European Journal of Educational Research
Volume 7, Issue 4, 813 - 826.
ISSN: 2165-8714
http://www.eu-jer.com/

Defining the Relationship between the Perceptions and the Misconceptions about Photosynthesis Topic of the Preservice Science Teachers

Mustafa Urey *
Trabzon University, TURKEY

Received: July 3, 2018 ▪ Revised: September 19, 2018 ▪ Accepted: September 25, 2018

Abstract: The aim of the research is to determine the perceptions of the preservice science teachers about the photosynthesis and to reveal the relation between these perceptions and the misconceptions of the existing concepts. In the research, field scanning method was used as a descriptive research method. The sample of the research is composed of 355 preservice science teachers trained in different universities. For the selection of the sample, purposeful sample selection was used and attention was paid to the fact that the preservice science teachers had taken the General Biology-I and General Biology-II courses at the undergraduate level in the determination of the class level to be included in the study. The "Photosynthesis Concept Achievement Test" (PCAT) developed by the researcher and composed of 4 questions was used as a data collection tool. Quantitative data obtained from the study were analyzed using SPSS.20 package program while content analysis was performed in the analysis of qualitative data. As a result of the research, it was determined that the preservice science teachers' perceptions of photosynthesis were in the direction of chemical and biological approaches and that the teacher candidates preferred the chemical approach rather than the biological approach. However, preservice science teachers who prefer the chemical approach have reached the conclusion that they are in much more misconception than the biologically approaching teacher candidates.

Keywords: *Perception, photosynthesis, misconception, preservice science teachers.*

To cite this article: Urey, M. (2018). Defining the relationship between the perceptions and the misconceptions about photosynthesis topic of the preservice science teachers. *European Journal of Educational Research*, *7*(4), 813-826.doi: 10.12973/eu-jer.7.4.813

Introduction

Science is a discipline that is conceptually predominant in nature and abstract concepts are used extensively. For this reason, there are many problems in learning some basic concepts in a meaningful and lasting way in the field of science. While teachers and textbooks are shown as reasons for this situation, preliminary knowledge that individuals had based on their experiences is also shown as one of the reasons of these misconceptions (Kose, Ayas, Costu and Karamustafaoglu, 2004; Lloyd, 1990). According to Ebenezer and Fraser (2001), the relationship between preliminary knowledge acquired and newly learned situations gains a mental depth over time and causes change-resistant concepts to emerge. This situation, which is defined as misconception or alternative concept, is frequently encountered in the field of science. Students may have different experiences, thoughts and beliefs about concepts related to science in their environment and may start their education with the acquisitions they have. The information that students obtain on their own experiences can often lead to the creation of misconceptions that are far from scientific. In other words, it can be said that "misconceptions are concepts that students have developed as alternatives to scientifically accepted concepts" (Cordova, Sinatra, Jones, Taasoobshirazi and Lombardi, 2014). It is expressed by many researches that some concepts in the field of science are learned meaningfully and permanently, and the concept which is not fully understood by the learners and students fall into misconception (Ahopelto, Mikkilä-Erdmann, Anto and Penttinen, 2011; Bacanak, Kucuk and Cepni, 2004; Duit and Treagust, 2003; Gunes, Dilek, Hoplan and Gunes, 2012; Sasmaz Oren, Karatekin, Erdem and Ormanci, 2012). It is stated that students have misconceptions depending on the reasons such as lack of preliminary knowledge, lack of experiment for concretization, teachers' presentation style, previous experience and thoughts of students, wrong relationship between textbooks and concepts (Sodervik, Mikkilä -Erdmann and Vilppu, 2014).

* **Correspondence:**
Mustafa Urey, Trabzon University, Fatih Faculty of Education, Trabzon – Turkey.
Email: murey01@gmail.com

When studies in the field of biology are examined, it is known that there are difficulties in teaching many biology concepts such as respiration (Akpinar, 2007), photosynthesis (Akcay, 2017), osmosis and diffusion (Odom and Barrow, 1995), protein synthesis, cell (Urey and Calik, 2008), inheritance (Lewis andKatman, 2004), ecology (Cordero, 2001), mitosis and meiosis (Atilboz, 2004) and that students are dragged into the misconceptions during teaching of these concepts. One of the concept that is very important in terms of biology teaching, which is hard to cover and students can be dragged into misconception at any moment is the concept of photosynthesis. Photosynthesis is a biochemical process that directly or indirectly affects many living things. Information about photosynthesis is important in order to correctly understand the functioning of the ecosystem and the interaction of living and non-living things with each other. Learning about photosynthesis will contribute to students' understanding of other issues such as environmental problems, environmental conditions, greenhouse gases, climate change, carbon footprint, forest protection. At the same time, this makes photosynthesis a key concept in terms of being a conscious citizen for a sustainable environment (Saka, 2016). Although from primary education to higher education, the chapter photosynthesis was thought in all levels. Many studies have shown that students come up with alternative concepts that are conflicting or incongruent with the classroom environment scientifically. It has been determined that students who are interested in the concept of "photosynthesis" which is important in the understanding of matter and energy cycles in the nature, have many misconceptions (Akcay, 2017; Canal, 1999; Crane and Winterbottom, 2008; Domingos-Grilo, Reis-Grilo, Ruiz and Mellado, 2012; Eisen and Stavy, 1988; Kose, et al., 2004; Marmaroti and Galanopoulou, 2006; Metioui, Matoussi and Trudel, 2016; SkribeDimec and Strgar, 2017; Svandova, 2014). These misleading situations lead to misconfiguration of the energy-matter, plant-animal and nutrient-nutrition relations in the ecosystem. A meaningful learning of the concept of photosynthesis will facilitate understanding of many other biology concepts along with matter and energy cycles.

When studies on the concept of photosynthesis are examined, it is possible to find comparative studies especially with the concept of respiration (Akpinar, 2007, Cokadar, 2012, KelesandKefeli, 2010, Svandova, 2014, Toman, CimerandCimer, 2016; Yenilmez and Tekkaya, 2006). In addition to all these studies, it is also possible to come across studies that specifically focus on the concept of photosynthesis (Efe, Oral, Efe and Sunkur, 2011; Larkin, 2012; Metioui, Matoussi and Trudel, 2015; Usak, Ozden and Eilks, 2011; Sodervik, Virtanen and Mikkila-Erdmann, 2015; SkribeDimec and Strgar, 2017). In recent years, studies on photosynthesis seem to be focused on the misconceptions that are experienced in the related concept and the strategies, methods, techniques and guide material development studies aimed at eliminating these misconceptions (Atici and Atici, 2012; BilenandAydogdu, 2010; Ekici, Ekici and Aydin, 2007; Goff, Reindl, Johnson, McClean, Offerdahl, Schroeder and White, 2017; Saka, 2016; Tas, Cepni and Kaya, 2012; Yenilmez and Tekkaya, 2006;). Despite these intensive studies especially at the beginning of 2000s, many studies have been put forward that conceptual misconceptions about photosynthesis have been continued today (Svandova, 2014; Toman, Cimer and Cimer, 2016; Urey, Sahin, Kilinc and Dogan, 2016; Waheed and Lucas, 1992). When Yip (1998) suggested that "*preservice teachers transfer the misconceptions they have to their students when they become teachers"* is thought, this creates a vicious cycle and causes misconceptions in every level of education. For this reason, it is important to identify and eliminate the existing misconceptions of preservice teacher who will teach in the future. In order to effectively use strategies, methods, techniques and guidance materials developed at the point of eliminating existing conceptual misconceptions, the researcher needs to know the different ways in which preservice teachers conceptualize the knowledge (Ebenezer and Fraser, 2001; Krall, Lott and Wymer, 2009). At this point, together with the teaching activities of preservice teachers; preliminary knowledge, attitudes and experiences of mental perception processes related to photosynthesis gain importance. In particular, that pre-service teachers coming to the classroom with wrong pre-misconstructed concepts of pre-service teachers' misconceptions and misconceptions in the classroom environment and their experiences related to these concepts contradict the real situation, leading to the development of negative attitudes and the emergence of different mental perceptions (Akdeniz, Yildiz and Yigit, 2001). These perceptions related to the related concept gain importance in terms of eliminating the misconceptions or making them more resistant.

It is seen as an important deficiency in the literature that there is no study to reveal the relationship between perceptions and misconceptions, while both mental perception processes for photosynthesis and importance of studies on determination and elimination of misconceptions are emphasized. The relationship between perception processes for concept of photosynthesis and misconceptions is very important in order to remove the present misleading situation.

The aim of the research in this context is to determine the misconceptions of science teachers' perceptions of photosynthesis and to reveal the relationship between these perceptions and misconceptions. Within the scope of this aim, the following questions were sought:

1. How does the preservice science teacher perceive the concept of "photosynthesis"?

2. What is the relationship between the perceptions of preservice science teachers' between photosynthesis and the misconceptions?

Methodology

Research Model

In the study survey model is used, which is one of the descriptive research methods to study phenomena and events in natural conditions. The survey model is a survey of the entire universe or a group of samples taken from it to reach a general conclusion about the universe (Cepni, 2012). In the survey model, the questions of what current situation of the incident or problem is and where we are sought (Buyukozturk, 2011). With the study, the answer was sought to the questions of "what are the perceptions of preservice teachers about photosynthesis?" and "what are these perceptions related to the misconceptions about photosynthesis"? The use of survey method match with the number and width of the sample, it does not match with the effort of revealing the mental perceptions of individuals. When the data collection tool of the study is developed, open-ended questions and drawings that can reveal the mental perceptions of the individuals through data collection are taken into account. Thus, the generalization concern of the results obtained from qualitative data was tried to be solved.

Sample

The sample of the study is composed of preservice science teachers. The study was carried out with preservice science teachers studying in 7 different universities' faculties of education in 2017-2018 academic year in Turkey. Careful attention has been given to the inclusion of universities in research from different geographical regions, taking into consideration the geographical divisions of the universities. Dokuz Eylul University from the Aegean region, Cukurova University from the Mediterranean region, Marmara University from Marmara region, Gazi University from the Central Anatolia region, Trabzon University from the Black Sea region, Ataturk University from the Eastern Anatolia region and Adiyaman University from the South-eastern Anatolia region were included in the study. For the selection of the sample, purposeful sample selection was used and attention was paid to the fact that preservice teachers had taken the General Biology-I and General Biology-II courses at the undergraduate level in the determination of the class level to participate in the study. A total of 355 preservice science teachers participated in the study, including 254 females and 101 males. While the ages of the teacher candidates participating in the study vary between 21 and 26 years, the grade levels are in the 3rd and 4th grades.

Data Collection Tool and Implementation

The "Photosynthesis Concept Achievement Test (PCAT)" developed by the researcher was used as data collection tool in the research. PCAT consists of 4 questions. The first and second questions in PCAT are open-ended questions. In the first question, it was asked from preservice science teachers to define the concept of photosynthesis, and in the second question they were asked to write photosynthesis reaction. The third question is a drawing question, and it is expected that the teacher candidates make a drawing that includes the factors that affect photosynthesis. In the 4th question in PCAT, misconceptions about the concept of photosynthesis are questioned. In this question, 10 concept misconceptions in the literature related to the concept of photosynthesis were presented to preservice teachers and they were asked to certify related expressions as correct or incorrect, and to indicate whether they were sure or unsure.

The questions in the test for the validity and reliability study of PCAT were presented to the views of 3 lecturers specializing in biology education. In addition, the "scoring reliability" (Miles and Huberman, 2002) between the researchers in the evaluation of PCAT was calculated. For this, the correlation values between the two scorers were examined and the values of 0.97 for the first question, 0.94 for the second question, 0.83 for the drawing question and 1.00 for the misconception question were reached. Scoring reliability for the entire test was calculated as 0.94. According to Buyukozturk (2011), the tests with a reliability coefficient of more than 0.70 seem satisfactory in terms of reliability. In this context, it can be said that PCAT is an applicable measuring tool at the point of determining the perceptions of preservice teachers about photosynthesis and the misconceptions.

In the implementation of PCAT, data collection tool was implemented through representatives in 4 universities, while 3 universities were directly implemented by the researchers. The data collection tool was carried out simultaneously in all universities. Implementations were conducted face to face through representatives and researchers. For the application process of PCAT, 40 minutes was given to the preservice teachers.

Analysis of Data

In the analysis of the quantitative data obtained from the study, SPSS 20 package program was used while content analysis was used in the analysis of qualitative data. In the analysis of the quantitative data obtained from the research, both arithmetic mean and Pearson correlation test were used together with frequency and percentage values. Each of the questions in PCAT was evaluated within itself and 2 different rubrics were used in scoring the questions. While rubric-1 is used to define the concept of photosynthesis (Question 1), to write the photosynthesis reaction (Question 2), and to point out misconceptions about the topic of photosynthesis (Question 4); rubric-2 was used in the scoring of the drawing question (Question 3) used in determining the factors affecting photosynthesis. Rubric-1 is presented in Table 1.

Table 1. Rubric-1

Answer	Sure / Not Sure	Level	Point
Correct	Sure	Scientific Knowledge (SK)	4
	Not Sure	Chance / Lack of Confidence (C / LC)	3
Wrong	Not Sure	Lack of Knowledge (LK)	2
	Sure	Misconceptions (M)	1

According to Table 1, 4 points are given in the category of "scientific knowledge" for those who are confident in the answer given correctly, 3 points are given in the category of "chance / lack of confidence" for those who are not sure about the answer given. 2 points are given in the category of "lack of knowledge" to those who are not sure; 1 point is given to the "misconception" category those who give wrong answer although who are sure about the answer.

Drawings are used to present the factors affecting photosynthesis and rubric-2 was used evaluating the drawing question. Rubric-2 used in scoring the drawing question is presented in Table 2.

Table 2. Rubric-2

Factors Affecting Photosynthesis	Category	Description	Point
For each genetic and environmental factor affecting photosynthesis	Interactive and special marked indication	Writing together with the source, expressing the elements that are visualized and interacted with special signs (lines, arrows, labels, etc. showing the direction and intensity of the interaction)	4
	Interactive indication	Expressing by both writing and visual	3
	Plain indication	Expressing just by writing	2
	No indication	No place in the drawing	1

According to Table 2, for each factor affecting photosynthesis, 4 points are given under the category of "interactive and special marked indication" for those who show their interaction with direction and intensity; while 3 points are given under the category of "interactive indication" for those who do not show the direction and intensity of the interaction. For those who do not show any interaction, 2 points are given in the category of "plain indication"; whereas 1 point is given in the category "no indication" for those who do not draw.

Qualitative data analysis as well as quantitative data analysis has been utilized in the identification, reaction writing and drawing questions of PCAT. Particularly in the identification and reaction writing questions, the student responses evaluated under the "Wrong" category were subjected to content analysis by two different researchers and the mistakes they made in describing the concept of photosynthesis and writing the reaction of photosynthesis were coded by the preservice teachers. In the drawing question, preservice teachers tried to determine which factors affect photosynthesis, and those common to these factors determined by each researcher were added to the code pool. The arithmetic average of the scores obtained from related code, theme or item is calculated by expressing the code, theme or item frequency and percentage values for each question.

Findings / Results

In the framework of the first problem situation of the research, it was tried to determine the perceptions of preservice teachers about the photosynthesis.

Preservice teachers' written statements about the definition of photosynthesis are examined and the findings are presented in Table 3.

Table 3. Findings obtained from preservice teachers' definition of photosynthesis

	Total		Correct				Wrong				$\bar{X}$
			Sure (SK)		Not Sure (C-LC)		Not Sure (LK)		Sure (M)		
	f	%	f	%	f	%	f	%	f	%	
Terminological Definition[1]	8	2	8	100	0	0	0	0	0	0	4.00
Biologic Definition[2]	64	18	34	53	4	6	5	8	21	33	
Not to express chorophyll pigment							3	12	16	62	
Not to express sunlight							1	4	9	35	2.79
Not to express he use of mineral or inorganic matter							5	19	21	81	
To misexpress the reactants and products of photosynthesis							2	8	7	27	
Chemical Definition[3]	283	80	101	36	23	8	17	6	143	50	
Tom is express there actants and products of photosynthesis							13	8	106	66	2.29
To read there action reverse							10	6	48	30	

1 "... the combination of the concepts of photo (light) and synthesis (combining, bring together) ..." (Terminological Definition)

2 "... produce organic nutrients and oxygen using inorganic compounds and minerals to convert light energy into chemical energy through chlorophyll pigments ..." (Biological Definition)

3 "... plants produce organic nutrients and oxygen by taking inorganic compounds such as water from soil and carbon dioxide from atmosphere ..." (Chemical Definition)

When Table 3 was examined, all preservice teachers participating in the survey tried to define the concept of photosynthesis. According to Table 3, preservice teachers describe the concept of photosynthesis in three different ways: terminologically, biologically and chemically. A large proportion (80%) of the preservice teachers attempted to explain the concept of photosynthesis by means of chemical description, while 18% of them tried to explain it by biological description and 2% of them by terminological definition.

All of the preservice teacher who make the terminological description correctly define the concept of photosynthesis ($\bar{x}$ = 4.00).

59% of the preservice teachers who are trying to make biologic definitions correctly define 41%, while 41% misidentify. It was found that 53% of preservice teachers identify at the level of scientific knowledge while 6% of them describe it due to lack of chance or confidence. While 8% of the preservice teachers were found to have lack of knowledge on the biological definition of the concept of photosynthesis, 33% of them were found to have misconceptions. 74% of preservice teacher who have misconceptions or lack of knowledge do not use chlorophyll concept, while 39% do not use sunlight concept. It was also found that 35% of the preservice teachers did not show understanding about reactants and products of photosynthesis and that all of the preservice teachers (100%) did not take into consideration the mineral and inorganic compounds of the plants. The mean score of the preservice teachers who made biologic definitions of photosynthesis was 2.79.

While 44% of the 283 preservice teachers who are trying to make a chemical identification of the photosynthesis reaction make the correct definition, 56% wrongly define it. It was found that 36% of preservice teachers, who define chemical definition, define it at the level of scientific knowledge, and 8% of them define according to lack of chance or confidence. %6 of preservice teacher had a lack of knowledge about chemical definition of the concept of photosynthesis, while 50% had misconceptions. 74% of preservice teachers who have misconceptions or lack of knowledge defines reactants and products of photosynthesis wrongly; whereas 36% of them define photosynthesis reactions reverse. The mean score of the preservice teachers who made chemical definition of photosynthesis was 2.29.

Written expressions of preservice teachers for photosynthesis reaction were examined and the findings are presented in Table 4.

Table 4. Findings from preservice teachers writing of photosynthesis reactions

		Total		Correct: Sure (SK)		Correct: Not Sure (C-LC)		Wrong: Not Sure (LK)		Wrong: Sure (M)		$\bar{X}$
		f	%	f	%	f	%	f	%	f	%	
Biologic Reaction[4]		59	17	37	63	4	7	12	20	6	10	
	Not indicate chlorophyll pigment							8	44	3	17	
	Not indicate sunlight							5	28	3	17	3.11
	Not write there action equally							10	56	4	22	
	Write reactants and products of there action wrongly							5	28	2	11	
	Show the direction of reaction reverse							7	39	5	28	
Chemical Reaction[5]		279	78	152	54	19	7	77	28	31	11	
	Write reactants and products of there action wrongly							51	57	12	11	
	Show the direction of reaction reverse							44	41	25	23	2.88
	Show reaction as equilibrium reaction							8	7	3	3	
	Not write there action equally							54	50	27	25	
No information		17	5									

[4] $6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{sun light}} C_6H_{12}O_6 + 6H_2O + 6O_2$ (biologic reaction)

[5] $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$ (chemical reaction)

When Table 4 is examined, it is seen that 95% of the preservice teacher participating in the study tried to write the photosynthesis reaction, only 5% did not write any reaction. According to Table 4, it is seen that the preservice teachers who write the photosynthesis reaction write biological and chemical reactions. Only 17% of the preservice teachers biologically write the photosynthesis reaction, while 78% of them write chemically photosynthesis reactions.

In the writing of the photosynthesis reaction, 70% of the preservice teachers who write the biological reaction write the reaction correctly, and 30% write it wrong. It was found that 63% of the preservice teachers who wrote biochemical reaction correctly at the scientific knowledge level and 7% of them correctly wrote the reaction depending on the lack of chance or confidence. It was found that 10% of the preservice teachers who wrote photosynthesis reaction as biologically had a lack of information, while 20% had misconceptions. It seen that, from preservice teachers with misconceptions or lack of knowledge 61% of them did not indicate chlorophyll pigment, 45% of them did not indicate the sunlight, 78% of them did not write the reaction equally, 67% of them indicated the reaction reverse and 39% of them made mistakes such as wrong writing of reactants and products in photosynthesis reaction. The mean score preservice teachers got from photosynthesis biological reaction was 3.11.

61% of the preservice teachers who prefer the chemical reaction mostly write the reaction correctly, and 39% write it wrong. It was found that 54% of the preservice teachers who wrote chemical reaction wrote reactions at the scientific knowledge level, while 7% of them wrote based on lack of chance or confidence. While 28% of the preservice teachers who indicates photosynthesis reaction as chemical were found to have lack of knowledge, 11% of them had misconceptions. 10% of preservice teacher with misconceptions or lack of knowledge showed photosynthesis reaction as an equilibrium reaction, 64% of them showed direction of the reaction reverse, 68% of them written reactants and products of photosynthesis wrongly and 75% of them did not write the reaction equally. The mean score preservice teachers got from photosynthesis chemical reaction was 2.88.

Drawings of the preservice teacher for the factors affecting photosynthesis were examined and the findings are presented in Table 5.

Table 5. Findings of environmental and genetical factors affecting the rate of photosynthesis

Theme	Category	No indication		Plain indication		Interactive indication		Interactive and special marked indication		$\bar{X}$
		f	%	f	%	f	%	f	%	
Environmental Factors	Amount of light	129	36	38	11	66	19	122	34	2.50
	Light wavelength	178	50	57	16	99	28	21	6	1.89
	Amount of carbon dioxide	29	8	164	46	64	18	98	28	2.65
	The amount of oxygen	16	5	137	39	75	21	127	35	2.88
	The amount of water	8	2	205	58	31	9	111	31	2.69
	Temperature	89	25	174	49	39	11	53	15	2.15
	Minerals	268	76	47	13	17	5	23	6	1.42
Genetical Factors	Chloroplast / Chlorophyll amount	67	19	173	49	46	13	69	19	2.32
	Number of leaves / width	193	54	105	30	19	5	38	11	1.72
	Trichomes amount	327	92	28	8	0	0	0	0	1.07
	Cuticle thickness	341	96	14	4	0	0	0	0	1.03
	Stoma amount	349	98	6	2	0	0	0	0	1.01

When Table 5 is examined, it is seen that prospective teachers have included environmental and genetic factors that affect the rate of photosynthesis in their drawings. As the environmental factors affecting the rate of photosynthesis, the teacher candidates included factors such as light amount, wavelength of light, amount of carbon dioxide, amount of oxygen, amount of water, temperature and minerals; genetic factors such as the amount of chloroplast / chlorophyll, the number of leaves / width, the number of tri comes, the thickness of cuticle and the number of stoma on the surface. Teacher candidates are mostly focused on environmental factors (98%), oxygen (95%) and carbon dioxide (92%) while genetic factors focus on chloroplast / chlorophyll content (81%). When these factors were examined in terms of the effect on the test score, the amount of oxygen ($\bar{x}$ = 2.88), the amount of water ($\bar{x}$ = 2.69), the amount of carbon dioxide ($\bar{x}$ = 2.65), the amount of light ($\bar{x}$ = 2.50) and the amount of chloroplast / chlorophyll have been tried to be explained in a much more dominant way.

In the second problem situation of the research, the current situation of the misconceptions that occurred when the teacher candidates have been working up to now have been investigated and the relationship between the perceptions of the teacher candidates and the misconceptions has been tried to be determined.

Table 6 presents the current status of the misconceptions that occur when teacher candidates have been working up to now.

Table 6. Findings of misconceptions on photosynthesis topic

Item No	Expressions	Answer	Misconception		Lack of Knowledge		Chance/ Lack of Confidence		Scientific Knowledge		No Knowledge / No Answer		$\bar{X}$
			f	%	f	%	f	%	f	%	f	%	
I1	Only **high-structured plants** do photosynthesis.	W	22	6	34	10	70	20	221	62	8	2	3.33
I2	When all parts of a plant **(root, stem, leaf, etc**.) are considered, all living cells in these parts do photosynthesis.	W	65	18	49	14	69	20	155	43	17	5	2.78
I3	Plants **nourishes** by taking carbon dioxide from the atmosphere and water and minerals from the soil.	W	213	60	74	21	23	6	34	10	11	3	1.59
I4	**The primary purpose** of photosynthesis for high-structured plants is to produce oxygen and nutrients.	W	131	37	108	30	23	6	36	11	57	16	1.57
I5	**The source of the oxygen molecule** that the high-structured plants release after photosynthesis is carbon dioxide.	W	91	26	64	18	27	7	119	34	54	15	2.18
I6	When the light and dark stage reactions of plants are taken into consideration, **the net energy production** is zero as a result of photosynthesis.	C	86	24	56	16	48	13	73	21	92	26	1.78
I7	Photosynthesis reactions occur faster **under green light**.	W	112	32	78	22	26	7	109	31	30	8	2.20
I8	Plants can not perform photosynthesis **in the dark**.	W	199	56	81	22	16	5	28	8	31	9	1.46
I9	Plant **photosynthesis during the day, breathing at night**.	W	168	47	78	22	16	5	87	24	6	2	2.02
I10	**No water output is observed** after photosynthesis.	W	155	44	75	21	20	6	83	23	22	6	1.99

C: Correct, W: Wrong

When Table 6 is examined, it is seen that the preservice teacher have some misconceptions about photosynthesis. Comparing the misconceptions and scientific knowledge ratios of the preservice teachers' answers to the statements given in Table 6, while it is seen that the scientific knowledge ratios in the 1st, 2nd and 5th items are much more than the misconceptions ratio; it is seen that in the 3rd, 4th, 8th, 9th and 10th items misconception rates are much more than the scientific knowledge ratio. In the 6th and 7th items, it was determined that scientific knowledge and misconceptions ratios are very close to each other.

Although the scientific knowledge ratios are high in items 1st, 2nd and 5th items, it is seen that preservice teacher have misconceptions in related topics. In item 1th, 6% of preservice teachers argue that only high structured plants can photosynthesize by ignoring photosynthetic bacteria and algae that are capable of photosynthesis. The mean score of that preservice teachers obtained from the related item was determined as 3.33. In item 2, 18% of preservice teachers suggest that all living things (root, stem, leaf, etc.) in a plant can photosynthesize. The mean score that preservice

teachers obtained from the 2nd item was 2.78. Another misleading situation in 5th item is the idea that the source of oxygen resulting from photosynthesis is the carbon dioxide molecule. 26% of the preservice teachers have the same idea and mean score that they obtained from the related item is 2.18.

It is seen that there are much more misconceptions in proportion to scientific knowledge in the 3rd, 4th, 8th, 9th and 10th items. The concept of "to be nourished" at the end of the relevant statement in the 3rd item was used as a dilemma and it was tried to question whether the preservice teachers were aware of the fact that they did not consume water, carbon dioxide and minerals used during photosynthesis. It is seen that 60% of the preservice teachers had difficulty against distracter and fell into misconception by accepted the statement as correct. This is also evident in the arithmetic mean obtained by the preservice teachers ($\bar{x}$ = 1.59). In 4th item, the primary goal of the photosynthesis reaction was questioned, and 37% of the preservice teachers identified the primary purpose of photosynthesis as producing nutrients and oxygen instead of energy conversion (the conversion of light energy into chemical energy). The mean score of preservice teachers obtained from the related item was determined as 1.57. In 8th item, 56% of preservice teachers argue that plants cannot perform photosynthesis in the dark by neglecting dark stage reactions. When the arithmetic mean ($\bar{x}$ = 1.46) of preservice teachers obtained from this item was examined, it was found that a fairly high level misconception was seen. Findings from 8th item support with the statement in 9th item. It appears that 47% of the preservice teachers in the expression at 9th item by advocating plants are making photosynthesis during night and breathing during the day and ignore the dark phase reactions. The mean score of preservice teachers obtained from the related item was determined as 2.02. In 10th item, it was determined that 44% of the preservice teachers were in misconception by claiming that the water was not generated during the photosynthesis. The score obtained by preservice teachers from the related item was determined as 1.99.

There appears to be close proportions between levels of scientific knowledge and misconception in 6th and 7th items. The status of the energy generated as a result of photosynthesis reactions was questioned in the expression at 6th item and it was tried to determine whether preservice teachers were aware of the fact that this energy was again used during photosynthesis reactions. It was determined that 24% of the preservice teachers reported that the net energy generated after the photosynthesis reactions was not zero, and they were in misconception. The mean score obtained by preservice teachers from the related item was calculated as 1.78. In 7th item, the effect of visible light on the speed of photosynthesis reactions was questioned, and 32% of the preservice teachers claimed that photosynthesis in the green light wavelength occurred much faster. The mean score of preservice teachers obtained from this item was 2.20.

Table 7. Findings of the relationship between the definition of the concept of photosynthesis and the writing of the photosynthesis reaction

		Biologic Reaction (N=59)	**Chemical Reaction (N=279)**
Biologic Definition	r	0.623	-
(N=64)	p	0.000*	-
Chemical Definition	r	-	0.911
(N=283)	p	-	0.000*

r: pearson correlation coefficient; p : level of significance

When Table 7 was examined, it was found that there was a significant correlation between biological definition and biological reaction at 0.01 level (p = 0.000, p <0.01). According to this, it was determined that there was a moderate and positive relationship between the preservice teachers who made biologic definition and those who wrote biological reaction. When the relationship between preservice teachers who made chemical definition and those who wrote chemical reactions were examined, it was found that there was a meaningful relationship at 0.01 level (p = 0.000, p <0.01). According to this, it was determined that there was a very high level and positive relation between the preservice teachers who made chemical definition and those who wrote chemical reaction. Considering the direction and strength of the relationship between defining and reaction writing, it can be said that the perception of photosynthesis is considered in two dimensions, biologically and chemically.

The relationship between the perceptions of preservice teachers about photosynthesis and the misconceptions are examined and the findings are presented in Table 8.

Table 8. Findings related to the relationship between the perceptions of preservice teachers for photosynthesis and the misconceptions

		I1	I2	I3	I4	I5	I6	I7	I8	I9	I10
Biologic Definition (N=64)	r	0.82	0.77	0.55	0.42	0.48	0.67	0.79	-0.31	-0.35	0.91
	p	0.000*	0.000*	0.156	0.203	0.021	0.000*	0.000*	0.000*	0.000*	0.000*
Chemical Definition (N=283)	r	0.22	0.71	-0.26	0.35	0.51	0.58	0.74	-0.36	-0.45	-0.73
	p	0.000*	0.000*	0.211	0.167	0.066	0.034	0.000*	0.000*	0.000*	0.000*

r: pearson correlation coefficient; p : level of significance

When Table 8 is examined, it was determined that there is a meaningful relationship between the levels of preservice teachers who made biological definition and the level of knowledge about photosynthesis in some items (I1, I2, I6, I7, I8, I9, I10). A positive correlation was found in I1, I2, I6, I7 and I10 and a negative correlation was found in I8 and I9. A high level of correlation (r_{I1} = 0.82, r_{I2} = 0.77, r_{I7} = 0.79) with knowledge levels in I1, I2 and I7 was found when a very high level of correlation (r_{I10} = 0.91) was found between the level of identification of the preservice teachers who made biological definition and the level of knowledge in item I10. There is a moderate correlation (r_{I6} = 0.67) between the level of identification of preservice teachers who made biological definition and the level of knowledge in item I6. It was determined that there is a negative correlation between the level of preservice teachers who made biological definition and I8 and I9 (r_{I8} = -0.31, r_{I9} = -0.35).

When Table 8 was examined, it was determined that there was a meaningful relationship between the levels of description about photosynthesis and the knowledge levels about present misconceptions (I1, I2, I7, I8, I9, I10). A positive correlation was found in I1, I2 and I7, while a negative correlation was found in I8, I9 and I10. A high correlation (r_{I2} = 0.71, r_{I7} = 0.74) with the knowledge levels of I2 and I7 items was determined when a very weak correlation (r_{I1} = 0.22) was found between the level of definition of preservice teachers who made chemical definition and the level of knowledge in item I1. There was a negative correlation between I8 and I9 (r_{I8} = -0.36, r_{I9} = -0.45) and a negative correlation with I10 (rI10 = -0.73).

Discussion and Conclusion

Findings from the PCAT show that preservice teachers exhibit two different approaches to the topic of photosynthesis; biological and chemical. Skribe Dimec and Strgar (2017) describe photosynthesis as a biochemical process, it is perceived as a chemical process by university students. Obtained findings also support this situation. Preservice teachers show more chemical approach both in the definition of photosynthesis and in the writing of reaction. Especially in the textbooks, the photosynthesis reaction is given as a chemical reaction through the net reaction, and students try to define photosynthesis as "reaction reading" helps students can be a reason for this. Moreover, the fact that photosynthesis is shown as an example of chemical change in chemistry lesson may be one of the reasons for this situation. Preservice teachers memorize the chemical reaction in the books and do not biologically make sense the subject of photosynthesis by taking the point that knowing the reaction of photosynthesis can be enough to describe photosynthesis and can not biologically make sense of it (Cokadar, 2012; Haslam and Treagust, 1987, Tekkaya and Balci, 2003; Usak, Ozden and Eilks, 2011; Urey, et al. 2016). This situation also manifests itself with the lack of information and misconceptions that arise in the definitions made. When the definitions are examined, it is possible to come up with different definitions and reaction writings (Anderson, Sheldon andDubay, 1990), including scientific definitions, lack of information and misconceptions. Particularly, there are cases such as misstating of the reactants and products of the photosynthesis (Brown and Schwartz, 2009; SkribeDimecandStrgar, 2017), reading the reaction reversely (Cakirogluand Boone, 2002; Svandova, 2014; SasmazOren, et al, 2012), writing the reaction as a reversible equilibrium reaction (Domingos-Grilo, et al, 2012; Sodervik, Virtanen andMikkila-Erdmann, 2015), and the absence of sunlight, chlorophyll and minerals which play an important role in the realization of the photosynthesis reaction (Urey, et al, 2016). Preservice teachers with a biological approach write the photosynthesis reaction taking into consideration the chlorophyll pigment and sunlight that are effective in the reaction and taking water rates out of the reaction and none of the preservice teachers with chemical approach write photosynthesis reaction taking into account the water input and output and are mostly exposed to sunlight and chlorophyll pigment (see Table 4). This can be interpreted as a better interpretation of the photosynthesis reaction by preservice teachers with biological approach. Both arithmetic mean of preservice teachers who made biologic definition and wrote biologic reaction and the findings in Table 4 supports this situation. It is observed that the arithmetic mean of preservice teacher candidates with biological approach is much higher than preservice teachers with chemical approach. A similar situation arises in relation to misconceptions of teacher candidates who show biological and chemical approaches. When Table 8 is examined, it is seen that the relation of preservice teachers who made biologic definition with misconceptions is much more positive and stronger than the preservice teachers who made chemical definition. In other words, preservice teachers who made biological definitions at scientific knowledge level are less exposed to misconceptions in the literature. This may be due to the fact that preservice teachers who made biologic definition trying to make sense of the entire

environmental and genetical factors involved in photosynthesis, rather than "reading the reaction," or trying to make sense of the factors by establishing relations between factors rather than memorizing them.

When the findings obtained from the analysis of the drawing question in PCAT are examined, it has been determined that preservice teachers include environmental and genetic factors that affect the speed of photosynthesis. Preservice teachers seem to focus more on environmental factors in particular. This can be thought that preservice teachers' chemical approaches are much more dominant to photosynthesis topic. While preservice teachers define the concept of photosynthesis, their definition of "reaction reading" through photosynthesis reaction also shapes their thinking about the factors that affect the rate of photosynthesis. When the drawings of preservice teachers are examined, it is seen that preservice teachers take more meaningful factors such as carbon dioxide, water, oxygen, sunlight and chlorophyll amount in the photosynthesis reaction. This leads to the conclusion that preservice teachers are far from content knowledge and only understand the concept of photosynthesis by the apparent face. The concept of photosynthesis can be one of the reasons that many concepts such as physics, chemistry, ecology, plant anatomy, plant physiology, and energy conversion are needed to be related to each other in every dimension (KoseandUsak, 2006; TekkayaandBalci, 2003; Waheedand Lucas, 1992). To understand the concept of photosynthesis correctly, it can be very difficult to have a command of so many disciplines and basic concepts in this discipline. Even if you have a command of the related concepts, the effort to create a meaningful whole between these concepts can lead to overloading of information and resulting in misconceptions. The results obtained from the misconceptions used in the study supports this case. When examining the mean scores obtained from the misconceptions of the preservice teachers, it is seen that they have conceptual misconceptions in all items, especially in I8, I4, I3, I6, I10 and I9.

56% of preservice teachers that formed the sample of the study neglected the dark phase reactions and were found to have a misconception that photosynthesis would not continue overnight. Again in relation to this misconception, 47% of the preservice teachers were found that they advocated plants would photosynthesize during the day and respiration at night. Similarly, among the results of the study conducted by Gunes, et al. (2012), there have some misconceptions about photosynthesis and respiration, such as "*plants do respiration by making photosynthesis", "photosynthesis is the respiration that make during the day", "plants photosynthesize during the day, do respiration only at night"*. Many studies have also suggested that students describe respiration as gas exchange and that plants do respiration instead of photosynthesis in dark environments (Canal, 1999; Griffard, 2001; Keles and Kefeli, 2010; Krall, et al., 2009; Ozay and Oztas, 2003; Yenilmez and Tekkaya, 2006). It is determined that 37% of the preservice teachers express that the main purpose in photosynthesis is to produce nutrients and oxygen, not energy conversion. This is due to the fact that the energy conversion is perceived as energy production in the definition of "conversion of light energy to chemical energy" for photosynthesis. In parallel with this misleading expression, 24% of the preservice teachers fall into misconceptions about the net energy production as a result of photosynthesis and suggest that energy releases as a result of photosynthesis (Barker and Carr, 1989; Gunes, et al, 2012; Sodervik, et al., 2015; Tekkaya and Balci, 2003; Urey, et al. 2016; YenilmezandTekkaya 2006). That preservice teachers participating in the research write "heat" concept at the end of the photosynthesis reaction supports this result.

It is found that most of the preservice teachers in the research (60%) expressed that plants used water from the soil and carbon dioxide as food source. This shows that words such as "nutrient" and "nutrition" are thought to with their meanings in everyday life besides their scientific uses (Cokadar, 2012; Marmaroti and Galanopoulou, 2006; Sasmaz Oren et al. 2012; Tekkaya and Balci, 2003) In particular, the perception of plants as fed from the soil through their roots opens up a pointless question of whether plants are autotrophic or heterotrophic (Domingos-Grilo, et al., 2012; Mintzes and Wandersee, 2005). That preservice teachers' idea of food and oxygen may have formed by consuming water and carbon dioxide by adhering to the reaction of photosynthesis may be a result of this case. However, plants are not nourished; they form nutrients through sunlight and chlorophyll from the nutrient contents. In other words, the main purpose of the photosynthesis is to convert the solar energy to chemical energy (SkribeDimecandStrgar, 2017). This suggests that preservice teachers ignore and can not make sense the energy conversion and the role of chlorophyll in this transformation (Metioui, et al., 2016; Morowitzand Smith, 2007).

It has been determined that only a small percentage of the preservice teachers (6%) ignored the photosynthetic bacteria and algae, and they had misconception that only high-structure plants can photosynthesize. This is due to the fact that the first thing that comes to mind with the concept of photosynthesis is the green plants (Cakirogluand Boone, 2002; Ceken, 2014). However, it is seen that some of the preservice teachers (18%) expressed that all living cells found in plants (root, stem, leaves are thought) can photosynthesize. It is also seen here that the preservice teachers cannot think photosynthesis would not be realized in the root by ignoring the necessity of solar light and chlorophyll pigment in living cells capable of photosynthesis.

Another misleading statement is that preservice teachers ignore the fact that plants reflect green light and suggest that photosynthesis will occur faster under green light. This situation is similar to the fact that the knowledge levels of "relationship between photosynthesis and light color" and "relationship between photosynthesis and leaf color" among the results of the studies performed by Sasmaz Oren, et al. (2012) are low. The presence of a large number of chlorophyll pigment, especially in the green parts of the plant, which is effective in photosynthesis, may have led to the formation of an idea such as faster photosynthesis in the green wavelength.

In order to reveal the relationship between the approaches of preservice teachers to the concept of photosynthesis and the misconceptions, it is first necessary to examine the relation between the definition of the concept of photosynthesis and the scores obtained from writing the photosynthesis reaction. Findings revealed that there is a positive and moderate relationship between the preservice teachers who made biologic definition and those who wrote biological reaction; there is a positive and very high level of relationship between preservice teachers who made chemical definition and those who wrote chemical reaction. In this case, it can be said that for both approaches, there is a positive and linear relationship between the level of description and the level of reaction writing. In other words, for both approaches, the more accurate the preservice teacher makes the definition, the more accurate the reaction is. Therefore, it was thought that it would be enough to take only one of the dimensions of definition or reaction writing to determine the relation of preservice teachers exhibiting biological and chemical approach to misconceptions. In this context, the relationship between the approaches of preservice teachers to the topic of photosynthesis and the misconceptions has been tried to be determined from the definition dimension.

It is seen that there is a more positive correlation between the preservice teachers with biological approach and misconceptions regarding the concept of photosynthesis. This can be interpreted as the fact that preservice teachers who define the concept of photosynthesis under the biological approach at the level of scientific knowledge have less conceptual misconceptions. When the relationship between preservice teachers who responded to the concept of photosynthesis and the misconceptions in the scientific knowledge level under the chemical approach is examined, it is seen that the dimension of the relationship is a medium and weak relationship. There is also a negative correlation in some misconception expressions (I3, I8, I9, I10). This suggests that preservice teachers with chemical approach to the concept of photosynthesis may be at variance in the concept, despite making scientific definitions. This may be due to the fact that preservice teachers try to define photosynthesis through chemical reactions of photosynthesis rather than to make sense the concept of photosynthesis.

References

Ahopelto, I., Mikkilä-Erdmann, M., Anto, E., & Penttinen, M. (2011).Future elementary school teachers' conceptual change concerning photosynthesis. *Scandinavian Journal of Educational Research*, *55*(5), 503–515.

Akcay, S. (2017).Prospective elementary science teachers' understanding of photosynthesis and cellular respiration in the context of multiple biological levels as nested systems. *Journal of Biological Education*, *51*(1), 52-65.

Akdeniz, A.R., Yildiz, I., & Yigit, N. (2001). Ilkogretim 6. sinif ogrencilerinin isik unitesindeki kavram yanilgilari [Misconceptions of primary school 6th grade students in light unit]. *Cukurova University Faculty of Education Journal*, *2*(20), 72-78.

Akpinar, E. (2007). The effect of dual situated learning model on students' understanding of photosynthesis and respiration concepts. *Journal of Baltic Science Education*, *6*(3), 16- 26.

Anderson, C. W., Sheldon, T. S., & Dubay, J. (1990).The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis .*Journal of Research in Science Teaching*, *27*(8), 761-776.

Atici, O., &Atici, T. (2012). Investigating in biology syllabus topics at photosynthesis experiments of the effect student achievement and their diversification.*The Journal of Turkish Educational Sciences*, *10*(1), 143-166.

Atilboz, N. G. (2004). 9th grade students' understanding levels and misconceptions about mitosis and meiosis. *Gazi University, Journal of Educational Faculty*, *24*(3), 147-157.

Bacanak, A., Kucuk, M., & Cepni, S. (2004). Primary school students of misconceptions about photosynthesis and respiration subjects: A case for Trabzon. *Ondokuz Mayis University Journal of Education, 17,* 67-80.

Barker, M., & Carr, M. (1989). Teaching and learning about photosynthesis Part 1: An assessment in terms of students' prior knowledge. *International Journal of Science Education*, *11*(1), 49- 56

Bilen, K., & Aydogdu, M. (2010). Using the predict-observe-explain (poe) strategy to teach of concetps photosynthesis and respiration in plants. *Mustafa Kemal University Journal of Social Sciences Institute*, *7*(14), 179-194.

Brown, M. H., & Schwartz, R. S. (2009).Connecting photosynthesis and cellular respiration: Preservice teacher's conceptions. *Journal of Research in Science Teaching*, *46*(7), 791–812.

Buyukozturk, S. (2011). *Sosyal bilimler icin very analiz el kitabi [Data Analysis for Social Sciences]*. Ankara: Pegem Academic Publication.

Canal, P. (1999). Photosynthesis and inverse respiration in plants: An inevitable misconception. *International Journal of Science Education*, *4*, 363-371.

Cakiroglu, J., & Boone, W. J. (2002). Preservice elementary teachers' self-efficacy beliefs and their conceptions of photosynthesis and inheritance, *Journal of Elementary Science Education*, *14*(1), 1-14.

Cordero, E. C. (2001). Misconceptions in Australian students' understanding of ozone depletion. *Melbourne Studies in Education*, *41*, 85–97.

Cordova, J. R., Sinatra, G. M., Jones, S. H., Taasoobshirazi, G., &Lombardi, D. (2014). Confidence in prior knowledge, self efficacy, interest and prior knowledge: Influences on conceptual change. *Contemporary Educational Psychology*, *39*(2), 164–174.

Crane, L., & Winterbottom, M. (2008). Plants and photosynthesis: Peer assessment to help students learn. *Journal of Biological Education*, *42*(4), 150–156.

Ceken, R. (2014). Insistence on teaching about photosynthesis of plants by their green colour. *Educational Research and Reviews,9*(2), 67-74.

Cepni, S. (2012). *Arastirma ve proje calismalarina giris [Introduction to research and project works]*. Trabzon: Celepler Publication.

Cokadar, H. (2012). Photosynthesis and respiration processes: Prospective teachers' conception levels. *Education and Science*, *37*(164), 82-94.

Domingos-Grilo, P., Reis-Grilo, C.,,&Mellado, V. (2012). An action research programme with secondary education teachers on teaching and learning photosynthesis. *Journal of Biological Education*, *46*(2), 72-80.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*, 671–688.

Ebenezer, J.V., & Fraser, M.D. (2001). First year chemical engineering students' conception of energy in solution processes: Phenomenographic categories for common knowledge construction. *Science Education*, *85*, 509-535.

Efe, H. A., Oral, B., Efe, R., & Sunkur, M. O. (2011). The effects of teaching photosynthesis unit with computer simulation supported co-operative learning on retention and student attitude to biology. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *5*(1), 313-329.

Eisen, Y., & Stavy R. (1988).Students' understanding of photosynthesis.*The American Biology Teacher,50*(4), 209-212.

Ekici, F., Ekici, E., &Aydin, F. (2007). Utility of concept cartoons in diagnosing and overcoming misconceptions related to photosynthesis. *International Journal of Environmental & Science Education*, *2*(4), 111 – 124.

Goff, E.E., Reindl, K. M., Johnson, C., McClean, P., Offerdahl, E.G., Schroeder, N.L., & White, A.R. (2017). Variation in external representations as part of the classroom lecture: An investigation of virtual cell animations in introductory photosynthes is instruction. *Biochemistry and Molecular Biology Education, 45*(3), 226-234.

Griffard, P. B. (2001). The two-tier instrument on photosynthesis: What does it diagnose?. *International Journal of Science Education*, *10*, 1039-1052.

Gunes, T., Dilek, N. S., Hoplan, M., & Gunes, O. (2012). Ilkogretim 8. Sinif ogrencilerinde fotosentez ve solunum konusunda olusan kavram yanilgilari [Misconceptions of the primary 8th grade students about photosynthesis and respiration]. *Journal of Educational and Instructional Studies in the World, 2* (1), 42-47.

Haslam, F., &Treagust, D. F. (1987).Diagnosing secondary students' misconceptions of photosynthesis and respiration in plant using a two-tier multiple-choice instrument. *Journal of Biological Education,21*(3), 203-211.

Keles, E., &Kefeli, P. (2010). Determination of student misconceptions in "photosynthesis and respiration" unit and correcting them with the help of cai material. *Procedia Social and Behavioral Sciences*, *2*, 3111-3118.

Kose, S., & Usak, M. (2006). Determination of prospective science teachers' misconceptions: Photosynthesis and respiration in plants. *International Journal of Environmental and Science Education, 1*(1), 25 – 52.

Kose, S., Ayas, A., Costu, B., & Karamustafaoglu, S. (2004). Evaluating photosynthes is topic in biology textbooks. *TheJournal of Turkish Educational Sciences*, *2*(2), 181-189.

Krall, R. M., Lott, K. H., & Wymer, C. L. (2009).Inservice elementary and middle school teachers' conceptions of photosynthesis and respiration. *Journal of Science Teacher Education*, *20*, 41-55.

Larkin, D. (2012). Misconceptions about ''misconceptions'': Preservice secondary science teachers' views on the value and role of student ideas. *Science Education*, *96*, 927–959.

Lewis, J., & Kattman, U. (2004). Traits, genes, particles and information: re-visiting students understandings of genetics. *International Journal of Science Education*, *26*, 195-206.

Lloyd, C. V. (1990). The elaboration of concepts in three biology textbooks: Facilitating student learning. *Journal of Research in Science Teaching*, 27(10), 1019-1032.

Marmaroti, P., & Galanopoulou, D. (2006).Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. *International Journal of Science Education, 28*(4), 383–403.

Metioui, A., Matoussi, F., & Trudel, L. (2015). The teaching of photosynthesis in secondary school: A history of science approach. *Journal of Biological Education*, 50(3), 275-289.

Milles, M. B., & Huberman, A.M. (2002). *The qualitative researcher's companion*. California: Sage Publications.

Mintzes, J. J., & Wandersee, J. H. (2005). Research in science teaching and learning: A human constructivist view. In J. J. Mintzes, J. H. Wandersee& J. D. Novak (Eds.), Teaching science for understanding: A human constructivist view (pp. 59–92). San Diego, CA: Academic Press.

Morowitz, H., & Smith, E. (2007).Energy flow and the organization of life, *Complexity,* 13(1), 51–59.

Odom, A. L.,&Barrow, H. L. (1995). Development and application of a two-tier diagnostic test measuring collage biology students' understanding of diffusion and osmosis after a course of instruction. *Journal of Research in Science Teaching*, *32*(1), 45-61.

Ozay, E., & Oztas, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education*, 37, 68-70.

Saka, A. (2016). Fotosentez denkleminin tarih odakli yaklasimla ogretimi [History-oriented teaching of photosynthesis reaction], VI.International Congress on Research in Education, p. 102, 13-15 October, Rize-Turkey.

SkribeDimec, D., & Strgar, J. (2017).Scientific conceptions of photosynthesis among primary school pupils and student teachers of biology. *Center for Educational Policy Studies Journal*, 7(1), 49-68.

Sodervik, I.,Mikkilä-Erdmann, M., & Vilppu, H. (2014). Promoting the understanding of photosynthes is among elementary school student teachers through text design. *Journal of Science Teaching Education.* 25(5), 581-600.

Sodervik, I., Virtanen, V., & Mikkilä-Erdmann, M. (2015). Challenges under standing photosynthesis in a university introductory biosciences class. *International Journal of Science and Mathematics Education*, 13, 733-750.

Svandova, K. (2014). Secondary school students' misconceptions about photosynthesis and plant respiration: Preliminary results. *Eurasia Journal of Mathematics. Science & Technology Education*, 10(1), 59-67.

Sasmaz Oren, F., Karatekin, P., Erdem, S., &Ormanci, U. (2012). Determining of teacher candidates' level of knowledge on the issue of plantrespiration-photosynthesisthroughconceptcartoonsanditsanalysisdepending on different variables. *Journal of Kirsehir Educational Faculty*,*13*(3), 155-174.

Tas, E., Cepni, S., & Kaya, E. (2012). The effects of web-supported and classical concept maps on students' cognitive development and misconception change: A case study on photosynthesis. *Energy Education Science and Technology Part B: Social and Educational Studies, 4(1), 241-252.*

Tekkaya, C., & Balci, S. (2003). Determination of students' misconceptions concerning photosynthesis and respiration in plants. *Hacettepe University Journal of Education,* 24, 101-107.

Toman, U., Cimer-Odabasi, S., & Cimer, A. (2016). Fotosentez ve bitkilerde solunum kavramlarinin farkliogrenim seviyelerinde ogrenilme durumlarinin arastirilmasi [An investigation into the conceptions of photosynthesis and respiration in plants at different educational levels] .*The Black Sea Journal of Social Sciences*, *2*(7), 15-30.

Usak, M., Ozden, M., & Eilks, I. (2011).A case study of beginning science teachers' subject matter (SMK) and pedagogical content knowledge (PCK) of teaching chemical reaction in Turkey. *European Journal of Teacher Education, 34*(4), 407-429.

Urey, M., & Calik, M. (2008). Combining different conceptual change methods within 5E model: A sample teaching design of 'cell' concept and its organelles. *Asia-Pacific Forum on Science Learning and Teaching, 9*(2), 1-15.

Urey, M., Sahin, N. F., Kilinc, A., & Dogan, M. (2016).Fen bilgisi ogretmen adaylarinin fotosentez konusuna yonelik kavram yanilgilarinin belirlenmesi [Determining of preservice science teachers' misconceptions about photosynthesis], VI. International Congress on Research in Education, p. 109, 13-15 October, Rize-Turkey.

Waheed, T., & Lucas, A. M. (1992). Understanding interrelated topics: Photosynthesis at age 14+. *Journal of Biological Education*, 26, 193–199.

Yenilmez, A., & Tekkaya, C. (2006) Enhancing student's understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and Technology*, *15*(1), 81-87.

Yip, D. Y. (1998). Identification of misconceptions in novice biology teachers and remedial strategies for improving biology learning. *International Journal of Science Education*, *20*(4), 461-477.