kutuda daha fazla sayıda şeker vardır.

SORU 8: 7 büyük ve 21 tane küçük köpek şekli aşağıda verilmiştir. Bazı köpekler benekli bazıları ise beneksizdir. Büyük köpeklerin benekli olma olasılıkları küçük köpeklerden daha fazla mıdır?

a. Evet

b. Hayır

Açıklaması :

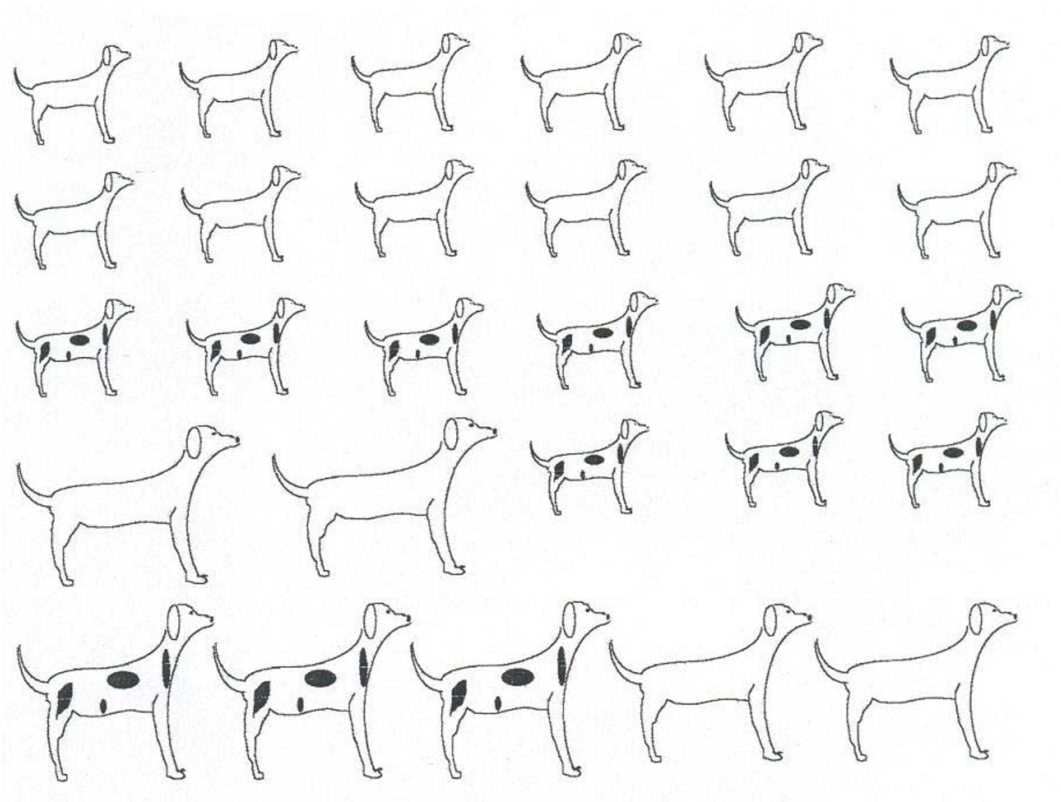
1. Bazı küçük köpeklerin ve bazı büyük köpeklerin benekleri vardır.

2. Dokuz tane küçük köpeğin ve yalnızca üç tane büyük köpeğin benekleri vardır.

3. 28 köpekten 12 tanesi benekli ve geriye kalan 16 tanesi beneksizdir.

4. Benekli köpeklerin 3/7 si ve küçük köpeklerin 9/21i beneklidir.

5. Küçük köpeklerden 12 sinin, fakat büyük köpeklerden ise sadece 4 ünün beneği yoktur.



SORU 9: Bir pastanede üç çeşit ekmek, üç çeşit et ve üç çeşit sos kullanılarak sandviçler yapılmaktadır.

Ekmek Çeşitleri	Et Çeşitleri	Sos Çeşitleri
Buğday (B)	Salam (S)	Ketçap (K)
Çavdar (Ç)	Piliç (P)	Mayonez (M)
Yulaf (Y)	Hindi (H)	Tereyağı (T)

Herbir sandviç ekmek, et ve sos içermektedir. Yalnızca bir ekmek çeşidi, bir et ve bir sos çeşidi kullanılarak kaç çeşit sandviç hazırlanabilir?

Cevap kağıdı üzerinde bu soruyla ilgili bırakılan boşluklara bütün olası sandviç çeşitlerinin listesini çıkarın.
Cevap kağıdında gereksiniminizden fazla yer bırakılmıştır.

Listeyi hazırlarken ekmek, et ve sos çeşitlerinin yukarıda gösterilen kısaltılmış sembollerini kullanınız.

Örnek: BSK = Buğday, Salam, ve Ketçap dan yapılan sandviç

SORU 10: Bir otomobil yarışında Dodge (D), Chevrolet (C), Ford (F) ve Mercedes (M) marka dört araba yarışmaktadır. Seyircilerden biri arabaların yarışı bitiriş sırasının DCFM olacağını tahmin etmektedir. Arabaların diğer mümkün olan bütün yarış bitirme sıralamalarını cevap kağıdında bu soruyla ilgili bırakılan boşluklara yazınız.

Cevap kağıdında gereksiniminizden fazla yer bırakılmıştır.

Bitirme sıralamalarını gösterirken, arabaların yukarıda gösterilen kısaltılmış sembollerini kullanınız.

Örnek: DCFM yarışı sırasıyla önce Dodge'nin, sonra Chevrolet'in, sonra Ford'un ve en sonra Mercedes'in bitirdiğini gösterir.