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Photosynthesis and Respiration Processes: Prospective Teachers' Conception Levels

Fotosentez ve Solunum Süreçleri: Öğretmen Adaylarının Anlama Düzeyleri

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Abstract

The purpose of this study was to determine and compare prospective teachers' conceptions of photosynthesis and respiration processes that are important subjects in a science and technology course. A questionnaire with two open-ended questions was administered to 90 senior students from the Elementary Science Department and 62 sophomore students from the Primary Education Department, in the Faculty of Education, Pamukkale University, Denizli, Turkey. A survey method was carried out in this study. The data were of qualitative nature and were analyzed by using the technique of content analysis to reveal the emerging themes. Prospective teachers' conceptions were categorized at three levels, namely, correct, partially correct, and incorrect. Results show that the scientifically acceptable definitions of photosynthesis and respiration are forty-two and twenty-nine percent for prospective elementary science teachers, and five and two percent for prospective classroom teachers, respectively. Participants held four misconceptions related to photosynthesis and two misconceptions related to respiration. The sources of prospective teachers' misconceptions about photosynthesis and respiration processes were discussed based on the science education literature. Their surface understanding of chemical reactions may be at the root of these misconceptions.

Keywords: Photosynthesis, respiration, content knowledge, prospective teachers, misconceptions

Öz

Bu çalışmanın amacı, öğretmen adaylarının fen ve teknoloji dersinin iki önemli konusu olan fotosentez ve solunum süreçlerini kavramalarını belirlemek ve karşılaştırmaktır. Pamukkale Üniversitesi Eğitim Fakültesi'ne kayıtlı, fen bilgisi öğretmenliğinden 90 dördüncü sınıf öğrencisi ve sınıf öğretmenliğinden 62 ikinci sınıf öğrencisine iki açık-uçlu soru içeren anket uygulanmıştır. Bu çalışmada tarama modeli kullanılmıştır. Nitel yolla toplanan veriler, içerik analizi tekniği ile çözümlenerek temalar elde edilmiştir. Öğretmen adaylarının fotosentez ve solunum süreçlerini kavramaları; doğru, kısmen doğru ve yanlış olmak üzere üç seviyede kategorize edilmiştir. Bulgular, fen bilgisi öğretmeni adaylarının %42'sinin fotosentezi ve %29'unun solunumu; sınıf öğretmen adaylarının ise %5'inin fotosentezi ve %2'sinin solunumu bilimsel anlamda tanımladığını gösterir. Katılımcılar fotosentezle ilgili dört ve solunumla ilgili iki kavram yanılgısına sahiptirler. Öğretmeni adaylarının fotosentez ve solunumla ilgili kavram yanılgılarının kaynakları alanyazına dayanılarak tartışıldı. Onların kimyasal denklemler hakkındaki yüzeysel anlayışları, kavram yanılgılarının bir kaynağı olabilir.

Anahtar Sözcükler: Fotosentez, solunum, alan bilgisi, öğretmen adayları, kavram yanılgıları

Introduction

Photosynthesis as a fundamental process for life on earth has long been a core part of the school biology curriculum (Matthews, 2009). For this reason, it is taught to different grades at

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school. Respiration is a process by which all organisms obtain energy from organic substances in aerobic or anaerobic conditions. Photosynthesis and respiration are essential in understanding the movement of energy and raw materials in the ecosystem. Someone who wants to learn how an organism, an ecosystem or the biosphere functions should understand the differences between these two processes as well as their common features and the interrelationship between them (Anderson, Sheldon & Dubay, 1990). To date, several studies have documented conceptual difficulties of students regarding photosynthesis and respiration (Anderson et al., 1990; Barker & Carr, 1989; Cañal, 1999; Eisen & Stavy, 1988; Haslam & Treagust, 1987; Lin, 2004; Lin & Hu, 2003; Özay & Öztaş, 2003; Stavy, Eisen, & Yaakobi, 1987). More importantly, some of these studies have found that prospective elementary school teachers (Brown & Schwartz, 2009; Cakiroglu & Boone, 2002; Köse, 2008; Köse & Uşak, 2006; Tekkaya et al., 2004) and elementary/secondary school teachers (Käpylä, Heikkinen, & Asunta, 2009; Krall et al., 2009; Mak et al., 1999; Sanders, 1993; Tekkaya, 2002; Tekkaya, Çapa, & Yılmaz, 2000; Yip, 1998) have difficulties with these concepts. For example, Barker and Carr (1989) described secondary school students' and first-year undergraduates' understanding of photosynthesis with a survey item in which students were required to write a paragraph about photosynthesis. In their responses some students grasped the idea that photosynthesis produces carbohydrate, and the others described photosynthesis as *food-making* or *energy-storing processes*. The notion that photosynthesis is how plants produce carbohydrate or store energy steadily increased with older students, but the *food-making* view peaked at form six and then declined. The view that photosynthesis was an *energy–storing process* was originated from teachers and textbooks. These studies revealed that the students at all ages held misconceptions about photosynthesis and respiration. Anderson et al. (1990) investigated college non-majors' conceptions of how plants and animals acquire and use matter and energy, including the roles of photosynthesis and respiration. The results showed that most students gave definitions of these concepts, which were obviously different from those generally accepted by biologists.

The results of research have indicated that there were important factors that influence students' understanding of those topics such as teachers (Barker & Carr, 1989; Barrass, 1984; Sanders, 1993), textbooks (Barker & Carr, 1989; Barrass, 1984; Hershey, 2004; Storey, 1989), and the difference between scientific discourse and everyday language (Anderson et al. 1990; Eisen & Stavy, 1988;). For example, Sanders (1993) indicated that teachers could be a factor contributing to the formation of misconceptions in their pupils. Biology teachers held erroneous ideas about respiration and related concepts, such as 'The purpose of respiration is to provide oxygen and to remove carbon dioxide' (77.2%), 'Respiration is a gaseous exchange process during which oxygen is taken in and carbon dioxide is given off' (42.6%), 'Photosynthesis is the process that provides plants with the energy they need for life processes' (41.9%), 'The equation for respiration is: O_2 + glucose = CO_2 + H_2O' (40.4%). Yip's (1998) study found that the statement 'Photosynthesis is made up of a light reaction and a dark reaction' was considered to be correct by majority of novice biology teachers (88%), and as based on the classroom observation, similar statements are frequently delivered by teachers during lessons. Cakiroglu and Boone (2002) investigated Turkish prospective elementary teachers' misconceptions about photosynthesis and respiration. Some of them held misconceptions such as 'Photosynthesis can occur in green plants all the time' (20%), 'Photosynthesis is a process in which plants take in CO_2 and change it to O_2' (14%), 'Respiration is gas exchange' (37%), 'Respiration is breathing' (33%), and 'Respiration is CO_2 for humans and exhaling O_2 for plants' (20%). Tekkaya (2002) reviewed the students' misconceptions as barrier to understand biology concepts, and Tekkaya et al. (2004) investigated Turkish prospective science teachers' understandings of science concepts. Participants held misconceptions such as 'Respiration is a gas exchange process' (83%), 'Plants respire only at night' (83%), and 'Respiration occurs in animals in lungs' (59%). In another study, Köse and Uşak (2006) found that most of pre-service teachers had some misconceptions in certain subjects like, "photosynthesis occurs only in green plants", "photosynthesis is a gas exchange process", "green plants respire only in nights when there is no light", "respiration occurs only in the leaf of plants". In their research, Käpylä, Heikkinen, and Asunta (2009) investigated and compared primary and secondary (biology) teacher students' content knowledge about photosynthesis and plant growth. The content knowledge of primary teacher students have been characterized piecemeal, less structured, and having more mistakes or inaccuracies. Secondary (biology) teacher students have more structured knowledge and they understand better the relationships between concepts.

According to Brown and Schwartz (2009), prospective elementary teachers were limited in their understanding of the process impacting multiple ecological levels, and they had inadequate representations of interconnections between the processes. Half of the participants indicated that they did not know how the plant used photosynthesis to grow. Photosynthesis was seen as the energy process by them (55%). They provided evidence from food chains and light energy to support their view. The study of Krall et al. (2009) revealed similarities between non-scientific conceptions of the teachers had, and non-scientific conceptions reported in the research literature on elementary and middle school students' understanding of the concepts. Unfortunately, if teachers retain the same misconceptions, then as classroom teachers they may reinforce the misconceptions currently held by the students or have their students accept different erroneous ideas for particular topics.

Significance of the Study

Previous studies revealed that teachers' understanding of science concepts, attitudes toward and beliefs regarding science teaching are strong predictors of effective science teaching in the classroom. Regarding the concepts, facts and skills concerning science, studies reported that classroom teachers possessed generally low level of content knowledge. Classroom teachers teach all subjects and may not be equally effective in teaching all of them. It is primary science that the classroom teachers have most troubles (Fulp, 2002). Of the four subject areas most often covered in primary grades—reading/language arts, mathematics, science and social studies—teachers consistently report that they feel least qualified to teach science. Recent figures indicate that approximately 77% of classroom teachers surveyed in 2000 reported feeling adequately prepared to teach reading, but only 30% said they were adequately prepared to teach science.

Teacher content knowledge is one of the three domains of content knowledge identified as inherent to teacher classroom effectiveness (Shulman, 1986). Previous research studies have emphasized the importance of teachers' content knowledge on determining students' achievement (Darling-Hammond, 2000; Wright, Horn & Sanders, 1997). Wright et al. (1997) found teacher factor had the greatest impact on students' achievement in comparison to other factors including class size and group heterogeneity. The events and experiences during the early years are important contributors to students' future success in science and the importance of qualified science teachers beginning in the early grades.

Students in every educational stage have some misconceptions about science concepts (e.g. photosynthesis and respiration), and they acquire their first experiences with school science at the elementary level. It is well known that only classroom and elementary science teachers teach the science topics in early formal education. Prospective classroom or elementary science teachers will be teachers who will teach science and technology course in the elementary schools in the next years, so they have a crucial effect/role in teaching students the science concepts correctly.

The importance of fostering science teaching at the elementary level, this study was designed to examine the understanding of prospective classroom and elementary science teachers' knowledge of science subject matter about photosynthesis and respiration, and basic concepts they are expected to teach. This study therefore examines the prospective teachers' learning outcomes based on their descriptions of photosynthesis, and respiration. The aims of this study are: (1) to explore and compare the prospective teachers' perception levels of these issues, and (2) to excerpt the concepts existing in their responses for these issues.

Method

Participants

Elementary science students will be a teacher who will teach science and technology course in grades 6, 7, and 8 in the following years. Similarly, primary education students will be a teacher who will teach science and technology course at grades 4 and 5 in the next years. The research sample (n=152, male: 80, female: 72) consisted of two groups from two different educational departments. The first group (two classes) was selected randomly from four separate classes and the other group (two classes) from six separate classes. The first group (science majors) consisted of fourth-year elementary science students (n=90; male: 44, female: 46) who had studied advanced courses in biology (in secondary school and at the university). The second group (non-science majors) consisted of second-year primary education students (n=62; male: 36, female: 26) who had no advanced studies in biology. A traditional lecturing approach was followed in the courses. Most of the participants were between the ages of 20 and 23.

Instrument

A total of 152 prospective elementary teachers participated in this study. Data were obtained through a written survey. Two open-ended questions (both consisted of four short questions) in the survey, which had been used earlier in other studies (Barker & Carr, 1989; Eisen & Stavy, 1988; Stavy, Eisen & Yaakobi, 1987) were used to probe participants' understanding levels of the respiration and photosynthesis processes and to recognize how they conceptualised these two important biological issues in general (Appendix A). It was considered that the participants' responses included the purposes, the requirements, and products of these issues. Photosynthesis and respiration processes are chemical reactions that occur in the cells. Biologists define photosynthesis as a process involving both a sequence of chemical reactions and an energy conversion. Chemical reactions and energy is one of the subject areas of chemistry education (Ceylan & Geban, 2010). The questionnaire was administered to prospective science teachers (PSTs) at the *Methods of Science Teaching* course and to prospective classroom teachers (PCTs) at the *Environmental Education* course in December of 2006. It aimed to investigate participants' conceptions about the goals and outputs of photosynthesis and respiration processes. It was observed that the participants responded the survey in approximately 20 minutes.

Data Analysis

A survey research method was used in this study. "The survey method gathers data from a relatively large number of cases at a particular time. It is concerned with the statistics that result when data are abstracted from a number of individual cases" (Best & Kahn, 2006:121). The responses to the open-ended questions were analysed to determine 'how prospective teachers conceptualise photosynthesis and respiration processes in living organisms'. "Open-ended question is an unrestricted question in which (unlike in a multiple choice question) possible answers are not given, and it calls for a free response in the respondent's own words. The respondents reveal their frame of reference and possibly the reasons for their responses." (Best & Kahn, 2006:314). Such questions usually begin with a *how*, *what*, *when*, *where*, *why* and provide qualitative instead of quantitative information. That exposes their conceptual framework for these concepts (*i.e.* photosynthesis and respiration) in detail, and reflects the nature of the relationship among other concepts. Relevant concepts would help to clarify the relationship among concepts. The purpose was to find out whether the prospective teachers had described the starting materials and reaction products of the *photosynthesis reaction* scientifically correctly. First, prospective teachers' understanding levels were assigned to one of three levels from their definitions: correct, partially correct, and incorrect categories. The correct understanding of photosynthesis requires formal operations because students must separate, control, and exclude variables to understand that water, carbon dioxide, light and chlorophyll/chloroplasts must be present before a plant can produce organic substances and oxygen. The partial understanding of photosynthesis is defined as the absence of one of the requirements or by-product, oxygen. Incorrect response is referred to the absence of main product, organic substance, food or store energy, and to no answer. The purpose was to find out whether the prospective teachers had described the starting materials and reaction products of the *respiration reaction* scientifically correctly. The correct understanding of respiration requires formal operations because students must separate, control, and exclude variables to understand that organic substances and oxygen must be present before a plant can produce energy, water, and carbon dioxide. The partial understanding of respiration is defined as the absence of one of the requirements or products excluded energy. Incorrect response is referred to the absence of occurrences of energy, and to no answer. Second, the data was analysed with regard to main processes and identified related concepts. The participants' descriptions were classified according to whether they referred to photosynthesis as a process which produces carbohydrate (i.e. sucrose or organic substances), or one which stores energy, or one which makes food. Other responses (e.g. produces energy, exchanges gas) were also noted. Participants who expressed more than one of these views contributed to only one trace (Barker & Carr, 1989). The participants' descriptions of respiration were classified according to whether they referred to respiration as a process of exchanging gases (+ energy release), or of oxidising food (+ energy release), or of producing energy from food (Eisen & Stavy, 1988). Third, a content analysis was made for photosynthesis and respiration processes, and two major concepts (requirements, and products) and other concepts were identified across the responses. Some of the misconceptions of prospective teachers were discussed.

Results

Prospective Teachers' Conception Levels of Photosynthesis

Before an evaluation of prospective teachers' responses of photosynthesis, scientific definition of this concept should be examined in brief. Biologists define photosynthesis as a process involving both a sequence of chemical reactions and an energy conversion. These photo chemical reactions produce carbohydrate and oxygen from carbon dioxide and water. The energy in sunlight is converted to chemical potential energy in glucose, i.e. photosynthesis is an endothermic reaction. Understanding of which ones are the inputs and outputs of the photosynthesis was analyzed by means of the written responses. The scientific definition of photosynthesis is used in the evaluation of the prospective teachers' responses is shown in Table 1. The prospective teachers described photosynthesis process; correctly (42% of PSTs, and 5% of PCTs), in partially correct (36% of PSTs, and 37% of PCTs), and incorrect (22% of PSTs, and 58% of PCTs).

Table 1.

Prospective Teachers' Conception Levels of Photosynthesis

Level	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Correct	*38*	42	*3*	5
Partially correct	*32*	36	*23*	37
Incorrect	*20*	22	*36*	58

According to the results, more than one fifth of participants (21% of PSTs, and 24% of PCTs) grasped the fundamental point that photosynthesis produces carbohydrates (Table 2). Organic compounds (i.e. carbohydrates) are a class of substances that organisms can use as sources of energy for metabolism or materials for growth (Anderson et al., 1990). Some of the participants stated that photosynthesis is '*a food-making process*' (45% of PSTs, and 23% of PCTs), or is '*an energy-storing process*' (11% of the PSTs, and 0% of PCTs). In other responses, some of the PCTs defined 'photosynthesis as a kind of respiration, a process of gas exchange, or process of inhaling carbon dioxide and exhaling oxygen.'

Table 2.

Prospective Teachers' Descriptions of Photosynthesis

Responses	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Produce carbohydrate	*19*	21	*15*	24
Make food	*40*	45	*14*	23
Store energy (i.e. food)	*10*	11	*0*	0
Other responses	*21*	23	*33*	53

Elaborated concepts of requirements and products from participants' responses of photosynthesis are presented in Table 3. The participants mentioned organic substances or food as the product of photosynthesis (84% of PSTs, and 55% of PCTs). They stated that the sunlight energy is used in the photosynthesis process (86% of PSTs, and 69% of PCTs). More than half of them wrote that carbon dioxide was a necessary starting material (71% of PSTs, and 55% of PCTs) and oxygen was one of the end products (63% of PSTs, and 55% of PCTs). In both groups more than eighty percent of the participants were aware of the fact that the sunlight absorption by chlorophyll is essential for photosynthesis process, but only few mentioned that photosynthesis occurred in chloroplasts. It was remarkable that none of the prospective teachers stated the catalytic effect of chlorophyll, the light reactions, or Calvin cycle in their definitions.

Table 3.

The Elaborated Concepts related to Photosynthesis

Related Concepts	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Requirements				
Light	*77*	86	*44*	71
Pigments				
Location: chloroplasts	*6*	7	*4*	6
Chlorophyll	*73*	81	*53*	85
Raw materials				
Carbon dioxide	*64*	71	*35*	55
Water	*44*	49	*11*	17
Minerals	*20*	22	*16*	26
Product(s)				
Carbohydrates				
Organic substance	*19*	21	*15*	24
Food	*56*	63	*19*	31
Oxygen	*57*	63	*34*	55

Prospective Teachers' Conception Levels of Respiration

Before an evaluation of prospective teachers' responses of respiration, scientific definition of this concept should be examined in brief. Respiration process refers to the overall process by which oxygen is absorbed from air and is transported to the cells for the oxidation of organic molecules while carbon dioxide and water, the products of oxidation, are returned to air. Cellular respiration, which is an exothermic reaction, is the process by which cells break down organic substances to get energy. Put more simply, respiration is the process by which all organisms obtain energy from organic substances (sucrose or other sugars, starch, lipids, and proteins) in aerobic (or anaerobic) conditions.

Understanding of the starting materials and products of the respiration was analyzed by means of the written responses. The scientific definition of respiration used in the evaluation of the prospective teachers' responses is shown in Table 4. According to the results, 29% of PSTs (2% of PCTs) described respiration correctly (i.e. as an energy obtaining process by oxidation of organic substances or food), and 25% of PSTs (16% of PCTs) described respiration in partial understanding, 46% of PSTs (82% of PCTs) described respiration incorrectly. In the incorrect responses, they used the term *breathing* as a synonym of respiration.

Table 4.

Prospective Teachers' Conception Levels of Respiration

Level	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Correct	*26*	29	*1*	2
Partially correct	*23*	25	*10*	16
Incorrect	*41*	46	*51*	82

The aspects of respiration that emerged in responses of participants are presented in Table 5. The prospective teachers described respiration as an energy production process in rates of 54% of PSTs (19% of PCTs) correctly. Twenty-nine percent of PSTs (5% of PCTs) saw both oxidation of food and energy release in respiration. Sixteen percent of PSTs (6% of PCTs) defined respiration as an exchange of gases and energy release. Some of the participants (11% of PSTs, and 5% of PCTs) defined respiration referring to oxidation of food, and some of them (9% of PSTs, and 8% of PCTs) defined respiration referring to energy production from food. Prospective teachers (32% of PSTs, and 8% of PCTs) wrote 'There are two kinds of respiration in organisms—aerobic and anaerobic.'

Table 5.

Prospective Teachers' Descriptions of Respiration

Responses	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Exchange of gases	*32*	35	*44*	71
Exchange of gases + Energy release	*14*	16	*4*	6
Oxidation of food	*10*	11	*3*	5
Oxidation of food + Energy release	*26*	29	*3*	5
Energy production from food	*8*	9	*5*	8

As can be seen in Table 6 as to the requirements of respiration, food was stated in the rate of 49% of PSTs' responses (12% of PCTs' responses) and oxygen was stated in the rate of 62% of PSTs' responses (90% of PCTs' responses). According to biologists, the purpose of respiration is the provision of energy for life processes in living organisms (Sanders, 1993). Only 59% of PSTs (24% of PCTs) expressed that the necessity of energy for organisms is provided by respiration. The other products of respiration, carbon dioxide appeared in the rate of 46% in the PSTs' responses (90% in the PCTs' responses) and water appeared in the rate of 17% in the PSTs' responses (0% in the PCTs' responses). A noteworthy result of this study was that the prospective teachers focused on breathing not cell respiration, so none of them wrote where the respiration took place in their responses.

Table 6.

The Elaborated Concepts Related to Respiration

Related Concepts	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
Requirements				
Food (e.g. sucrose, starch)	*44*	49	*7*	12
Oxygen	*56*	62	*56*	90
Location: in cells	*0*	0	*0*	0
Product(s)				
Energy	53	59	*15*	24
Carbon dioxide	*41*	46	*56*	90
Water	*15*	17	*0*	0

Prospective teachers' misconceptions about photosynthesis and respiration processes were presented in Table 7. They held four misconceptions related to photosynthesis and two misconceptions related to respiration processes. These are; 'respiration is an inverse reaction of photosynthesis' (11% of PSTs), 'glucose is the end product of photosynthesis' (14% of PSTs), and 'photosynthesis is a process that plants take in CO_2, and release O_2' (29% of PCTs). Some of the prospective teachers (35% of PSTs, and 71% of PCTs) referred only to the external aspects of respiration: gas exchange by inhaling and exhaling air. Some in PCTs group referred to the absorption of oxygen. They wrote 'living organisms inhale oxygen, and exhale carbon dioxide', and regarded respiration as basically a process of gaseous exchange between living beings and the atmosphere. In their descriptions of respiration process, they emphasized the respiratory organs, such as lungs, tracheas, or gills instead of cell respiration.

Table 7.

Prospective Teachers' Misconceptions about Photosynthesis and Respiration

Misconceptions	PSTs (N=90)		PCTs (N=62)	
	f	%	*f*	%
1. Photosynthesis is a process that plants take in CO_2, and release O_2.	*0*	0	*18*	29
2. Photosynthesis is a process that green plants convert CO_2 to O_2 in light.	*0*	0	*7*	11
3. Photosynthesis is a kind of respiration that plants make in light.	*0*	0	*4*	6
4. Glucose is the end product of photosynthesis.	*13*	14	*0*	0
5. Respiration is an inverse reaction of photosynthesis.	*10*	11	*0*	0
6. Respiration is the exchange of CO_2 and O_2 gases.	*32*	35	*44*	71

Discussion

The purpose of the current study was to find out whether prospective teachers had described the starting materials and reaction products of the *photosynthesis* and *respiration reactions* in a scientifically correct manner. Written responses of participants revealed that some of the prospective teachers had misconceptions such as gas exchange processes in their descriptions of the issues. The findings of study showed that these processes were not understood meaningfully by them. The results of this study parallel those of previous studies (Cakiroglu & Boone, 2002; Köse & Uşak, 2006; Sanders, 1993; Tekkaya et al., 2004). They might be had difficulties in recognizing and understanding of the concept of chemical change. They saw only the surface features of the photosynthesis or respiration reactions (i.e. a gas exchange) without considering the other input or output in the reactions. Moreover, the production of glucose cannot be directly observed. According to previous research, students have problems in recognizing and understanding the chemical change (Hesse & Anderson, 1992; Johnson, 2000), and their understanding of chemistry is built on the perceptual or surface features of physical signs (e.g. change in color, precipitation or gas output) (Kozma & Russell, 1997; Stains & Talanquer, 2008). There are many concepts that can be observed (macroscopic) at the perceptible levels, but that can only be explained at the reconstructed (symbolic or sub-microscopic) levels (Pekdağ & Le Maréchal, 2010). Students' understanding of chemistry relies heavily on sensory information, and the reconstructed levels are especially difficult for students because these levels are invisible and abstract. In the minds of many students, there is no connection between these perceptible and reconstructed levels. Regarding the subject matter knowledge of chemical reactions, the Turkish freshman science student teachers do not bring a well-developed understanding of the essential concepts of chemical reactions with them from secondary school (Usak, Ozden & Eilks, 2011). It is possible to say that some of prospective teachers have had lack of knowledge and understanding about chemical reactions. However, participants in both groups are being novice student teachers; the PSTs (majors in science) had more structured content knowledge than the PCTs (non-majors in science). The prospective teachers' incomplete knowledge in chemical reaction topic may be an important factor for their misconceptions related to photosynthesis and respiration processes.

Photosynthesis has been rated as one of the most difficult topics for students (Stavy et al., 1987; Waheed & Lucas, 1992). Its difficulty lies mainly in the fact that it is a complex biological topic, with a number of conceptual aspects (ecological, physiological, biochemical, energetic, autotrophic feeding) whose connection cannot be easily understood by the students (Waheed & Lucas, 1992). Prospective teachers are expected to reply photosynthesis process by which carbon dioxide and water are converted into carbohydrate and oxygen in the presence of sunlight and chlorophyll. Some of the prospective teachers stated that the *food* was the end product of photosynthesis. Food is used in biological contexts with a meaning different from its common meaning. Food can be defined as chemically, as well as class of substances containing usable organic compounds, or functionally, as a class of substances that organisms can use as sources of energy for metabolism or materials for growth (Anderson et al., 1990). It implies that carbon dioxide, water, and minerals are inorganic nutrients but not *food*.

Based on the overall chemical reaction, photosynthesis and respiration appear as opposites. The use of summary equations, in which photosynthesis is represented simply as the opposite of respiration, may cause some students to think that they are alternatives (i.e. both processes cannot occur simultaneously) (Barrass, 1984). Many teachers also see respiration and photosynthesis as mutually exclusive processes those do not occur simultaneously (Sanders, 1993). Some of PSTs wrote that 'glucose is the end product of photosynthesis'. However, it is well known that the end products of photosynthesis are primarily sucrose and starch (Storey, 1989; Matthews, 2009), fatty acids and proteins (Storey, 1989) in most plants. Although most biology textbooks state unequivocally that the product of photosynthesis is simple sugars (e.g. glucose), but practical work in photosynthesis in secondary schools lab is dominated by testing for starch in leaves with iodine (Barker & Carr, 1989).

Biologists accept that the purpose of respiration is the provision of energy for life processes in living organisms (Sanders, 1993). Similar to previous research, about half of PSTs and most of PCTs used a common definition for respiration in which the term as a synonym for breathing rather than a biological description of cellular respiration. Unlike respiration, photosynthesis has only been used with a scientific meaning, and there are no synonyms for it in daily language.

Conclusions and Implications

Photosynthesis and respiration are important because of the essential roles they play in organisms' acquisition and use of energy for metabolism and growth. They are also the basic processes in carbon cycle, in which matter is converted from inorganic to organic forms and from organic to inorganic forms. This study has argued two central issues in biology: photosynthesis (the production of carbohydrate) and respiration (the production of energy). Photosynthesis transforms radiant energy from the sun into chemical bond energy within the carbohydrate molecule. The chemical energy is transformed to a smaller unit of energy within the ATP molecule. The energy within the ATP molecule produced during cellular respiration allows photosynthesis to continue. Learning outcomes of the education period meets only limited success because of the participants' preconceptions about plant function and educational materials. The inadequate subject knowledge of prospective teachers suggests that the undergraduate chemistry and biology courses may not sufficiently equip them with a strong foundation in the discipline for teaching the elementary science curriculum.

Findings also suggest that a majority of prospective teachers in the sample did not have an accurate understanding of the concepts of photosynthesis and respiration. In too many cases, participants in the current study demonstrated misconceptions that have been shown to be held by elementary or secondary school students. Thus, this study adds to the growing body of research on teachers' understanding of science concepts, suggesting that far too often classroom and elementary science teachers have not been prepared adequately to teach science. Therefore, educators need to be aware of undergraduates' misconceptions as well as their sources, in order to improve the teaching of these processes. Awareness of students' misconceptions itself could contribute to improve new teaching strategies in teacher education programs.

The following educational implications may be presented to biology teachers and science educators. In this study, prospective teachers were found to have similar misconceptions as described in the science education literature. This provides an evidence of the *stability* of misconceptions despite *biology instruction.* Considering the fact that these prospective teachers would teach science and technology course (grades 4 to 8) in the following years, it is important to eliminate these misconceptions in the teacher education programs. Therefore, this study has some implications. Firstly, biology instruction in teacher education programs, which fosters conceptual understanding rather than rote memorization, may help to eliminate student teachers' misconceptions. For this purpose, an efficient learning environment where prospective teachers have the opportunity to discuss their ideas and reflect on their thinking may be helpful. In addition, the emphasis of photosynthesis and respiration topics with the daily life may prevent rote memorization and provide the link of the scientific knowledge with daily life.

Secondly, an educator must remember that different students not only learn differently, but also come to the classroom with different pre-knowledge and (mis)conceptions. She/he should pay more attention to teaching photosynthesis and respiration processes especially emphasizing the inputs and outputs of the chemical reactions of these issues. The students incline to see the surface features of reactions without learning underpinning concepts while reaction occurs. Therefore, teachers must help the students make the connections between their old (mis)conceptions and the new, scientifically acceptable connections being introduced.

Thirdly, the scientific opinions in the textbooks and other educational materials should be revised with a critical eye (e.g. the words *food* and *nutrient* should be revised in the textbooks). Concepts are packages of meaning; they capture regularities, patterns, or relationships among objects, events, and other concepts (Novak, 1996 in Cakir, 2008). Each concept is a human invention, a way of understanding and organizing the natural phenomena. Putting things into words is an essential part of science teaching and learning, a process that depends on interaction between teacher and learner because the learner cannot discover the vocabulary for science independently. Since educators and teachers must be careful when introducing and defining concepts to students. In general, if the main themes are comprehended by prospective teachers, the details can be learned in the first years of their professional working experiences at schools.

Limitations to the Study

This study has some limitations. In this study, data were collected from 90 prospective elementary science teachers and 62 prospective classroom teachers enrolled in a university in Turkey. As a future study, I would suggest conducting the same study (more questions should be added) with a large sample of prospective teachers from different universities in Turkey. Moreover, in-service science and technology teachers' (grades 4 to 8) conceptions about photosynthesis and respiration processes could be examined in future studies. As another limitation, this study only revealed prospective teachers' conceptions and misconceptions about photosynthesis and respiration processes but did not focus on how to eliminate these misconceptions despite some recommendations made. Therefore, as a future study, it would be beneficial to evaluate the effectiveness of several teaching strategies in teacher education programs.

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Appendix A. The science survey form administered to prospective teachers
Department: ……………….. Male: ( ) Female: ( ) Age: ……..
Write an answer to each of the questions. Question 1. What is photosynthesis? Please briefly describe the photosynthesis process regarding to the view of these points: (1) What is the aim of photosynthesis in plants? (2) What materials does a plant absorb from its environment? (3) How does a plant make photosynthesis? (4) Plants are called producers. What do they produce? Question 2. What is respiration? Please briefly describe the respiration process regarding to the view of these points: (1) What is the aim of respiration process? What kinds of respiration are possible? (2) How does a plant make respiration? Does a plant breathe? (3) How does an animal make respiration? (4) What are produced by respiration?