EXPLORING RELATIONSHIPS AMONG STUDENTS' PRIOR KNOWLEDGE, MEANINGFUL LEARNING ORIENTATION, REASONING ABILITY, MODE OF INSTRUCTION AND UNDERSTANDING OF PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

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Approval of the Graduate School of Social Sciences

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ABSTRACT

EXPLORING RELATIONSHIPS AMONG STUDENTS' PRIOR KNOWLEDGE, MEANINGFUL LEARNING ORIENTATION, REASONING ABILITY, MODE OF INSTRUCTION AND UNDERSTANDING OF PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

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The purpose of this study was to identify the relative predictive influences of prior knowledge, meaningful learning orientation, formal reasoning ability and mode of instruction on understanding in photosynthesis and respiration in plants concepts.

Two hundred thirty three 8th grade students from six classes of one elementary school in Ankara participated in this study. The study was carried out during the 2004-2005 Fall semester. Students in the

experimental group (N=117) received conceptual change instruction, and the students in the control group (N=116) received traditional instruction. Two-tier multiple choice diagnostic test, "Photosynthesis and Respiration in Plants Concept Test" developed by Haslam and Treagust (1987), was used to determine students' understanding of photosynthesis and respiration in plants concepts. The test was administered to the sample prior to the treatment as pre-test, and after the treatment as post-test. The pre-test scores were used as prior knowledge of students. Students' reasoning abilities were measured by the "Test of Logical Thinking" and their learning orientations were measured by "Learning Approach Questionnaire".

The results of the study indicated that students held several misconceptions concerning photosynthesis and respiration in plants concepts. Significant differences between the experimental group and control group with respect to understanding of the concept were found in favor of experimental group. The main predictor of achievement in the experimental group was students' prior knowledge, while it was reasoning ability in the control group. Meaningful learning orientation accounted for a small amount of variance in the experimental group but it did not contribute to understanding on post-test scores in traditional group.

Keywords: Photosynthesis and respiration in plants, misconceptions, conceptual change learning, reasoning abilities, learning approach

ÖZ

ÖĞRENCİLERİN ÖNBİLGİSİ, ÖĞRENME YAKLAŞIMLARI, MANTIKSAL DÜŞÜNME YETENEKLERİ, FARKLI ÖĞRETİM YÖNTEMLERİ VE FOTOSENTEZ VE BİTKİLERDE SOLUNUM KONULARINI ANLAMALARI ARASINDAKİ İLİŞKİLERİN ARAŞTIRILMASI

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Bu çalışma, önbilginin, öğrenme yaklaşımının, mantıksal düşünme yeteneğinin ve farklı öğrenme modellerinin fotosentez ve bitkilerde solunum konusunu anlamadaki etkisini araştırmak amacıyla yapılmıştır.

Ankara'daki bir ilköğretim okulunun 6 ayrı sınıfında bulunan 233 sekizinci sınıf öğrencisi çalışmaya katılmıştır. Bu çalışma 2004-2005 eğitim yılının

güz yarıyılında yapılmıştır. Deney grubundaki öğrenciler (N=117) dersi kavramsal değisim öğretim yöntemi ile, kontrol grubundaki öğrenciler (N=116) ise geleneksel öğretim yöntemi ile işlemişlerdir. Öğrencilerin fotosentez ve bitkilerde solunum konularındaki kavram yanılgılarını bulmak için Haslam ve Treagust (1987) tarafından geliştirilen iki aşamalı tanı testi "Fotosentez ve Bitkilerde Solunum Kavram Testi" kullanılmıştır. Bu test öğretim yöntemi uygulamasından önce ön-test, uygulamadan sonra da son-test olarak uygulanmıştır. Öğrencilerin ön-testte aldıkları puanlar onların önbilgileri olarak kullanılmıştır. Ayrıca, öğrencilerin mantıksal düşünme yeteneklerini ölçmek için "Mantıksal Düşünme Yetenek Testi" ve öğrenme yaklaşımlarını ölçmek için "Öğrenme Yaklaşımı Ölçme Testi" uygulanmıştır.

Sonuçlar, öğrencilerin fotosentez ve bitkilerde solunum konularında çeşitli kavram yanılgılarına sahip olduklarını göstermiştir. Deney grubu ve kontrol grubu arasında konuyu anlama bakımından, deney grubunun lehine anlamlı farklar bulunmuştur. Deney grubunda başarının temel belirleyicisi önbilgi iken, kontrol grubunda temel belirleyici mantıksal düşünme yeteneği olarak bulunmuştur. Anlamlı öğrenme yaklaşımı, deney grubundaki öğrencilerin konuyu anlamalarına az bir katkı sağlarken, kontrol grubuna hiçbir katkı sağlamadığı görülmüştür.

Anahtar Kelimeler: Fotosentez ve bitkilerde solunum, kavram yanılgıları, kavramsal değişim yaklaşımı, mantıksal düşünme yeteneği, öğrenme yaklaşımları

To My Parents

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LIST OF SYMBOLS

PRPT : Photosynthesis and Respiration Concept Test

TOLT : Test of Logical Thinking

LAQ : Learning Approach Questionnaire

LAQ-M : Learning Approach Questionnaire - Meaningful

LAQ-R : Learning Approach Questionnaire - Rote

TI : Traditional Instruction

CCI : Conceptual Change Instruction

EG : Experimental Group

CG : Control Group

CHAPTER I

INTRODUCTION

This study is undertaken to identify eighth grade students' understanding of photosynthesis and respiration in plants concepts and to describe the relationship between students' prior knowledge, meaningful learning orientation, reasoning ability, mode of instruction and meaningful understanding of photosynthesis and respiration in plants concepts.

Research suggests that students do not enter the classroom as blank pages, but rather they enter the classroom with a pre-existing understanding of many introductory concepts (Cavallo and Schafer, 1994). This pre-existing knowledge prior to instruction is one of the important determinants of students' learning in science (Hewson and Hewson, 1983). Piaget (1950) believed that students construct knowledge when they encounter input from the environment and relate it with their own mental structures and experiences, which is called as assimilation. If the newly assimilated information conflicts with previously formed mental structures, disequilibrium occurs. Disequilibrium motivates the learner to seek equilibrium. Regaining equilibrium or cognitive harmony results in

accommodation. Assimilation and accommodation represent the learner's adaptation to the environmental input.

It is known that if the new knowledge taught is not associated with prior knowledge, rote learning occurs. According to Cavallo and Schafer (1994) "students who learn by rote are driven by memorizing facts and definitions, cannot apply this information to new problems, and they do not demonstrate the ability to interrelate concepts" (p.394). On the other side, if new knowledge is associated with pre-existing ideas, meaningful learning occurs (Ausubel, 1968). "For meaningful learning to occur three criteria must be met: the material itself must have potential meaning (i.e., rather than a list of nonsense); the individual must possess a framework of relevant, domain-specific concepts to anchor the new knowledge; and the individual must choose voluntarily to incorporate new concepts in a nonarbitrary, nonverbatim fashion (i.e., a condition referred to as 'meaningful learning set')" (Pearsall, Skipper and Mintzes, 1997, p.195).

Research suggests that the topics related to science are primarily learned by rote (Cavallo, 1996). When students learn by rote, they may formulate misconceptions of science topics (BouJaoude, 1992). Learning science, therefore, should involve students in the construction of knowledge and the creation of new ideas from what they already know (Cavallo, 1996). The meaningful learning is the goal of science education since the concepts are what we think with. In line with this view, determining students' understanding is a basic study in the domain of science education. Despite its significance, research on students' understanding of scientific concepts has

revealed that students possess several ideas that are at variance with scientifically accepted knowledge (Bell, 1985; Haslam and Treagust, 1987; Waheed and Lucas, 1992; Lewis, Leach and Wood-Robinson, 2000; Pashley, 1994; Griffiths and Grant, 1985; Munson, 1994; Kinchin, 2000; Seymour and Longden, 1991; Sanders, 1993; Oliva, 1999, 2003; Lawson and Thompson, 1988; Odom and Barrow, 1995). Many of these focused on photosynthesis and respiration in plants. Briefly, these studies revealed that the majority of students at all grade levels hold misconceptions about plant nutrition, the role of water in plants, the role of the roots in plants, the role of leaves in plants, gas exchange, the definition and importance of photosynthesis, the role of light in photosynthesis, the role of chlorophyll in photosynthesis, the relationship between food and energy, and the nature of respiration and energy transformation (Amir and Tamir, 1995; Haslam and Treagust, 1987, Wandersee, 1985, Waheed and Lucas, 1992).

The conceptual change approach to science instruction, which is an alternative way of instruction, is designed to encourage students to alter their misconceptions (Wang and Andre, 1991). In this approach, learner's misconceptions are part of the underlying mental structures (Yezierski, 2003). The approach focuses on using in-class teacher-student and student-student interaction to promote conceptual change (Chambers and Andre, 1997). The teacher must create disequilibrium between existing ideas and new information. A new equilibrium is then established when the learner accommodates the new information into the newly constructed ideas. Text-based conceptual change features are among the strategies used in instruction.

These features include refutational texts (Guzzetti, 2000; Hynd, 2001; Palmer, 2003), conceptual change texts (Chambers and Andre, 1997; Hydn McWhorter, Phares, and Suttles, 1994; Mikkila 2001; Wang and Andre, 1991), and learning cycle texts (Musheno and Lawson, 1999). Among them, conceptual change text has stimulated considerable interest in the area of science education and many of them have reported that conceptual change texts are effective on creating conceptual change and promoting meaningful understanding in students concerning different science concepts (Chambers and Andre, 1997; Hydn *et al,* 1994; Mikkila 2001; Wang and Andre, 1991).

Throughout the courses taught in elementary and high school, 'science' is the one requiring intellectual skills and high levels of reasoning ability of students. According to Wood (1974), there is a direct link between formal thought and integrated processes such as identifying and controlling variables, and hypothesizing which construct the bases of science education. A number of research concerning the relationship between reasoning ability and conceptual change has been put forward. Some authors have shown that the level of formal reasoning improves the probabilities of conceptual change (Lawson and Thompson, 1988), and there is also evidence that this variable has a positive influence on the degree of structuralization of alternative conceptions (Oliva, 1994, 1999). In this way, it is expected that those students with lower formal reasoning ability change their preconceptions more easily than the others. On the other hand, there are those who directly link the possibility of change to student's thinking ability. From this point of view,

those students with higher reasoning ability tend to change alternative conceptions more easily.

In keeping the above mentioned background and customs, it seems worthwhile to investigate the factors which are in relation to students' meaningful understanding of photosynthesis and respiration in plants concepts. In this study, the relationship among students' meaningful learning orientation, reasoning ability and understanding photosynthesis and respiration in plants concepts; and the effectiveness of a strategy integrating conceptual change texts with 'writing for learning' and 'discussion webs' is investigated.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1. Introduction

In this part of the study, the previous studies concerning misconceptions in photosynthesis and respiration in plants concepts, constructivism, conceptual change approach, reasoning ability, and learning orientations are examined.

2.2. Misconceptions

In the past few decades, several research has been conducted with the aim of investigating and describing the aspects of students' understanding of scientific concepts. Some studies investigated students' ideas that are at variance with scientifically accepted knowledge which are commonly called as alternative conceptions (Arnaudin and Mintzes, 1985; Vaz, Carola and Neto, 1997), preconceptions (Gallegos, Jerezano and Flores, 1994), alternative frameworks (Driver, 1981), erroneous ideas (Sanders, 1993) children science

(Gilbert, Osborne and Fensham, 1982), and misconceptions (Fisher, 1985). To create a unity in this study, the term 'misconception' will be used to denote any ideas held by students that are inconsistent with the scientifically accepted knowledge.

Misconceptions are simply the incorrect ideas which are very popular among the students and even among the teachers. They are the alternative wrong ways of thinking. Students bring to lessons ideas and preconceptions which influence the course of their learning. It was demonstrated that many misconceptions were already in place before formal teaching of the topic began (Seymour and Longden, 1991).

Misconceptions are said to be pervasive, stable and often resistant to change through traditional teaching methods (Amir and Tamir, 1994; Fisher, 1985; Westbrook and Marek, 1991). Several research was conducted to investigate students' understanding of science concepts: Cell (Dreyfus and Jungwirth, 1988), photosynthesis (Bell, 1985; Haslam and Treagust, 1987; Waheed and Lucas, 1992; genetic (Lewis, Leach and Wood-Robinson, 2000; Pashley, 1994), ecology (Griffiths and Grant, 1985; Munson, 1994; Kinchin, 2000), respiration (Seymour and Longden, 1991; Sanders, 1993), classification (Trowbridge and Mintzes, 1988), mechanics (Oliva, 1999, 2003), genetics (Lawson and Thompson, 1988), food (Lee and Diong, 1999), diffusion and osmosis (Odom and Barrow, 1995), the circulatory system (Yip, 1998), and energy (Boyes and Stanisstreet, 1991). The findings of these studies revealed that students have misconceptions about many science concepts.

In order to eliminate these misconceptions, it is necessary to identify the sources of these misconceptions. Sanders (1993) suggested three categories of source that influence the development of misconceptions. These are: the misconceptions resulting from everyday experiences, the unscientific use of everyday language, misconceptions forming as a result of incorrect concept formation by the learner during formal schooling, and misconceptions that are learned when incorrect information is taught either by the teachers or the textbooks.

Many word in science are used in an alternative way in daily life, for this reason, some misconceptions may arise from the use of words that mean one thing in everyday life and another in a scientific context such as food, respiration, and population. Bell (1985), in one of her studies, suggests that words 'energy' and 'food' are often used in everyday sense of being 'energetic' and needing 'to stay alive' and 'be healthy'. Therefore, students have a concept of food that is variable and context-dependent. Gilbert et al., (1982), say "the word –particle- is scientifically used to mean atom, molecule or ion. However, in daily life it refers to small but visible piece of solid substance. Consequently this situation result in misapplication of that while explaining the air made up of small particles".

It has been also shown that teachers are sometimes served as a source of misconceptions (Sanders, 1993; Yip, 1998). These studies suggest that misconceptions pass from teachers to students through inaccurate teaching. Another factor that contributes occurrence of misconceptions is the assessment strategies used by the teachers. Sanders (1993) suggests that

"teachers should not only assess to get mark for the pupils. They need to listen to what their pupil tell them, as it can provide information about pupils' understanding or lack thereof. Pupils require constant feedback about their correct and incorrect ideas".

Another factor that contributes occurrence of misconceptions is textbooks, which include many errors and incorrect information (Barras, 1984; Stern and Roseman, 2004; Storey, 1991, 1992). For example, majority of students believed that photosynthesis and respiration function in an opposite and contrasting manner. Some textbooks encourage this view by presenting tables that compare and contrast the reactants, products, and equations of photosynthesis and respiration (Stern and Roseman, 2004). Likewise, many concepts in science are interrelated and they are keys to understanding other concepts. Therefore, not only lack of integration among topics but also inappropriate presentation of topics in textbooks influence students' further understanding. For example, without understanding of photosynthesis, the concepts of food chain and food web are meaningless to students. However, before photosynthesis, students must understand the distinction between producers and consumers, as well as organic and inorganic molecules (Özkan, 2001). Sanders and Cramer (1992) suggested that misconceptions about respiration might be developed by students' inability to link new information about respiration to concepts related to digestion, photosynthesis, and energy in food chains. Similarly, in many curricula, the topic of respiration is introduced relatively early in the course and inserted in somewhere between osmosis and mitotic cell division (Songer and Mintzes, 1994). They suggested

that "respiration and photosynthesis are better understood within the context of energy flow in natural ecosystems, following a consideration of important physiological topics such as gas exchange, digestion and transport mechanism".

To sum up, it can be said that children hold misconceptions that are developed before and during their school years, and these misconceptions may be compounded by daily life experience, use of everyday language in a scientific context, compartmentalization of concepts, teaching strategies, and textbooks. All these factors seem to be not only results in rote learning but also defeat the goal of the science education to promote meaningful learning.

2.2.1. Misconceptions in photosynthesis and respiration in plants

Photosynthesis is a biochemical process in which energy-rich organic nutrients are produced from simple inorganic molecules found in the environment. It is one of the most extensively studied areas in science education. Several studies in many countries have investigated students' understanding of photosynthesis and respiration in plants concepts (Soyibo, 1983; Wandersee, 1983, 1985; Smith and Anderson, 1984; Bell, 1985; Haslam and Treagust, 1987; Stavy, Eisen and Yaakobi, 1987; Eisen and Stavy, 1988; Barker and Carr, 1989a,b; Anderson, Sheldon and Dubay, 1990; Wood-Robinson, 1991; Seymour and Longden, 1991; Waheed and Lucas, 1992; Sanders, 1993; Smith, Blakeslee and Anderson, 1993; Hazel and Prosser, 1994; Amir and Tamir, 1994, 1995; Vaz, Carola and Neto, 1997; Canal, 1999; Mason

and Boscolo, 2000; Griffard and Wandersee, 2001; Mikkila, 2001 Carlsson, 2002; Stern and Roseman, 2004; Marmaroti and Galanopoulou, 2006). These studies reported a number of frequently held views of the concept which are at variance with accepted scientific thinking. There is a widespread confusion in students' minds between photosynthesis and respiration in plants, and that students frequently believe that plants get their food from the soil (Wood-Robinson, 1991). For example, Stavy et al., (1987) found a well-known confusion between photosynthesis and respiration in plants in Israeli students (aged 13-15). More than 60% of their sample regarded photosynthesis as a type of respiration. They believed that plants respired at night in a similar way to animals, however during the day the process was reversed. The rest of the sample (40%) did not know that plants respire at all. In a separate study, Amir and Tamir (1994) found that majority of Israeli students (grades 11th and 12th) accepted that plants did not respire at all.

In a further study, Wandersee (1983) working with American students (aged 10-18) demonstrated that students' ideas about photosynthesis do change as they move through educational system, but that there is little improvement in their understanding of certain aspects of the process, such as the roles of water and chlorophyll, the importance of carbon dioxide as the major raw material and the product of photosynthesis. In his study Wandersee (1985) highlighted some historical findings related to plant nutrition, photosynthesis and its role in energy flow. The most famous one among those was the Van Helmunt experiment. Van Helmunt, in his experiment, planted a willow tree in a pot and recorded the weight of the

plant and amount of soil. He watered the plant as needed. Five years later, he weighed the tree and the amount of the soil again. He observed that although the tree gained a lot of weight, the soil had lost very little. As a result of this experiment, he concluded that the tree had derived all its growth from the water, not from the soil or air. Wandersee (1985) suggested that history of science can serve as valuable adjunct for modern science teaching.

One way in which researchers diagnose misconceptions is to use paper and pencil tests with a multiple-choice format. This would allow researchers easily identify students' understanding of science concepts. Multiple choice tests have been used to evaluate students' content knowledge, but they have limitations with determining students' reasoning behind their choices. Therefore, two-tier diagnostic tests are commonly used instead of a multiple choice test. Haslam and Treagust (1987) developed a two-tier multiple choice instrument in order to diagnose secondary school students' misconceptions about photosynthesis and respiration in plants concepts. They studied with 438 secondary school students in Australia and identified several misconceptions of photosynthesis and respiration in plants concepts:

- Respiration in green plants takes place only during the day
- Photosynthesis occurs in green plants all the time
- Green plants respire only when there is no light energy
- Green plants make their food from oxygen gas in the presence of light energy
- Respiration in plants takes place in the cells of the leaves only since only leaves have special pores to exchange gases

- Respiration in plants is a chemical process to obtain energy which occurs in plants cells but not in animal cells
- Respiration in plants is the taking in of carbon dioxide and giving off of oxygen gases through the stomates
- Green plants respire only at night
- In the process of respiration carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen are produced
- The green pigment called chlorophyll combines with the carbon dioxide in the presence of light energy and produces glucose and water
- Respiration takes place in all plants only when there is no light energy and in all animals all the time

Soyibo (1983) identified many misconceptions in Nigerian students (aged 15-19). He demonstrated that 87% of their sample accepted that only animals used oxygen for respiration and 45% believed plants respired only at night. The belief that respiration is taking oxygen in and giving carbon dioxide off was shared by 90% of the students sampled. The studies reviewed by Bell (1985) showed that many secondary school students of varying ages have alternative ideas about plants' food. She reported that many of the students regarded plant food as anything taken in by the plant from outside, such as water, minerals and air. Stavy et al. (1988) investigated students' (aged between13-15) understanding of photosynthesis. They reported that students

perceive photosynthesis as the gas exchange process which is considered as same with respiration. They also found that students conceived photosynthesis as the reverse of respiration. Barker and Carr (1989a; b) investigated 13-17 years olds students' understanding of photosynthesis in New Zealand. They reported that after teaching by the guided discovery strategy on photosynthesis only 19% of the 13 years old students grasped the idea that photosynthesis produces carbohydrate and 54% regarded photosynthesis as a food-making process.

Research also showed that most of the students have misconceptions about respiration (Haslam and Treagust, 1987; Eisen and Stavy, 1988; Seymour and Longden, 1991; Amir and Tamir, 1992). For example, Seymour and Longden (1991) searched the understanding of the topics of gaseous exchange and respiration by means of questionnaires, diagnostic tests and interviews with students aged between 13 and 16. The results revealed that these topics are poorly understood by pupils and poorly known by teachers. The diagnostic test responses were used to draw up a list of specific misconceptions. Among that list, a common misconception held by 27.3% of the students is that 'plants do not respire; they photosynthesize instead'. Moreover, 21.6% of the students think that 'plants use up carbon dioxide when they respire and produce oxygen. Another general conception about respiration was that plants respire only at night (Haslam and Treagust, 1987, Amir and Tamir, 1992) Seymour and Longden offer that these misconceptions may arise and be perpetuated in the minds of children because of the use of imprecise language in the teaching of respiration. They suggested that such

imprecision in terminology does not allow children to distinguish between the meaning of words used in a scientific context and their meaning when used as a part of everyday language.

Several research reported students' responses to the conception of plants' food as the materials that plants take in from their environment such as water, soil, minerals and carbon dioxide (Anderson, Sheldon and Dubay, 1990; Eisen and Stavy, 1988; Lumpe and Staver, 1995; Smith and Anderson, 1984). Anderson et al. (1990) for example, reported that students defined photosynthesis as 'food making process' but they did not define food for plants correctly. According to them, since students 'parrot back memorized items', they cannot answer questions that need application of those terms.

Wood-Robinson (1991) reviewed some of the research studies about plants and grouped the findings under the following headings: the role of soil, the role of leaf, the role of chlorophyll, gas exchange and plant nutrition. Some examples of the findings are provided in Table 2.1.

Table 2.1. Common Misconceptions about photosynthesis and respiration in plants

The role of soil
The soil loses weight as plants grow in it
The soil is the plant's food
Roots absorb the soil
Soil has nothing to do with plant growth

Table 2.1. continued

Plants get protein from the soil
Plants get vitamins from the soil
The soil supplies most of the raw materials for photosynthesis
People put food (fertilizer) in the soil for plants to eat
The role of the leaf
The leaf's main job is to capture the rain and the water vapor in the air
The leaf's main job is to capture the sun's warmth
Leaves drink in the dew
Rain goes in the holes on leaves
Leaves change color because they can't breath
The role of chlorophyll
Chlorophyll is the plant's blood
The chemical that absorbs sunlight in leaves is 'chlorine' or 'chloroform' or 'chloraseptic'
Chlorophyll is no longer available in the air in fall so the leaf can't get food
In fall, chlorophyll can't get into the leaves from the trunk – a little valve in the leaf stem closes
Plants give off mainly carbon dioxide
Water vapor moves into the leaf during photosynthesis
Plants take oxygen out of the air during photosynthesis
Plant nutrition
Plants feed on water

Table 2.1. continued

Plants eat minerals
Plants get their food from the roots and then store it in their leaves
Plants change water into sugar
Plants produce protein in photosynthesis
There are things floating in the air for plants to live on
Food can't be made out of air
Plants convert energy from the sun directly into matter

In a very recent study, Marmaroti and Galanopoulou (2006) studied Greek students' (aged 13) understanding of photosynthesis. The results revealed that students were not able to conceive photosynthesis as a chemical reaction and they did not understand the role of chlorophyll. Some students thought that plants take all their nutrients from the environment, and they confuse photosynthesis with respiration. They also believed that respiration occurs when there is no photosynthesis.

Sanders (1993) investigated the teachers as a source of misconceptions about various aspects of respiration. A total of 136 teachers were asked to evaluate students' responses on a brief essay in which they defined respiration, its process, purpose and how it is linked to the acquisition of energy for life processes. The results showed that 77.2% of the teachers thought that the function of respiration in living organisms is to provide oxygen and remove carbon dioxide, and. Respiration is seen as a gaseous exchange process during which oxygen is taken in and carbon dioxide given

off by 42.6% of the teachers. 41.9% thought photosynthesis as the process that makes energy available for metabolism in plants.

Vaz et al. (1997) investigated the misconceptions of students in a biology and geology teacher education course regarding plant nutrition. Twenty three percent of the first year students answered that photosynthesis is the process that allows the plant to breath. Moreover, 65% of the first year students thought that the plant is nourished by absorbing nutrients through the root. Some other students thought that this nourishment is absorbed by the roots goes to the leaves.

Carlsson (2002) investigated the ways of understanding photosynthesis on ten prospective teachers by means of interviews. Photosynthesis is understood as a process in which some 'things' enter the plants and these are either transported through the plants, or simply used up. At the same time, some other 'things' are released. No explicit coupling exists between the initial components and the products of the photosynthesis. The plant itself is regarded as a kind of 'black box', the internal function of which is unknown. Simply, photosynthesis is seen simply in terms of input and output, in which the former is independent of the latter and vice versa. The findings of Bahar et al. (1999) also supported the findings, and stated that the 'chemistry of photosynthesis' is poorly understood.

More recently, Stern and Roseman (2004) examined nine comprehensive middle-school (Grades 6-8) curriculum materials which includes newly developed, commercially available materials funded by the National Science Foundation and textbooks that are widely used or

considered for use by selection committees. They note that the materials rarely care for transformations of matter and energy rather than just 'reactants' and 'products' Instead, the focus, both during instruction and in assessments, is on naming the reactants and products of photosynthesis and cellular respiration or on comparing the two processes. Similarly, instead of considering the energy transformations during photosynthesis and cellular respiration, most materials state, explain, and provide activities for the idea that light energy is necessary for making of sugars in plants. However, the idea that some of the light energy is transformed into chemical energy in the newly made sugars is usually ignored. Students usually think that light energy is a necessary 'ingredient' for photosynthesis to take place and it is used up like carbon dioxide and oxygen because many textbooks present light as a 'reactant' in the photosynthesis equation. Alternatively, students think that light is a 'facilitating agent' (just as light makes it possible for people to, say, read a book, so light makes it possible for plants to make food) rather than that light energy is converted to another form that is stored.

Eisen and Stavy (1988) identified several difficulties that students have in understanding of photosynthesis. For example, they stated that students had difficulty in treating the living body as a chemical entity and describing biological phenomena in chemical terms. They also reported that students tend to think of plants as dependent on man and not the other way around. This was reflected in their difficulty in understanding of autotrophic feeding. It is also claimed that students knew many separate items of detailed information related to photosynthesis but they lacked a meaningful overall

view. Authors mentioned that these problems originated from inadequate knowledge in chemistry, physics and biology. For instance, students' understandings of the photosynthesis influence their understanding of concepts of food chain and food web. Thus, students who understand photosynthesis from the scientific viewpoint can also understand how photosynthesis is related to other concepts and appreciate the central role of the photosynthesis in ecosystem. Moreover, the lack of prior knowledge in chemistry creates obstacle to understand biochemical aspect of photosynthesis (Amir and Tamir, 1994). Students' difficulties with photosynthesis can be also attributed to fundamental misunderstanding about how matter and energy are used and transformed in living systems (Anderson et al., 1990)

Although photosynthesis has been addressed with many populations of students, it has received little attention in Turkey. Çapa (2000) interviewed with ninth grade students to determine their misconceptions about photosynthesis and respiration in plants concepts. The findings revealed a total of 67 misconceptions which are commonly about the plant nutrition, role of water and leaves in plants, gas exchange, autotrophy, the definition and importance of photosynthesis, role of light in photosynthesis, energy transformation, respiration in plants, and the relationship between photosynthesis and respiration in plants.

In another study, Tekkaya and Balcı (2003) investigated high school students' understanding of photosynthesis and respiration in plants. Results of the study revealed that most of the students had misconceptions like, "photosynthesis is a gas exchange process", "plants take their food from soil",

"plants respire only at night" and "photosynthesis is the reverse of respiration", which are very consistent with the findings of other studies reported in the previous section.

Briefly, these studies revealed that the majority of students at all grade levels hold misconceptions about photosynthesis and respiration in plants concepts and the traditional instruction is not an effective way to eliminate these misconceptions. One of the alternative strategies to eliminate misconceptions is the use of conceptual change approach.

2.3. Constructivism

Constructivism is a theory about knowing and learning that asserts that knowledge cannot be directly transmitted but must be actively constructed by learners (Wu and Tsai, 2005). Eggen and Kauchak (1994) defined constructivism as a view of learning that says learners use their experiences to actively construct understanding that makes sense to them, rather than acquiring understanding by having it presented in an already organized form. This theory emphasizes the significance of learners' prior knowledge in subsequent learning.

In a constructivist classroom, knowledge is constructed by students own explanations and active participation in learning. The role of teacher is to provide the necessary environment, guide the students through the learning process, and help them to identify their misconceptions. From the constructivist view, misconceptions are important because they cannot be

erased just by telling the students the scientific explanation of the concept. Teacher should be the facilitator and help the student in diagnosing and eliminating the misconceptions.

The constructivist-oriented instruction promotes students' meaningful learning (Taylor and Fraser, 1991). Meaningful learning is defined as "the formation of viable relationships among ideas, concepts, and information" (Williams and Cavallo, 1995) and it has been strongly advocated by science educators (Mintzes et al., 2001).

Piaget (1950) described three phases through which meaningful learning occurs: assimilation, accommodation and equilibrium. Piaget believed that when a learner encounters input from the environment, the learner's schemes or mental structures incorporate the experiences. This is called assimilation. If newly assimilated information conflicts with previously formed mental structures, disequilibrium occurs, and this motivates the learner to seek equilibrium. If the existing scheme is revised or changed due to the new experience, accommodation occurs. Assimilation and accommodation represent the learner's adaptation to the environmental input (Williams and Marek, 1999) and equilibrium occurs when cognitive stability is created through assimilation and accommodation.

There is no doubt that the perspectives of constructivism in learning and teaching have profound influences on the development of science curriculum and science teaching process (Staver, 1998). Therefore, some teaching strategies based on constructivism are developed in science education, and many of them were found to improve students' performance

in science learning, such as, concept mapping (Kinchin, 2000); learning cycle (Lawson, 2001) and conceptual change instruction (Vosniadou *et al*., 2001, Tsai, 2000; Beeth, 1998; Smith *et al.,* 1993; Hewson and Hewson, 1983).

2.3.1. Conceptual Change Approach

Conceptual change approach has become one of the approaches most investigated by cognitive and educational psychologists as well as science educators interested in the learning processes that take place during the implementation of curriculum materials (Mason and Boscolo, 2000). Research on learning and instruction has shown that humans construct individual knowledge systems on the basis of their everyday experiences (Mason and Boscolo, 2000) and their individual knowledge is usually incompatible with the scientific knowledge. Individuals often do not see the reason to change their everyday beliefs since they provide good explanations of their everyday experiences which are tied to years of conformations (Vosniadou et al., 2001). Therefore, conceptual change learning is required in the class to re-organize the existing knowledge.

To learn science in a meaningful way means realigning, reorganizing, or replacing existing conceptions to accommodate new ideas. Theoretical models describing learning as an active process in which learners become aware of and reason about conceptual relations or describe learning as a process of conceptual refinement has been called conceptual change (Smith et al., 1993). Conceptual change theory, based on Piagets' notions of assimilation,

accommodation, and disequilibrium, focuses on the conditions where students' existing conceptions are modified by new conceptions. The conceptual change approach proposes two types of conceptual change, assimilation that describe the process where students use existing concepts to deal with new phenomena and accommodation which describe when the students must replace his concepts. According to Posner et al. (1982) four conditions are necessary for an accommodation to occur:

- There must be dissatisfaction with the existing conceptions. The learner must first encounter difficulties with an existing conception to consider a new one seriously.
- The new conception must be understandable. When the learner constructs a meaningful representation of the theory, it becomes a tool of thought.
- The new concept must appear initially plausible. It must be consistent with other concepts.
- The new concept should be fruitful. It should have the potential to be extended.

Asking the explanations of discrepant events, which is defined as a happening contrary to our current beliefs, and discussing the misconceptions may cause the students be aware of their own ideas, and dissatisfaction to occur. The teacher should ask for explanations, show the discrepancies, and encourage the students to discuss. Understanding the conception can be done

by constructing frameworks for the new idea and judging it to be consistent with other theories, beliefs and experiences. The teacher should encourage the students to develop ideas by using various illustrations and by focusing on some explanations that lead the students to minimal understanding of the new concept. The full understanding requires the sense of fruitfulness of the new idea. The students should see how the new conception helps make sense of new experiences, how it helps to explain familiar phenomena, and how it leads to new insights. Teaching strategies should engage students to modify their explanations in the light of new information and develop explanatory and problem-solving skills (Smith et al., 1993).

Hewson and Hewson (1983) investigated the effect of instruction constructed by using students' prior knowledge and conceptual change strategies on science learning. In developing the instructional strategy and materials, the researchers primarily concerned with students' misconceptions and prior knowledge about the concept. The concepts involved were mass, volume and density. A total of 46 students (ages ranging from 13 to 20) constituted the experimental group and received the developed instructional strategy. The control group involving 44 students at the same age range was taught the same concepts by using a traditional strategy and materials. Pre- and post-tests were used to assess the conceptual change that occurred in both groups. The results revealed that the experimental group showed a significantly larger improvement in the acquisition of conceptions as a result of the instructional strategy and materials used.

Smith et al. (1993) examined the use of teaching strategies associated with a conceptual change model of science teaching. A total of 13 seventh grade life science teachers taught units on photosynthesis, cellular respiration, and matter cycling in ecosystems in their regular classes under conditions varying as to whether or not conceptual change oriented instructional materials and training sessions were provided. The materials prepared by the project were used by nine teachers for the photosynthesis unit and by five teachers for the cellular respiration unit. No special materials were provided for the matter cycling unit. The materials included were student texts with workbook-style questions, overhead transparencies, and laboratory activities. As they reported, conceptual change strategies were used more often in class discussions by the groups using these materials. The results of the study indicated that these strategies promoted conceptual change learning. Students in classes where teachers were provided with these materials tended to perform better than those where such materials were not provided. The effect of the materials on student learning was strong especially in the photosynthesis unit. Differences among teachers using and not using the materials were significant for the photosynthesis unit and it approached to significance for the respiration unit.

Tanner and Allen (2005, p.115) offer some concrete implications of conceptual change theory that can guide instructional choices. They suggest that teaching toward conceptual change can significantly influence:

1. differentiation of instruction, namely choices about course goals and time spent on different topics

2. the extent to which one engages students in identifying their own preconceptions as part of the learning process, using a variety of approaches
3. using alternative conceptions to craft diagnostic "wrong answers" in assessment tools
4. designing assessment to detect conceptual change.

In summary, what a student learns results from what the student already knows and what is experienced during the instruction. Therefore, teaching strategies are important in facilitating meaningful learning. Conceptual change texts are one of the strategies used to eliminate misconceptions, and promote meaningful learning. The conceptual change texts are designed to make students aware of the shortage of their intuitive ideas and create conceptual conflict described as a necessary basic for conceptual change (Uzuntiryaki and Geban, 2005).

Conceptual change texts were designed to improve the conceptual understanding of the concepts. The text detects students' misconceptions by presenting some explicit examples that allow the students to present their misconceptions when making a prediction about a situation. Also, some questions are presented to create disequilibrium between students' preconceptions and the scientific phenomena. Then, the text presents evidence that their existing knowledge is insufficient and supports partial understanding. An explanatory part is included then, presenting the scientifically correct explanation. The explanatory text is discussed with the

students. Discussion helps student further understanding of the scientific concept and realizing the limitations of their own ideas (Uzuntiryaki and Geban, 2005).

Constructing a conceptual change text from the beginning sometimes requires a lot of teacher and student effort and time, and they are unsuitable for large group educational situations. Therefore, conceptual change texts can be inserted to traditional texts. Wang and Andre (1991, p.115) offer a set of guidelines for modifying science texts to conceptual change texts which improve the conceptual understanding. The guidelines include:

- identifying common misconceptions about the subject matter
- activating students' misconceptions by presenting simple examples that allow the misconceptions to be used to make a prediction about the situation
- presenting descriptive evidence in the text that the typical misconceptions are incorrect
- providing a scientifically correct explanation of the situation
- giving students the opportunity to practice or apply the correct explanation by using adjunct questions

In their study, Wang and Andre (1991) investigated the effect of conceptual change text and application questions on students' understanding of electricity concepts. The sample was 139 college students who did not take any college physics courses. The researchers designed a conceptual change

text by making changes on a traditional text. They asked the students read and study the texts on their own. The purpose was to activate the students' existing schemata and provide information countering the misconceptions. The results of the study revealed that conceptual change text and the application questions led to superior performances on understanding of electricity concepts.

Chambers and Andre (1997) examined the conceptual understanding of electrical concepts by administering a conceptual change text and a traditional didactic text. To change the misconceptions, strategies to promote conceptual change by challenging students' misconceptions were used. Dissatisfaction with the existing knowledge was created and it is followed by a correct explanation which is both understandable and plausible to the students. The results of the study showed that conceptual change texts lead to a better understanding of the concept. The researchers have also investigated the relationship between gender and conceptual change. While girls were initially lower than boys, they made faster over the course of the experiment. By the post-test, they were not significantly different from the boys. Similarly, in the conditions most similar to typical classroom situations, conceptual change text, as compared to traditional text, improved understanding of simple electric circuits concepts (Wang and Andre, 1991).

Conceptual change concerning photosynthesis is studied by Mikkila-Erdmann (2001). A total of 209 students (aged from 10 to 11) participated in the study. The students either received a traditional text or conceptual change text about photosynthesis. The conceptual change text took some common

misconceptions about photosynthesis into consideration and tried to foster metaconceptual awareness. According to the results, students who studied the conceptual change text performed statistically better than the traditional text group on questions which demanded construction of an adequate mental model of photosynthesis.

Besides conceptual change texts, refutational texts are also used to foster conceptual understanding. The major difference between refutational texts and conceptual change texts involves whether students are asked explicitly to make a prediction about a situation. In conceptual change texts before scientifically true explanation is given, students are asked some questions to activate their misconceptions about the related subject. In refutational texts, these misconceptions are contrasted with the scientific conceptions but the students are not asked first to make prediction before the refutation is given (Guzzetti et al., 1997), Hynd et al. (1994) studied the effects of the three variables (demonstration, discussion and refutational texts) about Newton's' laws of motion. A number of 310 students were randomly assigned within classes to the groups and the pre-test, treatment and post-test are conducted. The post-test results showed that, of the three instructional variables, refutational texts had the strongest overall effect. Despite the objections of science educators and the dislike of texts by students, the subjects in this study did better after reading the refutational texts. Students who discussed in a group or saw demonstrations used science terms without demonstrating that they understood them. Sönmez (2002) found that refutational text accompanied with discussion web oriented instruction was

more effective than traditional instruction on understanding electric current concepts. In another study, Hynd, Alvermann and Qian (1997) investigated whether the combination of demonstration and reading enabled preservice teachers to overcome their prior conceptions or not. The preservice teachers who made predictions and saw demonstrations before reading a text did significantly better than the group of teachers who just read the text.

The importance of prior knowledge on conceptual change was investigated by the study of Vosniadou et al. (2001). They designed a learning environment by paying attention to students' prior knowledge, to the use of measurements, representations and models, and to use cognitive conflicts. Moreover, attention was also paid to the sequence of the concepts to be taught and discussions were made to make the students aware of the differences between their everyday language meanings and scientific meanings of some words. This learning environment was used to teach mechanics to fifth-graders. Two groups, one experimental and one control group, were included in the study. The findings suggested that the experimental group receiving the designed learning environment had significantly higher cognitive gains than the other group.

The most recent study conducted by Kang et al. (2005) explored the relationships among students' cognitive/motivational variables, cognitive conflict and conceptual change. The cognitive/motivational variables were the tests of logical thinking ability, field dependence/independence, meaningful learning approach, failure tolerance, mastery goal orientation and self-efficacy tests. Computer-assisted instruction was used as a conceptual change

intervention for the density concepts. The sample was 159 seventh grade students. Results of the study showed that logical thinking ability, field dependence/independence and failure tolerance significantly contributed to the variance in conception test scores. Logical thinking ability accounted for the highest variance (28%), while the field dependence/independence and failure tolerance accounted for the 4% and 3% of the variance, respectively.

In Turkey, Sungur, Tekkaya and Geban (2001) investigated the effect of conceptual change texts accompanied by concept mapping instruction, science process skills and prior knowledge on tenth grade students' understanding of the human circulatory system. The results revealed a statistically significant contribution of treatment, science process skills and prior knowledge on students' understanding of human circulatory system. The conceptual change texts accompanied with concept mapping instruction produced a positive effect on students' understanding of the concept. In another study, Özkan, Tekkaya and Geban (2004) studied the effect of conceptual change texts oriented instruction on seventh grade Turkish students' understanding of ecological concepts. Using the related literature and the information collected through interviews, the researchers developed an Ecology Concept Test. Results revealed a statistically significant difference between the gain score means in favor of the group receiving conceptual change based instruction. Similarly, Uzuntiryaki and Geban (2005) investigated the effect of conceptual change texts accompanied with concept mapping instruction on eighth grade Turkish students' understanding of solution concepts. The researchers also investigated the students' attitudes towards science. The results revealed that

conceptual change text accompanied with concept mapping instruction resulted in a significantly better understanding of the solutions concept and produced significantly higher positive attitudes towards science. In this study, reasoning ability and prior knowledge were found to be strong predictors of concept learning of solutions.

It is also reported that the more pronounced effects have been obtained when text was combined with some type of supportive activity such as small group discussions after reading the texts (Guzzetti, 2000) or discussion webs (Alverman, 1991). A discussion web is found to be an appropriate way to structure discussion and an effective way of altering students' misconceptions (Alverman, 1991; Guzzetti, 2000, Sönmez, 2002). It is a special kind of graphic type tool providing students to look at both sides of an issue before drawing conclusions (Alvermann, 1991). It helps students to visualize the key elements of the issue, and allow them to see the opposing points and evaluate the arguments. A discussion web uses a graphic aid in which a central question or statement is put in the center; students are asked to choose a position, agree or disagree, and list their reasons for their positions on lines present on either side of the question. Students should support their ideas by evidence, such as statements from the different kind of documents. Students are directed to reach consensus on their positions by discussing in small groups. At the end, whole class is involved in the discussion to reach a consensus. By this way misunderstanding or misread of conceptual change text is prevented.

Alvermann (1991) suggested five steps that teachers and students typically proceed through in completing a Discussion Web:

- Students should be prepared to read an issue by activating their background knowledge, introducing new vocabulary and setting the purposes for reading.
- After the students read the issue, and satisfied their own purposes for reading, a question with YES and NO options is presented, and students are asked to discuss the question with their partners and write down the reasons behind their answer.
- As the partners wrote down their reasons, one set of partners are paired with another set of partners; and the group of four students are asked to compare their reasons to draw a conclusion.
- When each group of four reached a conclusion, the groups are asked to select a reason that best supports group's conclusion; and a spokesman, either selected by the teacher or the group itself, is asked to present that selected reason.
- As the final step, individual students are asked to write their answers to the discussion web question by including their own ideas as well as those expressed by others.

In addition to discussion web, the role of writing in affecting conceptual change is also important since writing tasks require students to reflect upon the differences between their own conceptions and the correct ones (Mason and Boscolo, 2000). When writing a task, the thoughts are clarified and reflected, and the writer is forced to make his or her thoughts more precise. Thinking is reinforced by writing and writing is used for

thinking and reasoning in the process of developing understanding. In their study, Mason and Boscolo (2000) investigated the role of writing both on knowledge development and conceptualization and evaluation of the writing activity itself. The sample was 36 fourth graders. Findings showed that a better conceptual understanding is achieved in the experimental group where writing activity is implemented as well as the writing activity itself functioned. Mason and Boscolo (2000, p.201) suggests two functions of writing; one from the point of view of the subject, the other from the experimenters point of view. On one hand, the subject can express and clarify his or her ideas, while on the other; the experimenter can analyze several aspects of conceptual change through writing.

Educators proposed that the integration of multiple teaching strategies could promote students' conceptual learning and knowledge construction in science (e.g. Odom and Kelly, 2001; Sungur, Tekkaya and Geban, 2001; Sönmez, 2002; Uzuntiryaki and Geban, 2005). In line with this idea, in the present study, a teaching strategy associated with conceptual change learning - conceptual change texts accompanied with 'writing for learning' and 'discussion webs' - was used to promote conceptual change concerning photosynthesis and respiration in plants concepts.

2.4. Research on Reasoning Ability

Piaget identified four stages of cognitive development which are the sensory motor, pre-operational, concrete operational and formal operational

stages. Understanding may depend upon individual's operational reasoning level: concrete or formal (Johnson, 1993). The individual at the concrete operational stage perform observable operations but not non-observable or imaginatory. The systems of thought relate directly to objects, not to verbally stated hypotheses. The concrete operational reasoner is not aware of the methods of generating and testing possible alternative hypotheses (Lawson, Abraham and Renner, 1989; cf. Johnson, 1993).

On the other hand, formal operational reasoners are aware of the process they use to generate or test the possible alternative hypotheses. "They are able to think *about* a theory, in contrast to concrete reasoners who are limited to thinking with a theory" (Johnson, 1993, p.44). The formal operational reasoners may analyze data in a complete, consistent and systematic way.

Successful learning in science requires an abstract thinking ability which begins with the development of formal reasoning ability of the individual. The five formal reasoning modes consisting of controlling variables, proportional, probabilistic, correlational and combinational reasoning are essential abilities for success in secondary school science and mathematics courses (Bitner, 1991; Lawson, 1982). Even by considering this importance, some authors have urged that the development of formal reasoning ability should be a major priority in science education (Lawson, 1982) and in eliminating the misconception in science (Lawson and Thompson, 1988; Oliva, 2003).

In line with this idea, researchers give special interest to students' reasoning abilities, methods to develop it and to the factors affecting it. Among these factors, the mostly studied ones are the effect of gender, prior knowledge, meaningful learning, instructional treatment, and the role of achievement (BouJaoude and Giuliano, 1994; Valanides, 1996; Cavallo, 1996). For example, a research investigating students' formal reasoning level was conducted by Lawson (1978). The sample was 523 students from eighth grade to tenth grade. He found that both formal reasoners and concrete reasoners exist among the school children. 35% of the students were at concrete level, 15% at the formal operational level, and 50% at a level in between that Lawson called "transitional", a level implying the early beginning of formal thought. According to Lawson, formal reasoners relate newly acquired concepts to the previously learned knowledge directly by apprehending verbal or symbolically stated relationships while concrete reasoners rely on concrete experiences to aid in understanding abstract concepts. Based on this, Lawson concludes that students who are still reasoning at the concrete level would have difficulty in learning science in an abstract verbal way (Lawson, 1978).

Tobin and Capie (1982) investigated the relationships between middle school students' reasoning ability, locus of control, academic engagement and process skill achievement in science. Formal reasoning ability found to be the strongest predictor of process skill achievement and retention, accounting for 36% of the variance, and it was positively correlated with engagement, generalizing and comprehending.

Lawson and Thompson (1988) found that reasoning ability is significantly related to the number of misconceptions. Their study with seventh grade students on genetics concept showed that better reasoning ability and larger mental capacity corresponded with fewer misconceptions and formal reasoning patterns are necessary for the elimination of some biological misconceptions.

Recently, the effect of reasoning ability on changing the misconceptions related to mechanics was investigated by Oliva (2003). The results of the study showed that the students with higher levels of formal reasoning tend to have misconceptions that are more structured than the ones having lower levels of formal reasoning. The results also showed that those students having higher levels of formal reasoning tend to change their alternative conceptions more easily.

A study, conducted by Kwon and Lawson (2000) ascertained that maturation of the brain during adolescence is highly correlated with scientific reasoning ability including the capacity to reject misconceptions and accept scientific conceptions.

Valanides (1996) examined seventh-, eighth-, and ninth-grade students' reasoning abilities, and the differences between males and females related to five reasoning modes. Only a small percentage of students (13.9%) have reached the formal operational stage, while 21.5% were at transitional, and 64.6% were at concrete stage. No significant differences were found between males and females on any of the five reasoning modes. Valanides also investigated the effect of grade level among the students of seventh-, eighth-

and ninth-grades on these five reasoning modes. He found a significant effect of grade level on student performance only on the problems related to proportional reasoning. The Scheffe test results revealed that ninth-grade students performed better than seventh graders on proportional reasoning. Moreover, mathematics and science achievement found to be significantly contributed to the prediction of reasoning ability but explained a small percentage of the variance (1.9% and 3.7%, respectively). In another study, Valanides (1997) investigated the formal reasoning abilities of students attending different sections of upper cycles of secondary schools. A total of 469 twelfth-grade students from four schools in a city of Cyprus were participated in the study. The sections were the science, the economic, the commercial, the classical, and the foreign languages sections. The commercial, the classical and the foreign languages sections were combined to form a 'unified section' because the number of students attending these sections was small. The results showed that 49.7% of the students were at the formal, 29.2% were at transitional, and 21.1% were at concrete stage of cognitive development. Boys did better than girls on controlling variables and probabilistic reasoning. The statistical analysis showed that gender predicted the 6.6% of the variance on reasoning ability. The students attending the science and economic sections did significantly better in all five reasoning modes than the students attending the 'unified' section. Section of study is also a significant predictor of reasoning ability, explaining 9.2% of the variance. Besides gender and section of study, achievement in mathematics and grade point average were also found to be significantly contributed to the

prediction of reasoning ability, but they explained smaller proportions of variance (3.6% and 0.07%, respectively). In a separate study, Valanides (1997) investigated the reasoning abilities of twelfth-grade Cypriot students with the participation of 132 students. A high percentage of the students (72.8%) were at formal operational stage, 22.8% were at transitional stage, and 4.4% were at the concrete stage of cognitive stage. The researcher also explored the differences between male and female students with respect to their reasoning abilities, and examined their performance on problems related to five reasoning modes. Males were found to have superior performance than females on probabilistic reasoning items. Valanides also examined the contribution of reasoning ability on students' grades in mathematics, physics, chemistry, Greek language, and their grade point average (GPA). He found that reasoning ability accounted for the 22.8% of the variance in mathematics achievement, 14.1% in physics achievement, 12.0% for chemistry achievement, 2.9% in Greek language achievement, and 12.5% in their GPA. Moreover, Sungur and Tekkaya (2003) investigated the effect of gender and reasoning ability on the human circulatory system concepts achievement and attitude toward biology. 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 a statistically significant mean difference between concrete and formal students with respect to those variables.

Johnson and Lawson (1998) explored the effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry

classrooms. Learning cycle instruction is used in inquiry classrooms. Subjects were 366 college students. The results did not suggest a significant correlation between prior knowledge and achievement in both expository and inquiry classrooms. On the other hand, reasoning ability significantly correlated with achievement on final examination in both the expository and inquiry classrooms. Reasoning ability explained 7.2% of the variance in inquiry classrooms, and 18.8% in expository classrooms. Vass, Schiller and Nappi (2000) investigated the effect of instruction to improve the reasoning skills of university students majoring in education. The researchers thought that such reasoning skills were important for the students who wanted to become teachers of mathematics or science. However, the results demonstrated a lack of proficiency in formal reasoning. This study provided evidence that students could improve their reasoning skills given a specific instructional intervention. The instructional intervention was three 20 min lectures each on the topics of proportionality, probability and correlations. In a recent study, Robinson (2004) studied whether success in conceptual understanding of mass/volume relationship and density concepts are based mainly on formal reasoning abilities of sixth grade students. Hands-on and group consensus activities as well as textbook and work sheets were used in the instruction. The results of the study showed that understanding the concept density is not mainly based on their ability to utilize formal reasoning abilities. However, the researcher suggests that this result may arise from the lack of the reliability of the instrument used to evaluate the content knowledge about density. Recently in Turkey, Yenilmez, Sungur and Tekkaya (2005) studied

the effect of gender and grade level on students' reasoning abilities. A total of 174 sixth, seventh and eighth grade students participated in the study. Results showed that students attending higher grade levels had higher reasoning abilities and boys had higher reasoning abilities than girls.

2.5. Research on Meaningful Learning

Meaningful learning is defined as "the formation of viable relationships among ideas, concepts and information" (Williams and Cavallo, 1995). If the new knowledge is not associated with prior concepts, rote learning occurs. On the other side, if new knowledge is associated with pre-existing ideas, meaningful learning occurs. According to Cavallo and Schafer (1994) students who learn by rote are driven by memorizing facts and definitions, cannot apply this information to new problems, and they do not demonstrate the ability to interrelate concepts. These authors also state that students who exhibit meaningful learning have the ability to personalize concepts, link these concepts to their prior knowledge, and apply these newly learned concepts to solve problems.

Pearsall, Skipper and Mintzes (1997, p.195) described Ausubel's cognitive assimilation theory as

> … The most important idea is that human beings are, fundamentally, *meaning-makers*; and, furthermore, that meanings are constructed by forming connections between new knowledge and concepts that are part of an existing framework of relevant, domain-specific knowledge. The distinction between meaningful and rote learning depends on the extend to which individuals incorporate new knowledge into their existing frameworks in a nonarbitrary, nonverbatim,

> substantive manner. For meaningful learning to occur three criteria must be met: the material itself must have potential meaning (i.e., rather than a list of nonsense syllables); the individual must possess a framework of relevant, domain-specific concepts to anchor the new knowledge; and the individual must choose voluntarily to incorporate new concepts in a nonarbitrary, nonverbatim fashion (i.e., a condition referred to as a "meaningful learning set")

Students' meaningful learning of genetics topics was investigated in previous studies (Cavallo, 1996; Cavallo and Schaffer, 1994). The results show that meaningful learning orientation of students is the predictor of meaningful understanding of the genetics topics. Meaningful learning was found to be a variable that contributes to students' learning (Cavallo, 1996). Prior knowledge and instructional treatment were also found to be significant predictors of biology achievement (Cavallo and Schaffer, 1994). BouJaoude (1992) explored the relationship between high school students' learning approaches, prior knowledge, and attitudes towards chemistry and their performance on a misconception test. The results showed that students' prior knowledge and learning approach accounted for a statistically significant proportion of the variance on students understanding. Prior knowledge accounted for the 27% of the variance while learning approach for 12%. The meaningful learners performed significantly better than the rote learners. In a similar study, BouJaoude (1994) investigated the relationships between students' approaches to studying, prior knowledge, logical thinking ability, and gender and their performance in a college chemistry course. The results suggest that females had higher meaning orientation than males. On the other hand, males had higher reasoning abilities than females. Prior knowledge,

reasoning ability and meaning understanding were significant predictors and accounted for 32% of the variance on final examination scores. Cavallo (1992) examined the predictive influence of meaningful learning orientation, prior knowledge and instructional treatment on tenth-grade students' retention of meaningful understanding of meiosis and Punnett square method. Students' retention of meaningful understanding of meiosis was found to be predicted by students' meaningful learning orientation and prior knowledge of meiosis. However, none of the predictor variables found to predict students' retention of meaningful understanding of the Punnett square method. In another study, learning approach was again not associated with conceptual understanding of chemistry concepts (BouJaoude and Barakat, 2003). In another study, Reap and Cavallo (1992) investigated the effect of gender on tenth-grade students' meaningful learning orientation and achievement in science. Results showed that males had higher achievement than females. No significant difference between males and females in terms of their meaningful learning orientation was found. Cavallo (1994) explored the male and female students' learning approaches. In the study, teachers rated their male and female students' learning orientations. The teachers rated the females as being more rote in their learning orientation than males. However, results of the students' self-reported questionnaire indicated no significant differences between the males' and females' learning orientations. Girls did not view themselves as learning in a more rote way than did the boys. In a separate study, Cavallo (1996) investigated the relationships between meaningful learning orientation, reasoning ability, and students' understanding of genetics in learning cycle

classrooms. The subjects were 189 tenth-grade students. The findings showed that there was no significant correlation between students' meaningful learning orientation and reasoning ability. However, both meaningful learning orientation and reasoning ability found to be significantly related to the performance on understanding genetics. Williams and Cavallo (1995) explored the same model on Newtonian physics concepts with university students. The findings were similar, reasoning ability and meaningful learning orientation were positively correlated to the understanding. The higher the students ability, the greater the understanding; and the greater the meaningful learning approach, the greater the understanding.

Although the research has shown positive relationships between the meaningful learning orientation and understanding, some other studies suggest that no correlations exist between them. Saunders (1998), for example, investigated the relationships among students' epistemological beliefs and approaches to learning, and examined the possible influence of instruction on students' beliefs and learning approaches. The researcher found that meaningful or rote learning approaches are not related to learning, and instruction is not correlated with learning approach. Renee (1997) explored the relationship between gender, learning orientation, self confidence and achievement in high school physics students. The results indicated that meaningful learners had higher achievement and higher self-confidence than rote learners. Gender was not significant in predicting learning orientation or achievement. However, males were more self-confident than females. Williams and Marek (1999) investigated the best predictor of overall and sub-

measure meaningful understanding of physics concepts among the variables of reasoning ability, meaningful learning orientation, prior knowledge and instructional treatment. The sample consisted of college students and the instructional treatment included learning cycle instruction and meaningful verbal reception learning instruction. Results revealed that none of the predictor variables were significant predictors of overall understanding of the physics concepts. However, for 'Forces' and 'Density/Archimedes' Principle' concepts, prior knowledge was the best predictor of concept understanding while reasoning ability was the next best predictor. For the 'Heat' concept, reasoning ability found to be the only significant predictor of concept understanding. No significant differences were found between the two instructional treatments for students' concept understanding of forces, density/Archimedes' Principle, and heat. In a recent study, BouJaoude (2004) compared eleventh grade students' performance on conceptual and algorithmic chemistry problems, and investigated the relationships between learning orientation, formal reasoning, mental capacity, and performance on conceptual and algorithmic problems. Results showed that students performed significantly better on algorithmic than conceptual problems. Meaningful learners did better than rote learners on conceptual problems but no significant differences found on algorithmic problems. Similarly, meaningful learning orientation, formal reasoning and mental capacity were significant predictors on conceptual chemistry problems but not on algorithmic problems. Formal reasoning predicted 18% of the variance, while learning orientation and mental capacity together predicted 8% of the

variance. In another study, Cavallo and Rozman (2004) investigated the effect of gender on learning approach, motivational goals, self-efficacy, epistemological beliefs, reasoning ability, and physics concept understanding of college students. The findings showed that males tend to use more meaningful learning approaches than females. Reasoning ability and self-efficacy were significant predictors of physics understanding for females. For males, self efficacy was a significant predictor of understanding, too; whereas learning goals and rote learning were also significant predictors, but in a negative direction.

2.6. Summary

In the light of the related literature, it can be said that students have several misconceptions concerning photosynthesis and respiration in plants concepts. These misconceptions are persistent to change and they influence students' further understanding and learning. Traditional instruction is shown to be insufficient in eliminating these misconceptions. Apart from the mode of instruction, various cognitive variables such as students' prior knowledge, their learning orientation and reasoning abilities found to be related to the meaningful understanding of the many science concepts. For this reason, this study investigated students' understanding of photosynthesis and respiration in plants concepts in relation to the meaningful learning orientation, reasoning ability, prior knowledge and mode of instruction. This topic was chosen due to its curricular significance. The processes

photosynthesis and respiration play important roles in understanding of many aspects of living systems. They are key to understanding how world functions as ecosystem (Eisen and Stavy, 1988). For example, these processes are the essential in the cycling of matter and energy flow through ecosystems. What is more, an understanding of respiration and photosynthesis is a prerequisite for systemic understanding of ecology (Anderson et al., 1990). Also, the topic of photosynthesis is taught at all level of education and judged to be the most important and difficult topic to learn. (Bahar et al, 1999; Finley et al., 1982). Photosynthesis is an essential topic in Turkish elementary science curricula. During the application of the treatment, photosynthesis is taught in 6th grade as a part of "Structure of Living Things" unit and in 8th grade as a part of "Matter and Energy for Living Things" unit.

CHAPTER III

METHOD

3.1. Introduction

This chapter includes the information about the research questions, hypotheses, sample, design of the study, instruments, treatment, data collection and analysis, and the assumptions and limitations of the study.

3.2. Research Questions and Hypotheses

The research questions are examined in two parts. In the first part (including the questions 1-4), the general characteristics of the sample are investigated. In the second part (including the questions 5-9), the relationship among the variables of the study are explored.

R.Q.1. What do 8th grade students know about photosynthesis and respiration in plants concepts?

R.Q.2. What are the common misconceptions of 8th grade students' concerning photosynthesis and respiration in plants?

R.Q.3. What are the formal reasoning abilities of students who took part in this study?

R.Q.4. What are 8th grade students' learning orientations who took part in this study?

R.Q.5. Is there a significant mean difference between the experimental group and control group with respect to the variables of the study (LAQ-M, LAQ-R, pre-PRPT and TOLT)?

Hyp: There will be no significant mean difference in the mean scores of experimental and control group with respect to LAQ-M, LAQ-R, Pre-PRPT and TOLT scores.

R.Q.6. What are the common misconceptions of 8th grade students' concerning photosynthesis and respiration in plants after the treatment?

R.Q.7. What is the possible relationship among 8th grade students' prior knowledge, meaningful learning orientation, formal reasoning ability, mode of instruction and students' understanding of photosynthesis and respiration in plants concepts?

Hyp: There will be no significant correlations among students' students' prior knowledge, meaningful learning orientation, formal reasoning ability, mode of instruction and their understanding of photosynthesis and respiration in plants concepts.

R.Q.8. What are the contributions of prior knowledge, meaningful learning orientation, formal reasoning ability and gender on 8th grade students' understanding of photosynthesis and respiration in plants concepts in relation to mode of instruction?

Hyp: There will be no contribution of students' prior knowledge, meaningful learning orientation, formal reasoning ability, and gender on students' understanding of photosynthesis and respiration in plants concepts.

R.Q.9. Which variable best predicted 8th grade students' understanding in traditional and conceptual change classrooms?

3.3. Design of the study

The design of the study is quasi experimental design, since it was not possible to assign the students to classes randomly (Table 3.1).

Table 3.1 Research Design of the Study

Groups	*Pretest*	*Mode of instruction*	*Posttest*
EG	TOLT, PRPT, LAQ	CCI	PRPT
CG	TOLT, PRPT, LAQ	TI	PRPT

In this table, EG represents the Experimental Group instructed by conceptual change text accompanied by discussion web instruction. CG represents the Control Group which traditional instruction. TOLT is Test of Logical Thinking, PRPT is Photosynthesis and Respiration in Plants Concept Test and LAQ is Learning Approach Questionnaire. CCI refers to Conceptual Change Instruction, and TI refers to Traditional Instruction.

3.4. Sample

The target population was all eighth-grade Turkish students. The accessible population of the study was 233 eighth-grade Turkish students with an age range of 13-14. Of 233 students, 128 (54.9%)were females, and 105 (45.1%) were males (Table 3.2). The students were members of a total of six intact classes in a public school in Eryaman, Ankara. Intact classes were used because it would have been too disruptive to the curriculum and too time consuming to be students out of their classes for instrument administration. All classes were instructed by the same science teacher. All students were exposed to the same content for the same duration. The instructional methods were randomly assigned to the groups. Two groups -6 classes- were involved

in the study. The experimental group consisted of 117 students. These students received conceptual change oriented instruction. The 116 students in the control group received traditional instruction. They began their formal science instruction in sixth grade and photosynthesis is presented in sixth grade science curriculum basically. The way to choose the sample was convenient-sampling.

3.5. Variables

There are two types of variables in this study; the dependent variable and the independent variable.

3.5.1. Dependent Variables

The dependent variable of the study is students' post-PRPT scores obtained by the instrument "What do you know about photosynthesis and respiration in plants? (PRPT)"

3.5.2. Independent Variables

The independent variables of the study are, gender, mode of instruction, reasoning ability, learning approach and prior knowledge. Gender and mode of instruction are considered as discrete variables and measured on nominal scale. Reasoning ability learning approach and prior

knowledge are considered as continuous variables and measured on interval scale. Pre-PRPT scores, TOLT scores and LAQ scores are also considered as covariates in this study.

3.6. Instruments

In the study students' understanding of photosynthesis and respiration in plants concepts is measured by the instrument "What Do You Know about Photosynthesis?" (PRPT), their formal reasoning ability is measured by Test of Logical Thinking (TOLT) and their learning approach is measured by The Learning Approach Questionnaire (LAQ).

3.6.1. Photosynthesis and Respiration in Plants Concept Test (PRPT)

The instrument "What do you know about photosynthesis and respiration in plants?" (Haslam and Treagust, 1987) is used to determine the students' misconceptions in photosynthesis and respiration in plants. It is a 13-item, two-tier diagnostic test which measures students' understanding of photosynthesis and respiration in plants. The first tier is a multiple choice content question related to propositional statements, and the second tier consists of a multiple-choice set of reasons for the answer given in the first tier. The set of reasons consists of identified misconceptions and a scientifically acceptable answer. The test includes items designed to determine students' misconceptions about the importance of photosynthesis, plant

nutrition, autotrophy, oxygen release by plants, respiration in plants, and energy concept.

The test is translated and adapted to Turkish by the researcher (See Appendix A). Each item in the test was examined by a group of science educators regarding content validity and format. The classroom teacher also examined the test items to check whether they are appropriate to the instructional objectives or not. For this study, reliability of the test was found as 0.76.

3.6.2. Test of Logical Thinking (TOLT)

The Test of Logical Thinking (TOLT), originally developed by Tobin and Capie (1981), was used to determine the formal reasoning abilities of students. It was translated and adapted into Turkish by Geban, Aşkar and Özkan (1992; See Appendix D). The test consists of ten items designed to measure control of variables (items 1&2), proportional (items 3&4), probabilistic (items 5&6), correlational (items 7&8), and combinational (items 9&10) reasoning. Students select a response from among five possibilities and then they are provided with five justifications among which they choose from. The correct answer is the correct choice plus the correct justification. The internal consistency of TOLT was reported as 0.85. For this study, reliability was found to be .81.

In this study, students' performance on TOLT is also used as a measure of formal reasoning abilities and as a means to categorize them. Test scores

from 0-3, 4-6, and 7-10 is used as a basis for classifying the subjects as low level, medium level and high level of formal thought as suggested by Oliva, (2003).

3.6.3. Learning Approach Questionnaire (LAQ)

The Learning Approach Questionnaire (LAQ) was used as the instrument to measure students' approaches to learning as meaningful or rote (Cavallo, 1996; Cavallo, Rozman, Blickenstaff, and Walker, 2003). It determines whether the student is a meaningful or rote learner. The LAQ scale consists of two subscales: Meaningful Learning Approach Questionnaire (LAQ-M) measuring the degree of meaningful learning orientation and the Rote Learning Approach Questionnaire (LAQ-R) measuring the degree of rote learning orientation. On the meaningful scale, a high score indicates students have a high meaningful learning approach; on the rote scale, a high score indicates students have a high rote learning approach. All questions in this questionnaire refer to students' study attitudes and processes in learning science in this science class. For each item there is a four point scale ranging from "Always True" to "Never True" or "Strongly Disagree" to "Strongly Agree". By adding up students' responses, their learning approach is determined. Both LAQ-M and LAQ-R scales have possible ranges of 11 – 44. The test is translated to Turkish by the researcher (See Appendix C). The Cronbach alpha reliability was reported as 0.81 for the meaningful scale, and

0.76 for the rote scale (Cavallo et al., 2003). For this study, The Cronbach alpha internal consistency is 0.78 for the meaningful scale, and 0.62 for the rote scale.

3.7. Treatment

This study was conducted over a 2-month period during 2004-2005 Fall semester. Photosynthesis and respiration in plants concepts were covered as part of the regular curriculum in the 8th grade science course. The classroom instruction was three 40-minute sessions per week. Prior to instruction, the science teacher was trained about the implementation of conceptual change text, discussion web and writing to learn in two hour training sessions. Instructions in all classes were observed by the researcher to verify the treatment.

The students are given the Test of Logical Thinking (TOLT) at the beginning of the study in the first class hour to evaluate their reasoning ability. In each class, students are informed about the purpose of the questionnaire, and procedure for completing it. After this short explanation, the answer sheets are distributed, and students are asked to complete the personal background information on the answer sheet. They are instructed to think about each question and answer it as it applies to them. Then, the tests are distributed and students are asked to complete the questions on their own. It will take about forty minutes for students to complete the test.

Then, in the next class hour, they are given the instrument "What do you know about photosynthesis and respiration in plants?" and the Learning

Approach Questionnaire. Again, the students are informed about the progress and the written questions are answered within one lesson; approximately thirty minutes for misconception test, and fifteen minutes for the questionnaire.

Of seven classes, six were used in this study. One class is excluded because the science teacher of that class was different. Moreover, if the seventh class was included, then the number of classes in experimental and control group will not be equal, as well. The remaining six classes were taught by the same science teacher.

Two groups, each consisting of 3 classes, were involved in the study. Three of the six classes were randomly assigned to the experimental group, and the remaining three formed the control group. The experimental group (N=117) received conceptual change instruction. The control group (N=116) received traditional instruction. Both of the groups are instructed by the same teacher.

In the regular classroom instruction, the teacher provided instruction through lecture and discussion to teach concepts. The students were required to read the related topic of the lesson from the textbook utilized in the course before the class hour. Teacher made frequent use of the chalkboard to illustrate the various concepts of the photosynthesis and respiration in plants. The main concepts at issue are the process of photosynthesis and respiration in terms of input and outputs. The focus during the instruction is on naming the reactants and products of photosynthesis and respiration. Little emphasis was given the idea of energy transformation. After teacher explanation

concepts were discussed by teacher-directed questions. The majority of instruction time was devoted to instruction and engaging in discussions stemming from the teacher explanation and questions. The remaining time was taken up with the worksheet study. In short, teaching strategies relied on teacher explanation, textbooks, and worksheet study within discussion.

Students in the experimental group were instructed with a strategy integrating conceptual change texts with 'writing for learning' and 'discussion webs' (See Appendix B). Two conceptual change texts, one for photosynthesis and one for respiration in plants were prepared by the researcher. The topic of photosynthesis and respiration in plants was divided into sub-topics such as the role of soil in photosynthesis, the role of leaves in photosynthesis, and respiration in plants. For each of these topics, suggestive questions were asked at the beginning to arouse the interest and to analyze students' preconceptions. For example, regarding the respiration in plants concept, students are simply asked whether the plants respire or not. First they recorded their answers as 'Yes' or 'No' and then they discussed reasons behind their answer, and finally recorded them (See Appendix B). Students first thought the answers by themselves, then discussed it by their seatmates and finally with the front-or-back seatmates - in groups of four. They then recorded their answer and the reasons behind the answer on the free space given them - as discussion webs. After that, a member from each group shared their idea with the class. The teacher did not give any feedback during this process. It was expected that students were dissatisfied with their existing conceptions. Then, the texts which stated common misconceptions about the

subject are read by the teacher together with the students. Students were asked to compare their conceptions with these misconceptions. Conceptual conflicts were created by this way. Following that, scientific explanations were given to help the students reconstruct the concepts on their minds. The explanations were supported by some images to help visualization. At the end of each topic, a few minutes are given to students to study the 'Writing for Learning' activity. In this activity, students are asked to compare and write what they have known previously and what they have learnt after the instruction about the topic. At the end of the unit, the PRPT is given as a post-test.

3.8. Data collection

During the beginning of the 2004-2005 Fall semester, before the treatment, the TOLT, the pre-PRPT and the LAQ was administered to the students. Following the two-week unit, students were re-assessed on their understanding of the concept through the scores on the post-PRPT.

Timeline

2004

September	November/December	December
Eighth graders take TOLT, PRPT and LAQ	Begin study of photosynthesis and respiration in plants concepts	Complete the treatment and re-administer PRPT

3.9. Data Analysis

The data collected was analyzed through using SPSS (Statistical Package for Social Sciences). The general characteristics of the sample are investigated as descriptive statistics and the means, standard deviations, percentages and histograms of the variables are presented under the corresponding research questions.

For the research questions investigating the treatment effect, several analyses including ANOVA, Pearson Correlation Analysis and Multiple Regression Analysis are conducted. The level of significance for all measures was defined as p=0.05.

3.10. Assumptions and Limitations of Research

The assumptions and limitations encountered during this study are given as below:

3.10.1. Assumptions

1. The teacher who applied this study was not biased during the treatment
2. There was no interaction between the students in the experimental and control groups.

3. All students' responses to the test items were sincere.

3.10.2. Limitations

1. The research findings are limited to photosynthesis and respiration in plants concepts.
2. The subjects of the study were limited to 233 eight grade students.
3. The study was limited to public schools.

CHAPTER IV

RESULTS

4.1. Introduction

This chapter presents the results of the analyses which were computed to answer the research questions. The research questions are examined in two parts. In Part I, the research questions regarding the general characteristics of the sample are addressed. In Part II, the relationships among variables of the study is looked into.

4.2. PART I: General characteristics of the sample

In this part of the study, general characteristics of the sample are addressed by answering several questions. These questions are as follows.

R.Q.1. What do 8th grade students know about photosynthesis and respiration in plants concepts?

R.Q.2. What are the common misconceptions of 8th grade students' concerning photosynthesis and respiration in plants?

R.Q.3. What are the formal reasoning abilities of students who took part in this study?

R.Q.4. What are 8th grade students' learning orientations who took part in this study?

Table 4.1 summarizes the instruments used, the possible and actual ranges, and the corresponding means and standard deviations gathered from the sample to address above-mentioned questions.

Table 4.1. Descriptive Statistics for the Variables of the Study

Variable	Instrument	Possible range	Actual range	Mean	SD
Formal Reasoning Ability	TOLT	0 – 10	0 – 10	2.72	2.29
Learning Orientation	LAQ-M	11 – 44	16 – 44	33.33	5.15
	LAQ-R	11 – 44	17 – 39	26.04	4.36
Prior knowledge	Pre-PRPT	0 – 13	0 – 13	3.38	2.23
Conceptual Understanding	Post-PRPT	0 – 13	1 – 12	5.67	2.71
Science Grade	-	0 – 5	2 – 5	3.38	1.17

The findings are interpreted in depth under the following research questions.

4.2.1. Research Question 1:

"What do 8th grade students know about photosynthesis and respiration in plants concepts?"

The instrument "What Do You Know about Photosynthesis?" (PRPT) is used to determine students' prior knowledge about photosynthesis and respiration in plants concepts prior to treatment. Of a possible 13 correct responses on the test, relatively a low mean score of 3.38 was attained by the two hundred and thirty three students (Table 4.1). Table 4.2 summarizes the frequency of students according to the scores they obtained. Only one student out of 233 answered all the questions correctly and got the maximum score of 13 from the test. The data from the PRPT showed a right-skewed distribution of scores as shown in Figure 4.1, indicating a low level of knowledge about the concept.

Table 4.2. Frequencies and percentages of correct responses on the pre-PRPT

Score	f	%
0	7	3.0
1	40	17.2
2	44	18.9
3	50	21.5
4	33	14.2
5	24	10.3
6	19	8.2
7	5	2.1
8	3	1.3
9	3	1.3
10	0	0
11	4	1.7
12	0	0
13	1	0.4

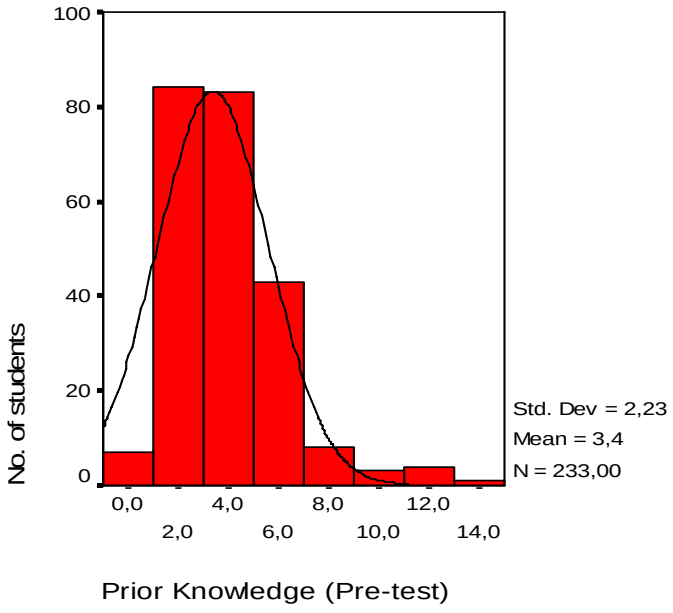

Figure 4.1. Range of PRPT scores

Since the instrument PRPT is a two-tier diagnostic test; it is also used to assess both the content knowledge and the reason beyond that knowledge. Hence, students' responses on each item were analyzed by content choice and the combination (content choice and reason). The percentages of students' selecting the desired content choice and combination are summarized in Table 4.3.

Table 4.3. Percentages of 8th grade students selecting the desired content choice and combination.

Items	Content choice	combination
1	72.1	17.6
2	48.9	10.3
3	77.3	49.8
4	57.5	43.3
5	27.0	22.7
6	82.0	67.8
7	21.0	9.9
8	30.5	16.7
9	25.8	8.6
10	31.8	21.9
11	45.5	41.2
12	24.0	10.3
13	34.8	17.6

Gilbert (1977) suggests that if a multiple-choice item has four to five distractors, understanding is considered satisfactory if 75% of the students answer the item correctly. However, the results of the two-tier test reveal that

none of the eight-grade students acquired a satisfactory prior knowledge about photosynthesis and respiration in plants concepts (Table 4.3). For the first tier of the test, the range of correct answers was 21.0% to 82.0%. When both tiers are combined, the correct response was reduced to a range of 9.9% to 67.8%. These results suggest that 8th grade students did not acquire a satisfactory pre-existing knowledge of photosynthesis and respiration in plants since none of the students scored above 75% on the test.

4.2.2. Research Question 2:

"What are the common misconceptions of 8th grade students concerning photosynthesis and respiration in plants prior to treatment?"

The same instrument (PRPT) is used to determine students' misconceptions concerning photosynthesis and respiration in plants concepts. In this two-tier diagnostic test each item is specified to address the misconceptions related to photosynthesis, respiration and relationship between photosynthesis and respiration in plants (Haslam and Treagust, 1987). In the following table, students' misconceptions determined by the test with percentages higher than 10% are presented.

Table 4.4. Students' misconceptions of photosynthesis and respiration in plants (in percentages)

Item	Misconceptions identified	%
1	Oxygen is given out in largest amounts by green plants in the presence of sunlight because	
	a. green plants only respire during the day	14.2
	b. green plants only photosynthesize and do not respire in the presence of light energy	25.8
2	i. Carbon dioxide is taken in by green plants in large amounts when there is no light energy at all because	
	a. this gas is used in photosynthesis which occurs in green plants all the time	15.5
	b. this gas is used in photosynthesis which occurs in green plants when there is no light energy at all	10.3
	c. this gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize	14.2
	ii. Oxygen is taken in by green plants in large amounts when there is no light energy at all because	
	a. this gas is used in respiration which only occurs in green plants when there is no light energy to photosynthesize	19.3
3	i. Carbon dioxide is given off by green plants in large amounts when there is no light energy at all because	
	a. this gas is given off by the green plant during photosynthesis which takes place when there is no light energy	11.6
	b. since green plants respire only when there is no light energy they give off this gas	12.9
	ii. Oxygen is given off by green plants in large amounts when there is no light energy at all because	
	a. green plants stop photosynthesizing when there is no light energy at all so they continue to respire and therefore they give off this gas	14.2

Table 4.4. continued

4	Oxygen is taken in by green plants in largest amounts in the presence of light energy because	
	a. green plants make their food from this gas in the presence of light energy	24.0
5	Respiration in plants takes place in the cells of the leaves only because	
	a. only leaves have special pores (stomata) to exchange gas	55.8
7	The exchange of carbon dioxide and oxygen gases through plant stomata is the most accurate statement about respiration in green plants because	
	a. green plants take in carbon dioxide and give off oxygen when they respire	18.9
	b. respiration provides the green plant with energy to live	10.7
8	Green plants respire only at night (when there is no light energy) because	
	a. cells of green plants can photosynthesize during the day when there is light energy and therefore they respire only at night when there is no light energy	39.5
9	Carbon dioxide + water → energy + glucose + oxygen best presents the process of respiration in plants because	
	a. carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced	12.0
10	Carbon dioxide + water + energy → glucose + oxygen best presents the overall process of photosynthesis because	
	a. the energy from sunlight is used by plants containing chlorophyll to combine carbon dioxide and water to form glucose and oxygen	24.5
	b. glucose and oxygen is combined in the presence of chlorophyll and light energy to form carbon dioxide and water	11.2

Table 4.4. continued.

11	Amount of chlorophyll is not important for the process of photosynthesis because	
	a. plants which do not contain chlorophyll or similar pigments can also photosynthesize	20.2
12	i. The most important benefit to green plants when they photosynthesis is the removal of carbon dioxide from the air because	
	a. carbon dioxide is taken in by the leaf through the stomata during photosynthesis	14.2
	ii. The most important benefit to green plants when they photosynthesis is the production of energy because	
	a. photosynthesis provides energy for plant growth	44.6
13	When it is to compare the processes of photosynthesis and respiration in plants; photosynthesis takes place in plants in presence of light energy and respiration takes place in all plants only when there is no light energy and all the time in all animals because	
	a. plants photosynthesize during the day and respire at night (when there is no light energy at all	11.6
	b. plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize	25.3

Twenty-two misconceptions are identified through the analysis of items on the test. They are grouped under the headings of photosynthesis, respiration, and relationship between photosynthesis and respiration in plants. Descriptions of these misconceptions are as follows.

Misconceptions concerning photosynthesis

Items 1, 2, 3, 4, 7, 8, 9, 10, 11, 12 and 13 examined students' understanding of photosynthesis. The most common misconception identified in this category is related to item 12, assessing the most important benefit to green plants when they photosynthesize. The misconception that the most important benefit to green plants when they photosynthesize is the production of energy because photosynthesis provides energy for plant growth is hold by 44.6% of the students. Students seem to confuse photosynthesis with respiration. Only 10.3% of the students selected the desired answer combination which was "the important benefit to green plants when they photosynthesize is the conversion of light energy to chemical energy because during photosynthesis energy from the Sun is converted and stored in glucose molecules".

Misconceptions related to respiration

Items 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 13 examined students' understanding of respiration. The most common misconception shared by 55.8% of the students was that "respiration in plants takes place in the cells of the leaves only because only leaves have special pores (stomata) to exchange gas". The desired content choice in this item was selected only by 22.7% of the students, and it was: "Respiration in plants takes place in every plant cell because all living cells need energy to live". Students had difficulty in understanding that respiration is a chemical process rather than a physical one involving gaseous exchange.

Another misconception shared by 39.5% of the students is related to students' understanding of when green plants respire. The desired combination selected by only 16.7% of the students was that "Green plants respire all the time because they need energy to live and respiration provides energy". However, 39.5% of the students believe that green plants respire only at night (when there is no light energy) because cells of green plants can photosynthesize during the day when there is light energy and therefore they respire only at night when there is no light energy. These students ascertained that respiration is an alternative way of photosynthesis; when there is light energy plants photosynthesize and when there is no light energy they cannot photosynthesize so they respire.

Misconceptions related to the relationship between photosynthesis and respiration in plants

Items 1, 4, 9, 10, 12, and 13 examined students' understanding of relationship between photosynthesis and respiration in plants. Analysis of responses again revealed numerous misconceptions. For example, 25.3% of the students thought that photosynthesis takes place in plants in the presence of light energy and respiration takes place in all plants only when there is no light energy and all the time in all animals. Because plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize. The desired content choice selected by 17.6% of the students was that "Photosynthesis takes place in green plants in the presence of light energy and respiration

takes place in all plants and animals at all times because respiration is continuous in all living things but photosynthesis occurs when there is light energy".

These responses provide evidence that photosynthesis and respiration are seen as mutual exclusive events by most of the students and they think that these events cannot occur at the same time (Sanders, 1993). The participants perceived respiration as a gas exchange process. The purpose of respiration is seen as providing oxygen to the living organisms and removing carbon dioxide which takes place only at night. Moreover, participants conceived photosynthesis as the process that provides organisms with energy for the metabolism when there is light energy.

4.2.3. Research Question 3:

"What are the Formal Reasoning Abilities of students who took part in this study?"

The Test of Logical Thinking (TOLT) is used to determine the formal reasoning abilities of students. Table 4.5 shows the distribution of students according to the scores they got from TOLT. It suggests a non-normal distribution of the scores with a mean of 2.72. The right-skewed diagram also shows that most of the students have lower scores on TOLT (Figure 4.2).

Table 4.5. Number and frequencies of students according to the scores on TOLT

TOLT Score	N	f
0	34	14.6
1	50	21.5
2	48	20.6
3	31	13.3
4	23	9.9
5	15	6.4
6	13	5.6
7	9	3.9
8	5	2.1
9	3	1.3
10	2	0.9

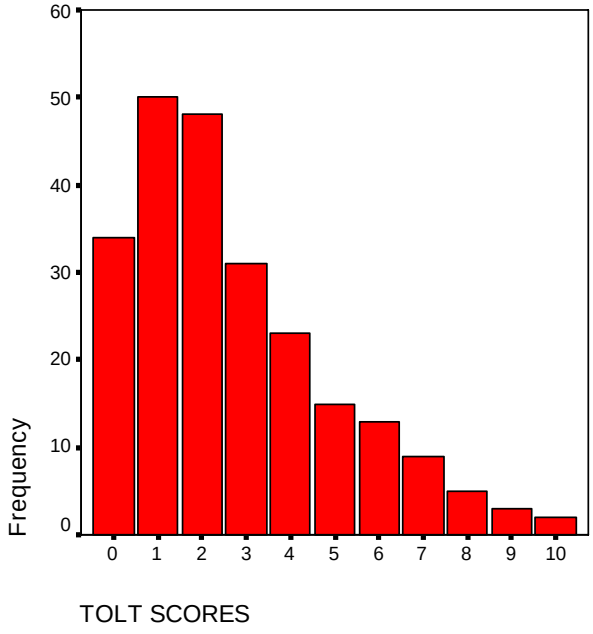

Figure 4.2. Range of TOLT scores

The TOLT is designed to measure five reasoning modes which are controlling variables, proportional, probabilistic, correlational, and combinational reasoning. Table 4.6 summarizes the frequencies of students who give the correct answers to the items on the test according to the reasoning modes. It shows that students did best on 9 & 10th items (51.9%) which measure the combinational reasoning. This means that 8th graders have higher level of combinational reasoning. They are also relatively good at proportional reasoning (25.1%) and controlling variables (24.9%). Students did least on probabilistic reasoning (16.5%) and correlational reasoning (17.6%).

Table 4.6. Frequencies and percentages of students with respect to five reasoning modes

Reasoning mode	Item	f	%
Proportional	1	79	33.9
Proportional	2	38	16.3
Total		*117*	*25.1*
controlling variables	3	65	27.9
controlling variables	4	51	21.9
Total		*116*	*24.9*
Probabilistic	5	50	21.5
Probabilistic	6	27	11.6
Total		*77*	*16.5*
Correlational	7	44	18.9
Correlational	8	38	16.3
Total		*82*	*17.6*
Combinational	9	137	58.8
Combinational	10	105	45.1
Total		*242*	*51.9*

TOLT is also used to classify the subjects as low level (scores from 0-3), medium level (scores from 4-6) and high level (scores from 7-10) of formal thought. In the present study, 163 (70%) of the students were in low level of formal thought, 51 (22%) were in medium level of formal thought, and 19 (8%) were in high level of formal thought (Table 4.7). This shows that majority of the participants were at low level of formal thought. Concerning gender differences, findings reveal that most of the girls and boys in this sample were at low level of formal thought. The number of boys at high formal reasoning level (N=14) is higher than that of girls (N=5).

Table 4.7. Distribution of students with respect to level of formal thought

	Formal Reasoning Level (N)			
	Low	Medium	High	Total
Males	68	23	14	105
Females	95	28	5	128
Total	163	51	19	233

4.2.4. Research Question 4:

"What are 8th grade students' learning orientations?"

The Learning Approach Questionnaire (LAQ) is used to measure students' approaches to learning as meaningful or rote (Cavallo, 1996; Cavallo, Rozman, Blickenstaff, and Walker, 2003). Table 4.1 summarizes the means and standard deviations on the two sub-scales. Both LAQ-M and LAQ-

R scales have possible ranges of 11 – 44. The actual ranges were 16 – 44 for LAQ-M and 17 – 39 for LAQ-R. While students' LAQ-M scores offer low to high meaningful approaches to learning, LAQ-R scores offer low to moderate rote approaches to learning. The mean of meaningful learning scores (M = 33.33) is higher than rote learning (M = 26.04) which means that students generally use meaningful learning approaches than rote learning approaches. A clear picture can be seen in Figure 4.3.

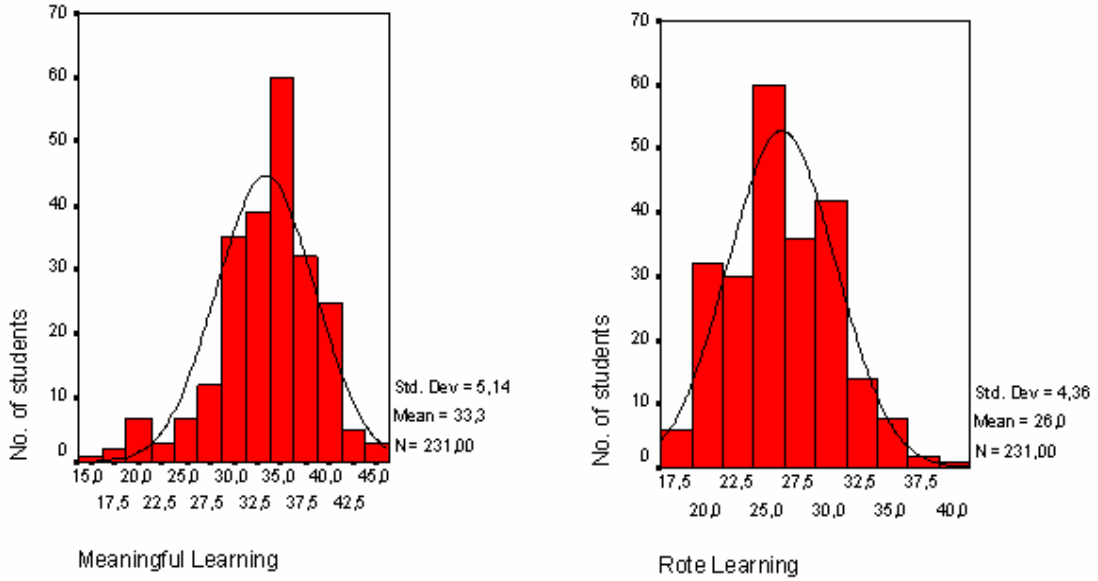

Figure 4.3. Range on LAQ-M and LAQ-R

Regarding gender difference, Table 4.8 suggests that girls (M= 34.13) tend to use more meaningful learning approaches than boys (M=32.37).

Table 4.8. Descriptives for the learning orientation with respect to gender

	Learning Orientation					
	LAQ-M			LAQ-R		
	Range	Mean	SD	Range	Mean	SD
Male	18-43	32.37	5.35	17-35	26.22	3.84
Female	16-44	34.13	4.85	17-39	25.90	4.75
Total	16-44	33.33	5.15	17-39	26.04	4.36

4.3. PART II: The Relationships among Variables of the Study

In this part of the study, the research questions including the relationships among variables of the study are investigated. The analyses are conducted both for the experimental group and the control group. First, the mean difference between the experimental group and control group in terms of the variables (LAQ-M, LAQ-R, pre-PRPT and TOLT) is investigated. Then, the questions including the relationships among the variables are addressed.

R.Q.5. Is there a significant mean difference between the experimental group and control group with respect to the variables of the study (LAQ-M, LAQ-R, pre-PRPT and TOLT)?

R.Q.6. What are the common misconceptions of 8th grade students' concerning photosynthesis and respiration in plants after the treatment?

R.Q.7. What is the possible relationship among 8th grade students' prior knowledge, meaningful learning orientation, formal reasoning ability, mode of instruction and students' understanding of photosynthesis and respiration in plants concepts?

R.Q.8. What are the contributions of prior knowledge, meaningful learning orientation, formal reasoning ability and gender on 8th grade students' understanding of photosynthesis and respiration in plants concepts in relation to mode of instruction?

R.Q.9. Which variable best predicted 8th grade students' understanding in traditional and conceptual change classrooms?

4.3.1. Research Question 5:

"Is there a significant mean difference between the experimental group and control group with respect to the variables of the study (LAQ-M, LAQ-R, pre-PRPT and TOLT)?"

Before investigating the treatment effect, it is important to determine whether there is a significant mean difference in the experimental and control group with respect to the variables of the study. Table 4.9 shows the means and standard deviations on the tests (LAQ-M, LAQ-R, pre-PRPT and TOLT) with respect to groups (experimental vs. control).

Table 4.9. Descriptives for treatment and control groups before the treatment

	Group	Mean	SD
LAQ-M	Treatment	33.43	4.91
	Control	33.24	5.39
	Total	33.33	5.15
LAQ-R	Treatment	26.10	4.50
	Control	25.99	4.23
	Total	26.04	4.36
Pre-PRPT	Treatment	3.44	2.40
	Control	3.31	2.05
	Total	3.38	2.23
TOLT	Treatment	2.82	2.53
	Control	2.62	2.02
	Total	2.72	2.28

To see whether there is a significant difference; ANOVA was conducted for each variable separately. The results were non-significant for LAQ-M (F (1,231) = .074, *p*=.786), LAQ-R (F (1,231) = .033, *p*=.856), pre-PRPT (F (1,231) = .210, *p*=.647), and TOLT (F (1,231) = .445, *p*=.506). Based on these results, it was concluded that students in both groups were similar with respect to these variables.

4.3.2. Research Question 6:

"What are the common misconceptions of 8th grade students' concerning photosynthesis and respiration in plants after the treatment?"

Table 4.10 shows the percentages of students' correct responses on pre- and post-PRPT with respect to the mode of instruction.

Table 4.10. Percentages of correct answers (combination) on pre- and post-PRPT with respect to the mode of instruction

	Conceptual Change Instruction		Traditional Instruction	
Item	Pre-PRPT	Post-PRPT	Pre-PRPT	Post-PRPT
1	16.2	33.3	19.0	19.0
2	12.8	38.5	7.8	29.3
3	48.7	65.8	50.9	61.2
4	43.6	58.1	43.1	56.9
5	19.7	18.8	25.9	26.7
6	70.9	78.6	64.7	69.8
7	9.4	28.2	10.3	21.6
8	16.2	55.6	17.2	30.2
9	12.0	35.0	5.2	21.6
10	26.5	30.8	17.2	30.2
11	41.0	59.8	41.4	50.0
12	12.0	24.8	8.6	14.7
13	15.4	48.7	19.8	28.4

After instruction, in general, there is a relative amount of increase in the percentages of students' correct responses for all items, except the fifth item. This item deals with respiration in plants and it is an item which students have higher degree of misconceptions. More than 50% of the students in both groups strongly held the misconception that "Respiration in plants takes plants in the cells of the leaves only because only leaves have special pores to exchange gas" after the instruction.

The percentages of some selected misconceptions on post-PRPT with respect to the mode of instruction are listed in Table 4.11. Students receiving conceptual change instruction tend to have fewer misconceptions than the ones receiving traditional instruction.

Table 4.11. Percentages of students' misconceptions on post- PRPT with respect to the mode of instruction

		Mode of instruction	
	Misconceptions	TI	CCI
1.	Oxygen is given out in largest amounts by green plants in the presence of sunlight because green plants only photosynthesize and do not respire in the presence of light energy.	29.3	9.4
2.	Carbon dioxide is given off by green plants in large amounts when there is no light energy because green plants respire only when there is no light energy.	12.1	1.7
3.	Respiration is a chemical process which occurs in plant cells but not in animal cells because only plant cells obtain energy to live in this way.	12.9	2.6
4.	Respiration is a process that does not take place in green plants when photosynthesis is taking place because respiration only occurs when there is no light energy.	12.9	0.9
5.	Green plants respire only at night because cells of green plants can photosynthesize during the day when there is light energy and therefore they respire only at night when there is no light energy.	30.2	10.3
6.	Amount of chlorophyll is not important for the process of photosynthesis because plants which do not contain chlorophyll or similar pigments can also photosynthesize.	17.2	9.4

The values in Table 4.11 suggest that conceptual change instruction tend to remediate the misconceptions concerning photosynthesis and respiration in plants concepts.

4.3.3. Research Question 7:

"What is the possible relationship among 8th grade students' prior knowledge, meaningful learning orientation, formal reasoning ability, mode of instruction and students' understanding of photosynthesis and respiration in plants concepts?"

In order to see the relationship that might exist among students' prior knowledge, meaningful learning orientation, rote learning orientation, formal reasoning ability, mode of instruction and students' understanding of photosynthesis and respiration in plants concepts, Pearson correlation analysis was computed for each group (Table 4.12).

Table 4.12. Correlation coefficients among variables of the study for each group

Group		LAQ-M	LAQ-R	TOLT	Pre-test
Experimental	LAQ-M	-	-	-	-
	LAQ-R	-.036	-	-	-
	TOLT	.168	-.156	-	-
	Pre-test	.194*	-.169	.571**	-
	Post-test	.311**	-.189	.577**	.605**
Control	LAQ-M	-	-	-	-
	LAQ-R	-.272**	-	-	-
	TOLT	.258**	-.127	-	-
	Pre-test	.073	-.049	.340**	-
	Post-test	.168	-.029	.613**	.513**

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

For the experimental group, students' formal reasoning ability was significantly correlated with their pre-test scores (r=.57, p=.000) and post-test scores (r=.58, p=.000). Moreover, students' pre-test scores were significantly correlated with both post-test scores (r=.60, p=.000) and meaningful learning orientation (r=.19, p=.038). Students' post-test scores were found to be significantly correlated with their meaningful learning orientation (r=.31, p=.001).

Similarly, for the control group, students' formal reasoning ability was significantly correlated with their pre-test scores (r=.34, p=.000), post-test scores (r=.61, p=.000) and meaningful learning orientation (r=.26, p=.005). In addition, a statistically significant correlation between pre-test scores and post-test scores (r=.51, p=.000) was found. A negative correlation between

meaningful learning orientation and rote learning orientation was also found (r=-.27, p=.003). However, no correlation between meaningful leaning orientation and pre-test scores was determined (p>0.5).

These results suggest that students' understanding of the concepts in both groups were related to their meaningful learning orientations, formal reasoning abilities and prior knowledge. Students having more meaningful learning approaches, higher formal reasoning abilities, and more prior knowledge had better acquisition of photosynthesis and respiration in plant concepts. However, rote learning orientation has no significant effect on students' understanding of the target concepts in both groups.

4.3.4. Research Question 8:

"What are the contributions of prior knowledge, meaningful learning orientation, gender, formal reasoning ability and gender on 8th grade students' understanding of photosynthesis and respiration in plants concepts in relation to mode of instruction?"

In the previous research question, significant correlations between prior knowledge, meaningful learning orientation, formal reasoning ability and post-test scores were found. Two separate Multiple Regression Analyses (MRC) were performed to determine the contributions of these variables and gender on students' understanding for the experimental and control groups (Table 4.13). Post-test scores served as the dependent variable, and pre-test scores, meaningful learning orientation, reasoning ability scores and gender as

independent variables. Rote learning orientation is not accounted in the analysis since it has no significant effect on students' post-test scores in both groups.

Table 4.13. Independent contributions of TOLT, LAQ-M, Pre-PRPT and Gender to understanding of the photosynthesis and respiration in plants concepts

Variables	Mode of Instruction							
	Traditional Instruction				Conceptual Change Instruction			
	B	*β*	*t*	*p*	*B*	*β*	*t*	*p*
Constant	1.887		1.647	.103	.590		.452	.652
TOLT	.629	.511	6.459	.000	.396	.383	4.328	.000
LAQ-M	-.010	-.021	-.279	.781	.086	.159	2.131	.036
Pre-PRPT	.396	.323	4.268	.000	.400	.364	4.177	.000
Gender	.601	.117	1.640	.104	.809	.152	2.030	.045

For the control group, which received traditional instruction, students' reasoning abilities and their prior knowledge significantly contributed to their understanding of the photosynthesis and respiration in plants concepts. The multiple correlation *(R)* was .697 with R^2=.47. This result showed that the model significantly accounted for 47% of the variation in students' understanding in traditional instruction classrooms (F=24.615, p=.000).

For the experimental group, which received conceptual change instruction, students' reasoning abilities, their prior knowledge, meaningful learning approaches and gender significantly contributed to the understanding of the photosynthesis and respiration in plants concepts. The

multiple correlation *(R)* was .710 with R^2=.48. This result showed that the model significantly accounted for 48% of the variation in students' understanding in conceptual chance classrooms (F=24.854, p=.000).

The results show that while formal reasoning ability and prior knowledge significantly contributed to the understanding in both traditional and conceptual change classrooms, meaningful learning orientation and gender significantly contributed to students' understanding only in conceptual change classrooms.

4.3.5. Research Question 9:

"Which variable best predicted 8th grade students' understanding in traditional and conceptual change classrooms?"

Two separate stepwise multiple regression analysis was performed to determine which variable best predicted students' understanding in traditional and conceptual change classrooms (Table 4.14).

Table 4.14. Multiple regression results for the traditional and conceptual change classrooms

		β	Adjusted R^2	F	p
Post-PRPT					
Control group	TOLT	.491	.463	47.572	0.000
	Pre-PRPT	.335			
Experimental group	Pre-PRPT	.364	.483	24.854	0.000
	TOLT	.383			
	LAQ-M	.159			
	Gender	.152			

For the traditional classrooms, results revealed that formal reasoning ability was the main predictor of performance on the post-test, explaining 37% of the variance, while prior knowledge accounted for the remaining 9.3%. For the conceptual change classrooms, results revealed that prior knowledge was the main predictor of performance on the post-test, explaining 35.8% of the variance, while formal reasoning ability accounted for the 7.7% of the variance on the post-test scores. Meaningful learning orientation, on the other hand, explained only 3.2%, and gender explained 1.6% of the variance on the post-test scores in conceptual change classrooms.

Briefly, this result suggest that while formal reasoning ability was the main predictor of performance on post-test in traditional classrooms, prior knowledge was the main predictor in conceptual change classrooms.

4.4. Conclusions

In conclusion, the results of the present study showed that students hold several misconceptions about photosynthesis and respiration in plants concepts and have a low level of conceptual understanding. Of a possible 13 correct responses on the test, relatively a low mean score of 3.38 was attained by participants.

The misconceptions hold by the students can be eliminated by using some different teaching methods rather than traditional methods. In this study, a combined strategy involving use of conceptual change texts, writing for learning and discussion webs is used as an alternative way of teaching the concept. The students in experimental group significantly did better than the ones in the control group on the post-test. The main predictor of achievement in the treatment group was students' prior knowledge, while it was reasoning ability in the control group. Prior knowledge was the most important determinant of the students' ability to learn photosynthesis and respiration in plants than is formal reasoning ability in conceptual change classroom since new knowledge is constructed upon what students already know (Ausubel, 1968) and thus, students' existing knowledge has great influence on their further learning in conceptual change approach. In other words, prior knowledge was more important in determining what students will learn than their formal reasoning ability and learning approaches in conceptual change classrooms. Meaningful learning orientation accounted for a small amount of variance in conceptual change classrooms. The failure of a MLO to account for

a greatest amount of the variance of the posttest scores is consistent with the results reported Kang et al., (2005). They found that meaningful learning approach was not significantly related to the density conception test scores in computer assisted instruction designed to promote conceptual change concerning density concepts.

In traditional classrooms, reasoning ability was the main predictor of achievement in post-test scores. The relation between formal reasoning and students' achievement indicates that students need to have a specific level of abstract thinking to be able understand the concepts related to photosynthesis and respiration in plants concepts. The results of the present study are consistent with the findings of previous research in which reasoning ability was the most important predictor variable on science achievement (e.g. Bitner, 1991: Johnson and Lawson, 1998; Lawson and Thomson, 1988). Johnson and Lawson, (1998) reported that reasoning ability but not prior knowledge accounted for a significant amount of variance in final examination score in both instructional methods employed (expository versus inquiry). Reasoning ability explained more of the (18.8%) variance in final examination scores for students enrolled in expository classes than in inquiry classes (7.2%). Meaningful learning orientaion did not contribute to achievement on post-test scores in traditional classrooms.

CHAPTER V

DISCUSSION

This study was conducted to identify the relative predictive influences of prior knowledge, meaningful learning orientation, formal reasoning ability and mode of instruction on understanding in photosynthesis and respiration in plants concepts.

The topic of photosynthesis and respiration are basic concepts in life science. However, the research indicate that many students have difficulties in learning these concepts and these concepts require high levels of formal reasoning of students (Lawson and Renner 1975). Findings of this study indicate that majority of the participants in this study are not formal reasoners. The distribution of students' scores on TOLT revealed that majority of the students (70%) was at low formal level. Only 8% were high formal reasoners. Lawson and Renner (1975) claimed that low formal reasoners encounter learning difficulties when they were asked to deal with concepts which require formal reasoning. Students with low formal reasoning must deal with concrete concepts to form understanding. A mismatch occurs between students' reasoning ability and their level understanding when low

formal students try to learn formal concepts. Hence, it can be said that understanding formal concepts may be difficult among students who have not developed formal reasoning ability (Williams and Cavallo, 1995). Lawson *et al.*, (2000) also reported a significant relationship between conceptual knowledge and developmental level. Present study is consisted with this view. Statistical analyses showed that formal reasoning ability was the main predictor of performance on the post-test explaining 37% of the variance in traditional classrooms. Students having greater reasoning ability had greater understanding while students having lower reasoning ability had lower understanding of the photosynthesis and respiration in plant concepts. In fact, the items included in test required students not to memorize isolated facts but to comprehend, relate the concepts and construct a coherent body of scientific knowledge. Moreover, the content covered in the test was abstract in nature. Thus, it was as expected that high formal students who no longer requires concrete objects to make rational judgments and are capable of hypothetical and deductive reasoning performed better than low formal students. In addition, formal operational students possessing the formal patterns necessary for evaluating competing hypothesis by comparing the predicted outcomes are expected to overcome misconceptions which interfere with meaningful learning while low formal students are predicted to continue to use their misconceptions failing to recognize the limitations of these misconceptions and appreciate the merits of the scientific conception (Lawson and Thompson, 1988).

Johnson and Lawson (1998) reported that prior knowledge is another factor which can predict achievement, depending on the instructional procedure used. The findings of present study revealed that prior knowledge was the main predictor of the performance on the post-test in conceptual change classrooms, explaining 36.4% of the variance. Since new knowledge is constructed upon what students already know (Ausubel, 1968) and thus, students' existing knowledge has great influence on their further learning, it was expected that students' prior knowledge would be related to their understanding of the concepts. Ausubel (1968) claimed that, students learn meaningfully by constructing new knowledge on the basis of what they already know. Thus, students' existing conceptions have great influence on their further learning.

Although reasoning ability was the main predictor in traditional instruction classrooms, prior knowledge became the main predictor in conceptual change classrooms. This can be explained as follows: Students in the conceptual change classrooms were involved in activities that helped them revise their prior knowledge and struggle with their misconceptions. In the conceptual change classrooms, emphasis was given to students' misconceptions. In order to deal with these misconceptions, students became dissatisfied with their existing conceptions, which let them accept better explanations to the problems that were introduced. In this way, students were allowed to think about their prior knowledge and reflect on it. Actually, the important part of the use of the conceptual change approach used in this study was the social interaction provided by teacher guided discussions.

Discussion of the concepts in the texts could facilitate students' understanding as well as encourage their conceptual restructuring. Similarly, in writing for learning parts students are asked to compare and write what they have known previously and what they have learnt after the instruction about the topic, and thus encouraged to reconstruct their understanding.

Beside reasoning ability and prior knowledge, meaningful learning orientation also has positive effects on students' understanding of concepts of photosynthesis and respiration in plants. The participants of this study have more meaningful learning orientation compared to rote learning orientation (M=33.33 and M=26.04, respectively). In the present study, stepwise multiple regression analysis revealed that meaningful learning orientation was a predictor of concept understanding in conceptual change classrooms, explaining 3.7% of the variance. When compared to reasoning ability and prior knowledge, this effect is too low. This result was not in line with results obtained by Cavallo (1996) who reported that meaningful learning orientation explained more of the variance in the test genetic meaning (13%) as compared to reasoning ability (3%) in learning cycle classroom.

Another finding of the current study was related to the gender difference. Results showed that the number of boys at formal reasoning level (N=14) is higher than that of girls (N=5). However, with respect to the learning orientations, girls (M=34.13) found to have more meaningful learning approaches than boys (M=32.37). Although a statistically significant contribution of gender, in favor of girls, to achievement scores was observed, the difference between boys (M=5.47) and girls (M=5.83) was not large. In fact,

findings of the studies in the literature, in general, indicated that difference between boy and girls with respect to achievement in concepts related to life sciences are not statistically significant (Hupper *et al*., 2002; Sungur and Tekkaya, 2003; Soyibo, 1999; Young and Fraser, 1994).

The strategies used in this study supported change in students from passively receiving information to actively examining their own conceptions. A more dynamic role is given to the teacher having the capability to respond to the ideas expressed by the students. This new role required that the teacher provided metacognitive tools such as intelligibility and plausibility as part of his or her instruction and that students can learn to apply these tools when discussing science concepts (Beeth, 1998). In line with this idea, in the present study, conceptual change texts, writing for learning and discussion webs were integrated to promote conceptual change concerning photosynthesis and respiration in plants concepts. Findings indicated that the students who are taught by conceptual change approach performed significantly better on a posttest and demonstrated more of a change in their understanding of photosynthesis and respiration in plant concepts. However, the study also revealed that there were still some misconceptions even in the experimental group after treatment. For example, conceptual change with respect to 5th item was not effective. Still after the instruction, 58.1% of the students in the conceptual change classroom thought that respiration in plants takes place in the cells of the leaves because only leaves have special pores to exchange gas. They also believed that the most important benefit to green plants when they photosynthesize is production of energy because photosynthesis provides

energy for plant growth. Responses of several students indicated a persistent belief that respiration and photosynthesis are mutually exclusive processes that do not occur at the same time in plants (Sanders, 1993). They thought that plant respire only at night because they make photosynthesis in the sunlight. Moreover, they failed to realize that purpose of respiration is not taking in oxygen and releasing off carbon dioxide but proving energy to organism. As a result, students concluded that respiration is a gas exchange process and takes place in leaves.

The present findings have also some instructional implications for elementary science teachers. First, the teachers should be aware of students' misconceptions and their prior knowledge before starting a new topic. Next, findings highlight that reasoning ability and prior knowledge are important predictors of conceptual understanding; teachers should provide a rich learning environment for the students to deal with individual differences. For example, multiple representations such as models, simulations, diagrams, or analogies may help make abstract concepts understandable to students (Posner, Strike, Hewson, and Gertzog, 1982). Also, to promote 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). In addition to reasoning ability, meaningful learning orientation is another important factor to consider. Regardless of the low variance, the results highlighted that meaningful learning orientation contributed to a portion of the overall learning. Therefore, science teachers must select instructional strategies, such

as conceptual change texts, discussion webs, Vee diagrams and concept mapping, which encourage student to develop meaningful learning approach. Teaching should help students to relate new information to old one and to integrate knowledge from one area to another. Only then can these students become meaningful learners who are better able to maintain and apply information in new situation.

There may be some recommendations for further research studies. For example, the conceptual change instruction can be implemented during a whole semester so that some other science topics will be included. Moreover, some other instructional strategies like learning cycle can also be used in other groups, and the effects of these strategies on students' understanding can be compared. Further research can also include the investigation of conceptual change instruction on retention. Lastly, the same study can be conducted to different grade levels or to a larger sample.

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APPENDICES

APPENDIX A

FOTOSENTEZ VE BITKILERDE SOLUNUM KAVRAM TESTI

13 sorudan oluşan bu test, fotosentez ve bitkilerde solunum konuları üzerine bilginizi ölçmektedir. Her soru iki bölümden oluşmaktadır. Birinci bölüm konu bilgisini içeren çoktan seçmeli soruyu; ikinci bölüm ise olası nedenleri içermektedir. Her soru için bir cevap ve her cevap için bir neden işaretlemeniz gerekmektedir.

Hiçbir soruyu boş bırakmayınız.

Verdiğiniz cevabın nedenini en iyi açıklayan şıkkı Cevap Anahtarı'nda işaretleyiniz.

Soru 12 2 **Neden** C

Verdiğiniz cevap için size verilenler dışında bir nedeniniz varsa cevap anahtarındaki boş alana bu nedeni yazınız.

"Cevap Anahtarı" ndaki diğer detayları doldurmayı unutmayınız.

Soruların bulunduğu kağıda herhangi bir işaretleme yapmayınız.

İYİ ŞANSLAR

SORULAR

1- Güneş ışığında yeşil bitkilerin büyük miktarlarda açığa çıkardıkları gaz hangisidir?

(1) Karbondioksit

(2) Oksijen

Çünkü;

(a) bu gaz güneş enerjisinin varlığında açığa çıkar çünkü yeşil bitkiler sadece gündüz solunum yaparlar.

(b) bu gaz yeşil bitkiler tarafından açığa çıkarılır çünkü yeşil bitkiler güneş enerjisinin varlığında sadece fotosentez yaparlar solunum yapmazlar.

(c) Yeşil bitkinin solunum ve diğer işlemler için ihtiyacı olandan daha fazlası fotosentez sırasında yeşil bitkiler tarafından üretilir, ihtiyaç fazlası gaz açığa çıkar.

(d) Bu gaz yeşil bitkiler fotosentez yaptıktan sonra açığa çıkan bir atık üründür.

(e) ----------

2- Hangi gaz güneş enerjisi olmadığında yeşil bitkiler tarafından büyük miktarda kullanılır?

(1) karbondioksit

(2) oksijen

Çünkü;

(a) bu gaz yeşil bitkilerde her zaman gerçekleşen fotosentez için kullanılır.

(b) bu gaz yeşil bitkiler tarafından güneş enerjisi yokken yapılan fotosentez için kullanılır.

(c) bu gaz fotosentez yapmak için güneş enerjisi yokken yeşil bitkiler tarafından solunum yapmak için kullanılır.

(d) bu gaz yeşil bitkilerde her zaman gerçekleşen solunum için kullanılır.

(e) ----------

3- Hangi gaz yeşil bitkiler tarafından güneş enerjisi yokken büyük miktarlarda açığa çıkarılır?

(1) karbondioksit

(2) oksijen

Çünkü;

(a) Yeşil bitkiler güneş enerjisi yokken fotosentez yapmazlar, fakat solunum yapmaya devam ederler ve bu yüzden bu gazı açığa çıkarırlar.

(b) Bu gaz, güneş enerjisi yokken meydana gelen fotosentez sırasında yeşil bitkiler tarafından açığa çıkarılır.

(c) Yeşil bitkiler sadece güneş enerjisi yokken solunum yapabildikleri için bu gazı açığa çıkarırlar.

(d) ----------

4- Aşağıdaki gazlardan hangisi güneş enerjisinin varlığında yeşil bitkiler tarafından büyük miktarda alınır?

(1) karbondioksit

(2) oksijen

Çünkü;

(a) Yeşil bitkiler güneş enerjisinin varlığında bu gazı kullanarak besinlerini yaparlar.

(b) Hayvanlar güneş enerjisinin varlığında solunum yapmak için bu gaza ihtiyaç duyarlar.

(c) ----------

5- Bitkilerde solunum nerede gerçekleşir?

(1) sadece kök hücrelerinde

(2) bütün bitki hücrelerinde

(3) sadece yaprak hücrelerinde

Çünkü;

(a) bütün canlı hücrelerin yaşamak için enerjiye ihtiyacı vardır.

(b) sadece yapraklar gaz değişim işlemi için gerekli olan gözeneklere (stomatalara) sahiptir.

(c) sadece kökler nefes alıp vermek için küçük deliklere sahiptir.

(d) sadece köklerin topraktan su emmek için enerjiye ihtiyaç vardır.

6- Solunum nedir?

(1) bütün bitki ve hayvan hücrelerinde meydana gelen kimyasal bir işlemdir.

(2) bitki hücrelerinde gerçekleşen ama hayvan hücrelerinde gerçekleşmeyen kimyasal bir işlemdir.

(3) sadece hayvan hücrelerinde gerçekleşen ama bitki hücrelerinde gerçekleşmeyen kimyasal bir işlemdir.

Çünkü;

(a) sadece bitki hücreleri yaşamak için enerjiyi bu şekilde elde ederler.

(b) bütün bitki ve hayvan hücreleri enerjiyi bu işlem sayesinde elde ederler.

(c) sadece hayvan hücreleri yaşamak için enerjiye ihtiyaç duyarlar çünkü hayvan hücreleri fotosentez yapamazlar.

(d) ----------

7- Aşağıdakilerden hangisi yeşil bitkilerde solunumu açıklayan en doğru cümledir?

(1) Solunum bitkilerin su ve karbondioksit kullanarak besin ürettiği kimyasal bir işlemdir.

(2) Solunum besinlerde toplanan enerjinin oksijen kullanılarak açığa çıkarıldığı kimyasal bir işlemdir.

(3) Solunum bitkilerdeki stomalar tarafından karbondioksit ve oksijen gazlarının değiştirilme işlemdir.

(4) Solunum, yeşil bitkilerde fotosentez olurken gerçekleşmeyen bir işlemdir.

Çünkü;

(a) Yeşil bitkiler asla solunum yapmazlar, onlar sadece fotosentez yaparlar.

(b) Yeşil bitkiler solunum yaparken karbondioksit alırlar ve oksijen verirler.

(c) Solunum yeşil bitkilerin yaşaması için gereken enerjiyi sağlar.

(d) Solunum sadece yeşil bitkilerde güneş enerjisi yokken gerçekleşir.

(e) ----------

8- Yeşil bitkiler ne zaman solunum yaparlar?

(1) sadece geceleri (güneş enerjisi yokken)

(2) sadece gündüz vakti (güneş enerjisi varken)

(3) her zaman (güneş enerjisi varken veya yokken)

Çünkü;

(a) Yeşil bitkilerin hücreleri gündüz (güneş enerjisi varken) fotosentez yaparlar bu yüzden sadece akşamları (güneş enerjisi yokken) solunum yaparlar.

(b) Yeşil bitkiler yaşamak için enerjiye ihtiyaç duyarlar ve solunum bu enerjiyi sağlar.

(c) Yeşil bitkiler solunum yapmaz, onlar sadece fotosentez yapar, ve fotosentez bitki için gereken enerjiyi sağlar.

(d) ----------

9- Aşağıdaki denklemlerden hangisi bitkilerdeki solunum işlemini en iyi gösterir?

(1) Glikoz + Oksijen ----------→ Enerji + Karbondioksit + Su

(2) Karbondioksit + Su ----------→ Enerji + Glikoz + Oksijen

(3) Karbondioksit + Su ----------→ Oksijen+ Glikoz

(4) Glikoz + Oksijen ----------→ Karbondioksit + Su

Çünkü;

(a) Solunum sırasında yeşil bitkiler güneş enerjisinin varlığında glikoz oluşturmak için karbondioksit ve su alırlar.

(b) Yeşil bitkiler enerji üretmek için karbondioksit ve su kullanırlar oksijen ve glikoz açığa çıkarırlar.

(c) Solunum sırasında yeşil bitkiler oksijen alır, karbondioksit ve su verir.

(d) Solunum sırasında, yeşil bitkiler oksijen kullanarak glikozdan enerji elde ederler.

(e) ----------

10- Aşağıdaki denklemlerden hangisi fotosentez işleminin tümünü en iyi gösterir.

(1) Glikoz + Oksijen ----------→ Karbondioksit + Su

(2) Karbondioksit + Su ----------→ Glikoz + Oksijen

(3) Karbondioksit + Su + Enerji ----------→ Glikoz + Oksijen

Çünkü;

(a) Klorofil güneş enerjisinin varlığında karbondioksit ile birleşir, glikoz ve su üretir.

(b) Güneş enerjisi klorofil içeren bitkiler tarafından karbondioksit ve suyu birleştirip

glikoz ve oksijen oluşturmada kullanılır

(c) Glikoz ve oksijen, klorofilin ve ışık enerjisinin varlığında birleşerek karbondioksit ve suyu oluşturur.

(d) ----------

11- Aşağıdaki faktörlerden hangisi fotosentez işlemi için gerekli değildir?

(1) Oksijen miktarı

(2) Karbondioksit miktarı

(3) Klorofil miktarı

(4) Işık miktarı

Çünkü;

(a) Fotosentez güneş enerjisi yokken gerçekleşebilir.

(b) Klorofil veya benzeri pigmentler içermeyen bitkiler de fotosentez yapabilirler.

(c) Fotosentez karbondioksit yokken gerçekleşmez.

(d) Oksijen fotosentez için gerekli değildir, oksijen fotosentezin bir yan ürünüdür.

12- Fotosentezin yeşil bitkilere en önemli faydası hangisidir?

(1) Havadan karbondioksit alınması

(2) Işık enerjisinin kimyasal enerjiye dönüşmesi

(3) Enerji üretilmesi

Çünkü;

(a) Fotosentez bitkinin büyümesi için gerekli olan enerjiyi sağlar.

(b) Fotosentez sırasında güneş enerjisi glikoz moleküllerinde depolanır.

(c) Fotosentez sırasında karbondioksit yapraklardaki stomalar (gözenekler) tarafından alınır.

13- Aşağıdaki fotosentez ve yeşil bitkilerde solunum karşılaştırmalarından hangisi doğrudur?

Fotosentez	**Solunum**
1- Sadece yeşil bitkilerde gerçekleşir.	Sadece hayvanlarda gerçekleşir.
2- Bütün bitkilerde gerçekleşir.	Sadece bütün hayvanlarda gerçekleşir.
3- Yeşil bitkilerde güneş enerjisinin varlığında gerçekleşir.	Bütün bitkilerde ve bütün hayvanlarda her zaman gerçekleşir.
4- Yeşil bitkilerde güneş enerjisinin varlığında gerçekleşir.	Bütün bitkilerde güneş enerjisi yokken, ve bütün hayvanlarda ise her zaman gerçekleşir.

Çünkü;

(a) Yeşil bitkiler fotosentez yapar ama solunum yapmazlar.

(b) Yeşil bitkiler gündüzleri fotosentez , geceleri ise solunum yaparlar (güneş enerjisi yokken).

(c) Solunum bütün canlılar için devamlı bir işlemdir. Fotosentez ise sadece güneş enerjisi varken gerçekleşir.

(d) Bitkiler fotosentezden yeterli enerji elde edemezlerse solunum yaparlar (mesela akşamları) hayvanlar ise devamlı solunum yaparlar çünkü hayvanlar fotosentez yapamazlar.

(e) ----------

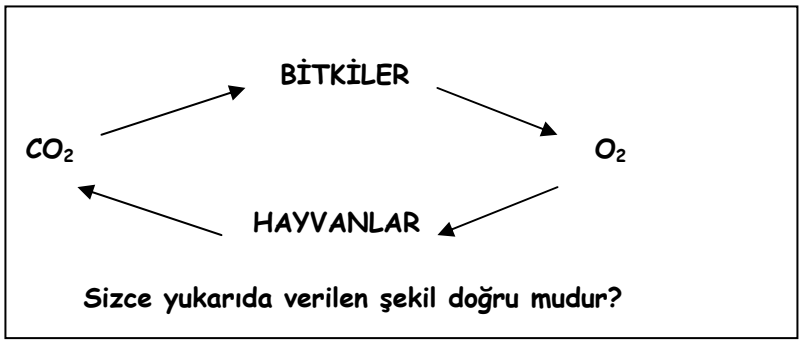
APPENDIX B

KAVRAMSAL DEĞİŞİM YAKLAŞIMI

Ekosistemlerde bütün canlılar birbirleri ile ve cansız çevreleri ile etkileşim halindedirler. Bir ekosistemi oluşturan canlı varlıklara üreticiler, tüketiciler ve ayrıştırıcılar diyoruz.

Örneğin, YEŞİL BİTKİLER ÜRETİCİDİRLER, PEKİ BİTKİLERE NEDEN ÜRETİCİ DENİR HİÇ DÜŞÜNDÜNÜZ MÜ?

Bu soruya cevap vermeden önce aşağıdaki soruyu cevaplamaya çalışalım.



EVET □ HAYIR □

NEDEN?

SONUÇ:

8. sınıfa gelinceye kadar eğitiminizin birçok aşamasında bitkilerin üretici olduğunu öğrendiniz. Peki bitkilere neden üretici denildiğini hiç düşündünüz mü? Bu sorunu cevabı "fotosentez" işleminde gizli olabilir mi? Peki, fotosentez nedir?

Sizce fotosentez nedir?

Bu soruya birçok öğrenci aşağıdaki yanıtları vermişlerdir:

☹ Fotosentez bir çeşit solunumdur.

☹ Fotosentez bitkilerin güneş ışığı altında yaptığı solunumdur.

☹ Fotosentez solunumun tersidir.

☹ Fotosentez bir gaz değişim işlemidir, yani bitkiler karbondioksiti oksijene çevirir.

Bu cevapların hepsi bilimsellikten uzaktır. Fotosentez öğrencilerin çoğu tarafından solunum olayının tersi olarak yada bitkinin solunum yapması olarak bilinmektedir.

Fotosentezi çeşitli yönleri ile incelemeden önce, şu soru hakkında düşünelim:

Sizce bitkinin besini nedir?

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Hepimiz fotosentez işleminde toprağın, yaprakların, güneş ışığının etkili olduğunu biliyoruz.

Şimdi fotosentez işlemini çeşitli yönleriyle inceleyelim:

A. TOPRAĞIN FOTOSENTEZDEKİ ROLÜ NEDİR?

AKTİVİTE: Dr. Van Helmont Deneyi

Bu deneyi tartışmadan önce aşağıdaki soruyu inceleyelim ve cevaplayalım:

Bitkiler besinini topraktan mı alır?

EVET □ HAYIR □

NEDEN?

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SONUÇ:

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Bitkilerin besinlerini nereden aldığını öğrenmek için geçmiş yıllarda birçok deneyler yapılmıştır. Örneğin, yıllar önce yaşamış olan Aristo, bitkilerin besininin toprak olduğunu düşünüyormuş. Şimdi günümüzden 350 yıl öncesine gidelim. O zamanlarda bilim adamları çevrelerinde gerşekleşen olaylarla daha yeni yeni ilgilenmeye başlamışlardı. Bu bilim adamlarından biride Dr. Van Helmont idi. Bir fizikçi olmasına rağmen Van Helmont bitkilerle de deneyler yapıyordu. Helmont bitkilerin besininin toprak olduğu hipoteziyle çok yakından ilgileniyordu. Helmont, bitkilerin besininin toprak olup olmadığını test etmek için bir deney yaptı.

Helmont önce 90 kilogram toprağı hiç nem kalmayacak şekilde kurutmuş. Sonra bu toprağa 2 kilogram ağırlığında bir ağaç fidanı ekmiş. 5 yıl boyunca bu ağacı gerektikçe sulamış. 5 yıl sonra ağacı topraktan çıkartmış. Köklerinde kalan toprakları iyice temizledikten sonra ağacı ve toprağı tekrar tartmış.

Sizce toprağın ağırlığla ilgili olarak aşağıdakilerden hangisi doğrudur?

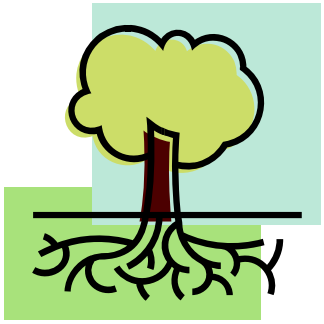
a. Toprak 45 kg ağırlık kaybetmiştir.

b. Toprağın ağırlığı değişmemiştir.

c. Toprağın ağırlığı artmıştır.

d. Toprak ve bitki aynı ağırlığa sahiptir.

e. Toprak 88 kg ağırlık kaybetmiştir.



NEDEN?

SONUÇ:

Toprağın fotosentezdeki rolü ile ilgili sorulara birçok öğrenci şu şekilde cevap vermiştir.

☹ Bitki büyüdükçe toprak miktarında eksilme olur
☹ Toprak bitkinin besinidir
☹ Bitkiler kökleri ile toprağı emer
☹ Toprağın bitkinin büyümesiyle ilgisi yoktur
☹ Bitkiler topraktan protein ve vitamin alır

Van Hemont ölçümlerin sonucunda ağacın 76, toprağın ise 90 kilogramdan birkaç gram az olduğunu görmüştür. Bitkiler fotosentez sırasında KÖKLERİ YARDIMIYLA TOPRAKTAN SU VE MİNERALLERİ ALIR. Bitkinin büyümesiyle toprak miktarında bir eksilme olmaz. Helmont'un deneyinde gözlemlediği birkaç gramlık azalma da topraktaki minerallerin alınmasındandır. Bu deney bıze BİTKİNİN BESİNİNİN TOPRAK OLMADIĞINI GÖSTERMEKTEDİR.

B. YAPRAĞIN FOTOSENTEZDEKİ ROLÜ NEDİR?

	Sizce, yaprağın fotosentezdeki rolü nedir?

Yaprak yüzeyindeki gözeneklerin fotosentez işleminde görevi var mıdır?

EVET □ HAYIR □

NEDEN?

SONUÇ:

Yaprağın fotosentezdeki rolüyle ilgili öğrencilerin düşünceleri ise şu şekildedir

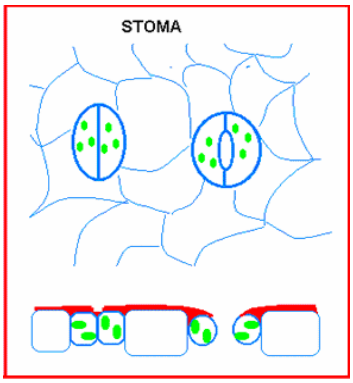
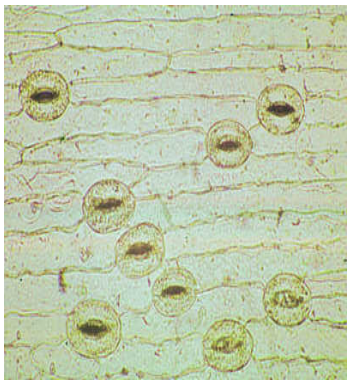
☹ Yaprağın temel görevi havadaki yağmuru ve su buharını tutmaktır

☹ Yaprağın temel görevi güneşin ısısını tutmaktır

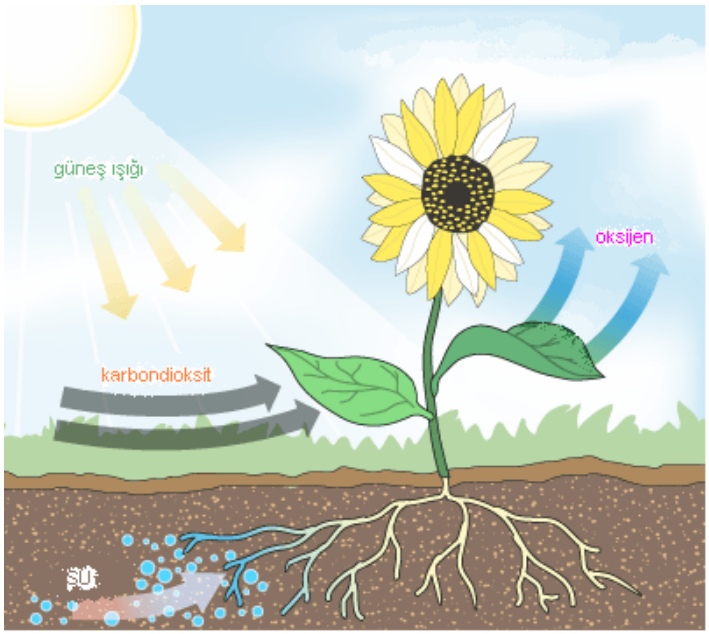
☹ Yapraklar çiy damlalarındaki suyu içerler

☹ Yağmur yaprakların üzerindeki deliklerden içeri girer

Görüldüğü gibi sizler arasında yaygın olarak, yaprağın yağmur esnasında düşen damlardan su aldığı sanılmaktadır. Oysaki, fotosentez için gerekli olan SU, BİTKİNİN KÖKLERİ VASITASIYLA alınır.

	**Gözenek (stoma):** BU HÜCRELER FOTOSENTEZ IÇIN GEREKLI OLAN KARBONDIOKSITIN ATMOSFERDEN ALINIP, AÇIĞA ÇIKAN OKSIJENIN ATMOSFERE VERILMESINI SAĞLAR.	

Yaprakların yapısında bulunan klorofiller güneş ışığını emer. Güneş ışığı, su ve karbondioksit üzerine değmesine rağmen, onların birlikte reaksiyona girmesini sağlayamaz. Güneş enerjisi yakalanmalıdır, sonra da reaksiyonda kullanılmalıdır. Yeşil bitkilerde bunu yapacak olan madde klorofildir. Klorofil bitkilerin yeşil görünmesini sağlayan bir yapıdır. Güneş ışığı klorofil molekülü üzerine düştüğü zaman enerji emilir. Enerji kloroplastın içindeki enzimlerin yardımıyla karbondioksit ile suyu birleştirir.



Fotosentez, klorofil taşıyan canlılarda inorganik maddelerden (CO_2, H_2O) güneş ışığı yardımıyla besin üretilmesi olayıdır. Bu olay sırasında oksijen yan ürün olarak ortaya çıkar. Fotosentez olayının gerçekleşmesi için GÜNEŞ IŞIĞININ VARLIĞI **ŞARTTIR**. Peki ışık enerjisine ne olmuştur? Işık enerjisi kimyasal bağ enerjisine dönüşür. Yani güneş enerjisi tüketilmemiş yada yok olmamıştır, sadece dönüşmüştür.

Fotosentez bir enerji dönüşüm işlemidir diyebiliriz

Güneş enerjisi ---------- > Kimyasal Bağ Enerjisi

Fotosentezde amaç BESİN ÜRETMEKTİR, fakat yeşil bitkiler fotosentez yaptıktan sonra **YAN ÜRÜN** (ATIK ÜRÜN) olarak OKSİJEN gazı da açığa çıkar. Bu durumda güneş ışığının varlığında yeşil bitkilerin büyük miktarlarda açığa çıkardıkları gaz **OKSİJENDİR**.

Öğrenmek için yazmak:

Bu bölümde buraya kadar öğrendiklerinizle ilgili olarak, önceden ne bildiğinizi ve sonradan ne öğrendiğinizi yazalım.

1. Buraya kadar öğrendiklerimle ilgili olarak, başlangıçtaki fikirlerim:

Fikirlerim ne yönde değişti? Şimdi neler biliyorum?

C. BİTKİLERDE SOLUNUM

Sizce, solunum nedir?

Peki, bitkiler solunum yapar mı?

EVET □ HAYIR □

NEDEN?

SONUÇ:

Eğer bitkilerin solunum yaptığını düşünüyorsanız, ne zaman yaparlar?

GECE □ GÜNDÜZ □ GECE-GÜNDÜZ □

NEDEN?

SONUÇ:

Solunum hakkında öğrencilerin sahip oldukları yanlış bilgiler şu şekildedir:

☹ Bitkiler sadece gündüz solunum yaparlar

☹ Bitkiler sadece gece ya da karanlıkta solunum yapar

☹ Bitkiler hiçbir zaman solunum yapmazlar, onun yerine fotosentez yapar

☹ Bitkiler gündüz fotosentez, gece solunum yaparlar

☹ Solunum fotosentezin tersidir

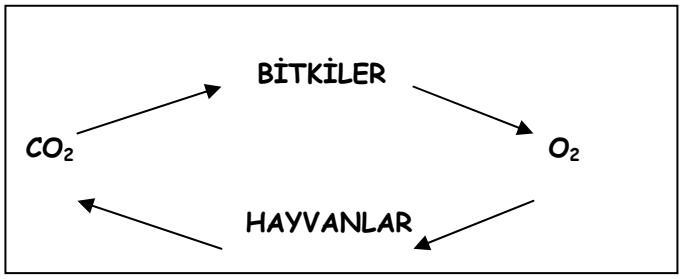
☹ Bitkiler gündüz fotosentez, gece solunum yapar.

☹ Bıtkıler solunum sırasında karbondioksit alır, oksijen verir

Bitkilerin gündüz fotosentez, gece solunum yaptığı bilgisi öğrenciler arasında çok sıklıkla karşılaşlan yanlış bir bilgidir. Öğrenciler bazen solunumu fotosentezin bir alternatifi, bazen ise fotosentezin tam tersi bir işlem olarak düşünmektedir. Hatta bazı öğrenciler fotosentez ve solunumu aynı amaca yönelik işlemler olarak yorumladıkları için, bitkilerin solunum yapmak yerine fotosentez yaptıklarını yada gündüz fotosentez, gece ise solunum yaptıklarını düşünmektedir. Çoğu öğrenci geceleri bitkilerin çok olduğu odalarda yatılmaması gerektiği YANLIŞ bilgisinden yola çıkarak bitkilerde solunumun yalnızca gece gerçekleştiğini sanmaktadırlar.

Oysaki, fotosentez ve solunum iki farklı olaydır ve ikisinde de amaç farklıdır. **FOTOSENTEZDE AMAÇ BESİN ÜRETMEKTİR**, fotosentezin gerçekleşmesi için güneş ışığına ihtiyaç vardır. Dolayısıyla **FOTOSENTEZ SADECE GÜNDÜZ GERÇEKLEŞİR**. Fakat, **SOLUNUMDA AMAÇ ENERJİ**

ÜRETMEKTİR. Tüm canlılarda olduğu gibi bitkilerin de birtakım yaşamsal faaliyetlerini gerçekleştirebilmek için enerjiye ihtiyaçları vardır. Enerji de solunum olayı ile açığa çıktığına göre, bitkiler sürekli solunum yaparlar. Bu yüzden **SOLUNUM GECE VE GÜNDÜZ DAİMA GERÇEKLEŞİR**.



Şimdi öğrendiklerimize dayanarak, yukarıda verilen şeklin doğru olup olmadığını tekrar tartışalım:

Verilen şekil doğru mudur?

EVET □ HAYIR □

NEDEN?

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SONUÇ:

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Eğer şeklin doğru olmadığını düşünüyorsanız, doğrusunu aşağıda verilen boşluğa çiziniz:

Öğrenmek için yazmak:

1. Buraya kadar öğrendiklerimle ilgili olarak, başlangıçtaki fikirlerim:

2. Fikirlerim ne yönde değişti? Şimdi neler biliyorum?

APPENDIX C

ÖĞRENME YAKLAŞIMI ÖLÇEĞİ

	Kesinlikle **Katılmıyorum**	**Katılmıyorum**	Katılıyorum	Kesinlikle **Katılıyorum**
1. Genellikle ilk bakışta zor gibi görünen konuları anlamak için çok çaba sarfederim.	1❑	2❑	3❑	4❑
2. Bir konuya çalışırken, öğrendiğim yeni bilgileri eskileriyle ilişkilendirmeye çalışırım.	1❑	2❑	3❑	4❑
3. Ders çalışırken, öğrendiğim konuları günlük hayatta nasıl kullanabileceğimi düşünürüm.	1❑	2❑	3❑	4❑
4. Konuları en iyi, öğretmenin anlattığı sırayı düşündüğümde hatırlarım.	1❑	2❑	3❑	4❑
5. Öğrenmek zorunda olduğum konuları ezberlerim.	1❑	2❑	3❑	4❑
6. Önemli konuları tam olarak anlayana kadar tekrar ederim.	1❑	2❑	3❑	4❑

7. Konuların birbirleri ile nasıl ilişkilendiğini anlayarak, yeni bir konu hakkında genel bir bakış açısı edinmenin benim için faydalı olduğunu düşünürüm.	1❑	2❑	3❑	4❑
8. Anladığımdan iyice emin olana kadar dersten ya da laboratuvardan sonra notlarımı tekrar tekrar okurum.	1❑	2❑	3❑	4❑
9.Bir konu hakkında çok fazla araştırma yapmanın zaman kaybı olduğunu düşündüğümden, sadece sınıfta ya da ders notlarında anlatılanları ciddi bir şekilde çalışırım.	1❑	2❑	3❑	4❑
10. Okumam için verilen materyalleri, anlamını tam olarak anlayıncaya kadar okurum.	1❑	2❑	3❑	4❑
11. Gerçek olaylara dayanan konuları, varsayıma dayanan konulardan daha çok severim.	1❑	2❑	3❑	4❑
12. Bir konuda öğrendiğim bilgiyi başka bir konuda öğrendiğimle ilişkilendirmeye çalışırım.	1❑	2❑	3❑	4❑
13. Benim için teknik terimlerin ne anlama geldiğini anlamanın en iyi yolu ders kitabındaki tanımı hatırlamaktır.	1❑	2❑	3❑	4❑
14. Bulmaca ve problemler çözerek mantıksal sonuçlara ulaşmak beni heyecanlandırır.	1❑	2❑	3❑	4❑

15. Bir konuda öğrendiğim bilgiyi başka bir konuda öğrendiğimle ilişkilendirmeye çalışırım.	1❑	2❑	3❑	4❑
16. Benim için teknik terimlerin ne anlama geldiğini anlamanın en iyi yolu ders kitabındaki tanımı hatırlamaktır.	1❑	2❑	3❑	4❑
17. Bulmaca ve problemler çözerek mantıksal sonuçlara ulaşmak beni heyecanlandırır.	1❑	2❑	3❑	4❑
18. Genelde okumam için verilen materyalin bana sağlayacağı faydayı **düşünmem.**	1❑	2❑	3❑	4❑
19. Genelde okumam için verilen materyalin bana sağlayacağı faydayı **düşünmem.**	1❑	2❑	3❑	4❑
20. Çoğunlukla, konuları gerçekten anlamadan okurum.	1❑	2❑	3❑	4❑
21. Bir konuyla ilgili verilen fazladan okumalar kafa karıştırıcı olabileceğinden sadece derste öğrendiklerimize parallel olarak tavsiye edilen birkaç kitaba bakarım.	1❑	2❑	3❑	4❑
22. Ekstra birşeyler yapmanın gereksiz olduğunu düşündüğüm için, çalışmamı genellikle derste verilen bilgiyle sınırlarım.	1❑	2❑	3❑	4❑

APPENDIX D

MANTIKSAL DÜŞÜNME YETENEK TESTİ

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

NOT: Soru Kitapçığı üzerinde herhangi bir işlem yapmayınız ve cevaplarınızı yalnızca cevap kağıdına yazınız. CEVAP KAĞIDINI doldururken dikkat edilecek hususlardan birisi, 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'nci sorunun cevabı sizce b ise ve Açıklaması kısmındaki en uygun açıklama ikinci şık ise cevap kağıdını aşağıdaki gibi doldurun:

12. [b] AÇIKLAMASI [2]

9. ve 10. soruları ise soru kitapçığında bu sorularla ilgili kısımları okurken nasıl cevaplayacağınızı daha iyi anlayacaksınız.

SORU 1: Bir boyacı, aynı büyüklükteki altı odayı boyamak için 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 kutusuna oranı daima $\frac{3}{2}$ olacaktır.
2. Daha fazla boya kutusu ile fark azalabilir.
3. Oda sayısı ile boya kutusu 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

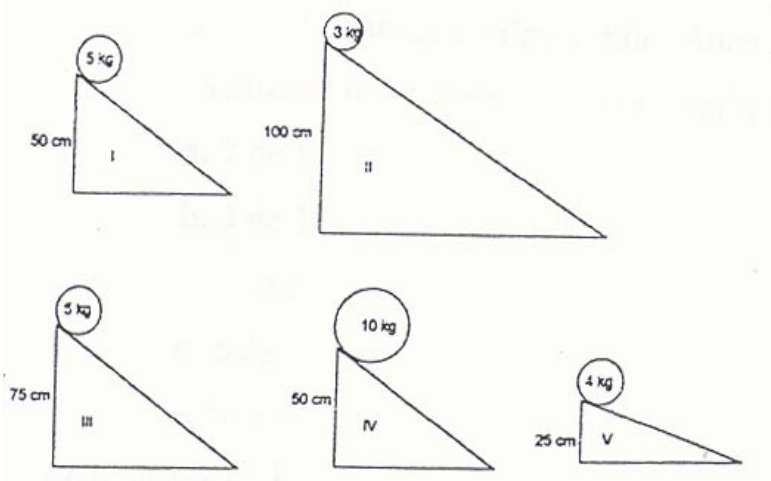
d. 9 kutu

e. Hiçbiri

Açıklaması:

1. Boya kutusu sayısının oda sayısına oranı daima $\frac{2}{3}$ 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 kat ettiği 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

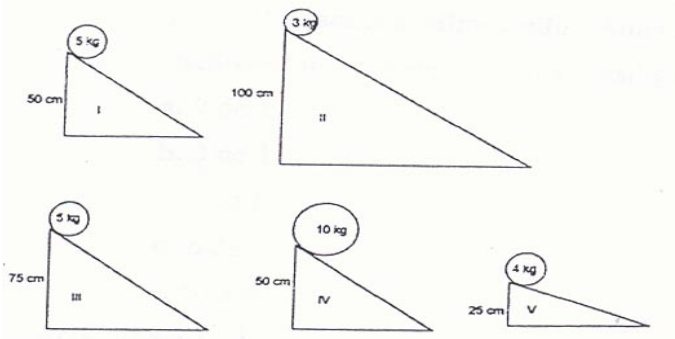
e. Hepsi

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 kat ettiği 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:

a. En ağır olan top en hafif olanla kıyaslanmalıdır.

b. Tüm eğik düzlem setleri birbiriyle karşılaştırılmalıdır.

c. Topun ağırlığı arttıkça, yükseklik azaltılmalıdır.

d. Ağırlıklar farklı fakat yükseklikler aynı olmalıdır.

e. Ağırlıklar aynı fakat yükseklikler farklı olmalıdır.

SORU 5: Bir Amerikalı turist Şark Expresi'nde altı kişinin bulunduğu bir kompartımana girer. Bu kişilerden üçü yalnızca İngilizce ve diğer üçü ise yalnızca Fransızca bilmektedir. Amerikalının 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 yapmak 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 yanısıra, 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. Paraların $\frac{1}{4}$ ü ve yüzüklerin $\frac{4}{9}$ u altından yapılmıştır.
3. Torbadan çekilen nesnenin para ve 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 için 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 oranı daha fazladır.
5. Birinci kutuda daha fazla sayıda şeker vardır.

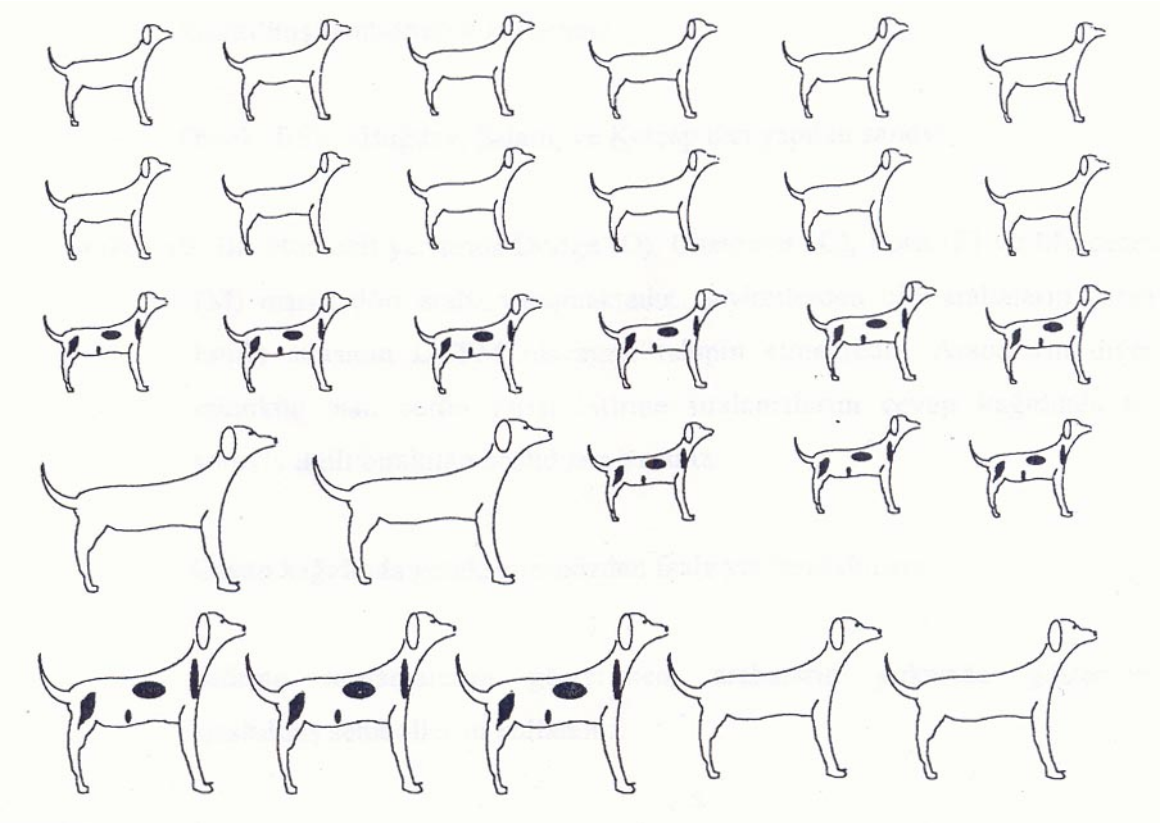
SORU 8: 7 büyük ve 21 tane küçük köpek şekli aşağıda verilmiştir. Bazı köpekler benekli bazıları ise beneksizdir. Büyük köpeklerin benekli olma olasılıkları küçük köpeklerden daha fazla mıdır?

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. Büyük köpeklerin $\frac{3}{7}$ si ve küçük köpeklerin $\frac{9}{21}$ i beneklidir.
5. Küçük köpeklerden 12 sinin, fakat büyük köpeklerden ise sadece 4ünün 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)

Her bir sandviç ekmek, et ve sos içermektedir. Yalnızca bir ekmek çeşidi, bir et 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 yarışı bitirme sıralamalarını cevap kağıdında bu soruyla ilgili bırakılan boşlukalara yazınız.

Cevap kağıdında gereksiniminizden fazla yer bırakılmıştır.

Bitirme sıralamalarını gösterirken, arabaların yukarıda gösterilen kısaltılmış sembollerini kulanınız.

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