American-Eurasian J. Agric. & Environ. Sci., 13 (9): 1207-1231, 2013
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2013.13.09.11032

The Concept of Photosynthesis Which is an Indicator of Life in Plants: A Cognitive Structure Study

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Abstract: The concept of photosynthesis is one of the subjects on which participants from all educational levels struggle to form their cognitive structures and have many alternative conceptions. This research was carried out in order to determine biology student teachers' cognitive structures and alternative conceptions related to the concept of photosynthesis. The qualitative research method was employed in the study. Free word association test and drawing-writing technique were used to collect data. These data, collected using both of the above-mentioned instruments, were arranged based on the content analysis technique. The cognitive structures of the participant biology student teachers were grouped under the following nine categories: *"molecules in the process of photosynthesis", "factors influencing photosynthesis", "units where photosynthesis occurs", "living beings that photosynthesize", "periods and times in which photosynthesis takes place", "enzymes in photosynthesis", "photosynthesis-respiration", "defining photosynthesis"* and *"importance of photosynthesis"*. In both of the assessment instruments, the categories of *"molecules in the process of photosynthesis", "living beings that photosynthesize", "factors influencing photosynthesis"* and *"units where photosynthesis occurs"* emerged as the common and dominant categories. Besides, almost half of the participants presented *non-representative drawings* and *drawings with alternative conceptions* and it was determined that they are incompetent on the subject. On the other hand, the participants were observed to have alternative conceptions under a total of six categories defined in both of the instruments. It was determined that the participants are not proficient in the categories of "*defining photosynthesis"* and *"importance of photosynthesis"*, where they were supposed to come up with micro- and macro-level correlations.

Key words: Photosynthesis · Cognitive structure · Free word association test · Drawing-writing technique · Alternative conception · Drawing level

INTRODUCTION

How plants maintain their lives has always been one of the most interesting issues for human beings. In this respect, the concept of "photosynthesis" is regarded to refer to one of the most important processes that are indicators of life in plants. This process has numerous different features from other biochemical processes. These features make photosynthesis one of the most important subjects of biology courses at all levels, especially secondary and high school [1]. However, its connections to other micro- and macro-level subjects such as cellular respiration render it one of the most difficult subjects in biology [2]. Researches show that students experience difficulties in learning and forming their cognitive structures about, systems that signify healthy life among living beings [3-17]. The subject of photosynthesis is one of the main subjects about which students experience learning difficulties and develop alternative conceptions [18-26].

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The subject of photosynthesis is a difficult subject to learn, because it involves complex transformations and biochemical processes and it is correlated with many other subjects in the curriculum such as ecology, physiology, biochemistry, transformation of energy, autotrophic nutrition and transport system in plants [1,27]. On the other hand, its abstract nature makes it a further difficult subject. As a result, concepts related to the process of photosynthesis are most of the time misunderstood by students, who thus fail to fully learn those concepts and to construct their cognitive structures.

The main reason students struggle to construct their cognitive structures is their failure to link the conceptual structures related to the subject in their minds. The cognitive structure is a structure that represents the relations of concepts in the student's long-term memory and that is based on assumption. At this point, teachers should guide their students to render meaningful the concepts in their minds and to improve their learnings in order to increase the quality of their cognitive structures. Knowing students' prior knowledge [28, 29] helps carry out researches on students' conceptual changes, because prior knowledge always affects new learning. Incorrect prior knowledge always negatively affects learning [30-34] and students' ability to construct high-quality cognitive structures. There are different terms used in the literature for conceptual structures that are scientifically incorrect or that contradict scientific facts. "*Misconception*", "*preconception*" and "*alternative frameworks*" are among these terms [35-40]. In this study, the term "*alternative conception*" was preferred. The difference between the scientific language and the language used in the daily life is one of the main reasons lying beneath the emergence of alternative conceptions. Alternative conceptions are not preferred in learning and teachers try to keep them at the lowest level possible.

The questions "How should a high-quality cognitive structure be?", "What is cognitive structure?", "How can cognitive structure be determined?" are only a few questions to which researchers of cognitive structure and learning have been seeking answers for years, because biology teachers, while designing their teaching practices, try to contribute to their students' formation of high-quality cognitive structures by using results of cognitive structure studies. It is highly difficult to explain individuals' cognitive structures, which is formed as a result of learning. However, by revealing individuals' opinions on certain key concepts, very important data can be obtained and thus individuals' cognitive structures can be unveiled [41,42,43], because researches on concepts demonstrate individuals' cognitive structures related to those concepts. Conceptual knowledge is not only to know the name or definition of a concept, but also is to be able to see the transitions and relations between concepts. Biology is a course which requires students to be able to see the micro and macro relations among concepts. Otherwise, learning cannot be realized. When learning is not realized, a cognitive structure full of imperfect-incorrect knowledge and alternative conceptions may emerge.

While, various methods are employed in order to determine conceptual learning, especially those techniques labelled as alternative measurement and evaluation techniques are frequently used [44-49]. These techniques are employed not only to determine students' knowledge; but also to determine the relations that students establish between concepts, students' cognitive structures, whether they manage to accomplish meaningful learning by linking existing knowledge with new information, the extents to which they make sense of the operation of events in the natural life by associating them with their conceptual knowledge and alternative conceptions they develop. In this respect, in order to determine the cognitive structures and alternative conceptions related to the concept of photosynthesis; two-step multiple-choice tests [50, 51], drawings [52-59], interviews [60, 61, 62], free word association test [47, 63-66], concept maps [67,68], prediction-observation-explanation (POE) [69,70], along with structured grid, diagnostic tree, conceptual change texts, analogy and other techniques can be used [71,72]. In this research, the free word association test and drawing-writing technique were employed.

Cognitive Structure Researches on the Concept of Photosynthesis: It was determined that numerous studies on the concept of photosynthesis have been carried out in years with different participants from different educational levels. These studies indicate that students struggle to comprehend the process of photosynthesis and develop many alternative conceptions.

Photosynthesis has numerous distinctive features from other biochemical processes and it is one of the subjects that students struggle most to learn [2]. The subject of photosynthesis is a difficult subject to learn, because it involves complex transformations and biochemical processes and it is correlated with many other subjects in the curriculum such as ecology, physiology, biochemistry, transformation of energy and autotrophic nutrition [1,73]. While these processes are misunderstood most of the time by students, many students think of

photosynthesis as synonymous to breathing [13, 74]. In fact, this perception is correct, because the purpose in respiration is to produce energy. However, students have misunderstandings related to the inputs, outputs as well as the role and necessity of chlorophyll in cellular respiration and photosynthesis [1]. This situation requires them to understand the chemical reactions occurring between organic and inorganic molecules at the micro and macro levels along with the relationship between chemistry and biology [16]. It has been reported that students experience difficulties in understanding the subjects of respiration and photosynthesis due to their lack of knowledge in chemistry [1], in learning the chemical process aspect of respiration apart from being a physical process [75], that they consider plant respiration as the opposite of gas exchange when compared with most of animals and that they see photosynthesis as a type of respiration [76].

It is possible to see the participants' cognitive insufficiencies pertaining to the process of photosynthesis in the intensity of alternative conceptions determined in researches. In this framework; Gunes *et al.* [76], in their study carried out with 8th grade students, determined the following alternative conceptions: "*plants only photosynthesize during the day", "plants respire only at night", "plants produce energy through photosynthesis", "photosynthesis and respiration are opposite acts", "CO2 emerges as a result of photosynthesis", "photosynthesis is the respiration that plants perform during the day" and "plants do not need energy"*. Yuruk and Cakir [77], in the study they carried out with high school students, determined the following alternative conceptions: *"plants cannot respire", "energy is produced through photosynthesis for the metabolism of a plant", "germinated seed needs energy while photosynthesizing" and "fungi photosynthesize in illuminated environments"*. Similarly, Kose and Usak [78] found the following alternative conceptions among science student teachers on respiration in plants and the nature and process of photosynthesis: *"green plants photosynthesize", "respiration in plants occur only at night", "photosynthesis is the opposite of respiration" and "plants obtain their food from water"*. On the other hand, in studies conducted with the participation of science student teachers and high school students, it has been determined that participants have alternative conceptions such as *"the most important use of photosynthesis for green plants in production of energy", "energy is produced as a result of photosynthesis reactions", "plants do not respire", "plants respire at night", "energy is produced as a result of photosynthesis", "photosynthesis is the respiration of plants" and "plants do not respire and energy is produced as a result of photosynthesis"*; and that they struggle to comprehend the inputs and outputs of the process as well as the process itself [18-23, 25,26, 51, 79- 82].

While Keles and Kefeli [24] found that secondary school students have alternative conceptions on the subjects of *food production, oxidation of foods, photosynthesis-carbondioxide, respiration-gas exchange and respiration;* Mak and *et al.* [83] determined that student biology, chemistry and physics teachers *struggle to differentiate between the roles of chlorophyll and chloroplast in photosynthesis, fail to understand the mechanism of photosynthesis and think that chloroplasts should absorb light in order for photosynthesis to take place.* They also found that more than half of the participants think that *"green plants primarily use the green parts of sunlight for photosynthesis"*. Hogan and Fisherkeller [80], on the other hand, determined that students have learning difficulties in *decomposition of substances in the nutrient cycle or their correlations with photosynthesis*. Griffiths and Grant[84] found alternative conceptions among students about the analysis of the nutrient cycle, whereas Barak *et al.* [85] determined that high school students *fail to adequately comprehend the compounds used in photosynthesis, think that ATP has a significant role in processes of photosynthesis and is one of the main outputs and emphasize glucose production among outputs of the process of photosynthesis*.

Canal [86] determined that secondary school students think firstly about *parts of flowers (shape of leaves, anatomies of certain fruits, roots and flowers) and their functions before thinking about the process of photosynthesis,* think that *green plants need light for life* and have alternative conceptions about the subjects of *absorption of water by roots, transpiration in leaves and germination*.

Lin and Hu [87] determined that secondary school students fail to comprehend the concept of energy, that they have misunderstandings related to photosynthesis, respiration and energy flow in the food chain and that they fail to transfer their knowledge on energy conservation; whereas Jin and Anderson[88] found that secondary and high school students have misconceptions about processes such as photosynthesis, digestion, biosynthesis, cellular respiration, oxidation and energy and that they believe the imbalances between

these processes are the main cause of global climatic changes. Lenton and McNeil [89] found that classroom teachers have the incorrect knowledge that plants produce their own food out of water and carbondioxide, whereas Griffard and Wandersee [90] found similar alternative conceptions among medical students. On the other hand, Tekkaya and *et al.* [91] and Brown and Schwartz [92] found that student teachers have the misconception regarding the source of energy that *"photosynthesis is a mechanism where the energy needed by metabolisms of plants is produced and the energy required for life comes directly from the sun"*,.

These findings indicated that the alternative conceptions that emerge during the elementary education persist until the university and even the student teachers, who are going to provide science education, have alternative conceptions regarding photosynthesis. However, understanding the relationships between the macro- and micro-level biological systems is of importance for biological literacy [92]. This finding can lead to the interpretation that participants lack proficiency in terms of biological literacy. It is observed in studies that participants fail to adequately acknowledge these micro- and macro-level relationships. They fail to figure out that both photosynthesis and respiration are the bases of energy reactions within biological systems and the global and local ecosystems are founded on these bases.That is, it is a process that starts in the cell and continues at the global level; in which more than one chemical reaction occur simultaneously. For example, while the cellular respiration in plants occur in more than ecological level and more than one complex systems, students fail to comprehend these continuous and simultaneous complex processes [92,93]. This is a very important finding. Therefore, photosynthesis points to a process which starts in the cell and continues at the global level.

In order for students to learn the subject of photosynthesis in the best manner; Ross and *et al.* [94] taught the subject to university students through modeling, whereas Ray and Beardsley [95] developed a survey-based approach using aquatic plants and Ryoo and Linn [96] used moving visuals while teaching energy in photosynthesis to secondary school students. However, in many studies, it is suggested that, for students to be able to perfectly comprehend the subject of photosynthesis, they need to combine the relationship between the observable aspects of energy transformation and plant growth [97,98], they need to understand that plants cannot produce glucose without stimuli for the rearrangement of water and carbondioxide during photosynthesis [99], they need to comprehend the energy transformation in photosynthesis in order to be able to comprehend how energy is distributed in the ecosystem [96]. It is also suggested that students are confused about whether plants need luminous energy or thermal energy for photosynthesis [1,100] and that they have difficulties in comprehending how luminous energy is converted into chemical energy during photosynthesis [1, 2, 101].

Determining the cognitive structures of biology student teachers, who are going to be biology teachers in the future, about the concept of photosynthesis, is of utmost importance, because they are among the most important branch teachers who are responsible for teaching the concept to students. As it is seen in the research examples presented above from the relevant literature, participants from all grade levels have learning difficulties and numerous alternative conceptions about photosynthesis. However, no cognitive structure research was found, which was carried out with the participation of biology student teachers and using free word association test and drawing-writing technique, on the concept of photosynthesis. Therefore, it is believed that the results of the current study, which was carried out using the above-mentioned techniques, will provide a significant insight into the subject. Cognitive structures of biology student teachers about the concept of photosynthesis are of high importance for their construction of biological concepts.

Aim of Research: The aim of this study is to determine biology student teachers' cognitive structures on the concept of "photosynthesis" by using the techniques of free word association and drawing-writing. To this aim, answers were sought to the following questions:

- What cognitive structures do biology student teachers have, according to the free word association test, on the concept of photosynthesis?
- What cognitive structures do biology student teachers have, according to the drawing-writing technique, on the concept of photosynthesis?
- What are the alternative conceptions of biology student teachers on the concept of photosynthesis?

MATERIALS AND METHODS

In this research, the qualitative research method was employed. Examination of different aspects of education through the qualitative research method has been a very

widespread approach especially in the last 20 years [102-105]. A qualitative research approaches the subject with an interpretative and natural perspective, tries to convey the situation with the conditions expressed by participants and focuses on more than one method. The main purpose in such researches is to present the subject in a detailed and realistic manner. Therefore, it is of importance to present the data as detailed and direct as possible including participants' opinions [106, 107, 108]. The qualitative research method was preferred in this study, since the cognitive structures of biology student teachers on the concept of photosynthesis are presented in detail using the free word association test and the drawing-writing technique in this research.

Study Group: In this study, purposive sampling was employed due to reasons such as the subject required the collection of detailed data, the data had high quality and the research needed to be carried out with biology student teachers who would be responsible for teaching the subject of photosynthesis to their students. In this framework, the study was carried out with the participation of 44 biology students teachers' studying at the 4th and 5th grades of biology education department in Necmettin Erbakan University in spring term of 2011-2012 academic years. Since some problems could arise in the selection of purposive sample, some criteria were taken into consideration in order to minimize the problems in purposive sampling [107,109,110,111]. In this vein, several criteria were taken into consideration while selecting the participants such as having completed the field courses in Biology, willingness to participate in the study, being seniors in the department of Biology teaching and having completed the courses and being available to the researcher. However, preference of purposive sampling was of importance in terms of the quality of the study since its aim was to collect detailed data about the cognitive structures of student biology teachers on the concept of photosynthesis. Of the participants, 35 (79.5%) are females and 9 (20.5%) are males. In addition, 19 of the participants (43.20%) are 4th year students and 25 (56.80%) are 5th year students. Moreover, the student biology teachers were informed by the researchers of the aim of the study and how to complete the measurement tool. At the each stage of filling out the assessment instruments, participants were assisted when they needed.

Data Collection Instruments: In this research, it was aimed to collect detailed information regarding biology student teachers' conceptual structures on the concept of "photosynthesis", by using free word association test and drawing-writing technique in this research as data collection instruments. The main reason these instruments were selected is to enable participants to express without limitation their cognitive structures on the concept. Below is information on these assessment instruments and how they were employed:

Free Word Association Test: This technique is among the most widely used techniques with the purpose of determining individuals' cognitive structures about concepts, analyzing the links between concepts in these structures, revealing the webs of knowledge in their minds and finding out whether the links between concepts in individuals' long-term memories are adequate or not [112-116]. This technique is based on the assumption of giving responses to free stimulant words without limiting the ideas coming to the mind [117, 118] and it is suggested that these response words extracted from the long-term memory reflect a meaningful structure existing between concepts [119]. This structure is an individual's cognitive structure about a concept. Besides, results of several researches [120,121,122] point to a perfect order in the semantic memory structure.

In this research, the concept of "photosynthesis" was selected as the stimulant for the word association test and presented to the participants in the following format. Fig. 1 shows an example response given by a participant (P31) in the word association test.

STIMULANT WORD: PHOTOSYNTHESIS
Photosynthesis -1:……
Photosynthesis -2:……
.
.
.
Photosynthesis -10:……
SENTENCE:…….

As is seen in the Fig. 1, the word association test consists of two stages. These are the stages of sequencing words and writing sentences after hearing the stimulant word. These stages are explained below in detail:

At the first stage; participants are required to write down the concepts that the stimulant word has brought to their minds in a given duration 40 seconds in this research [123]. The biology student teachers were asked to write down the first ten words that come to their mind first, when they see or hear the word "photosynthesis" in 40 seconds. The reason the key concept was written more

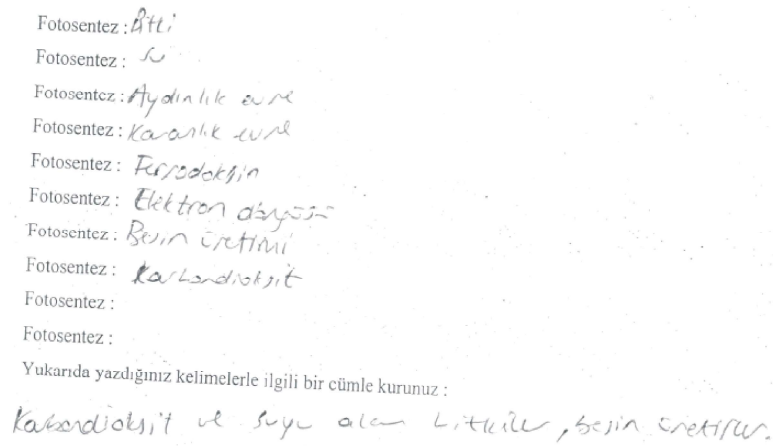


Fig. 1: Response paper of *P31*

Concepts: *Plant, water, light stage, dark stage, ferredoxin, electron cycle, nutrient production, carbondioxide*
Sentence: Plants that intake carbondioxide and water produce nutrients.

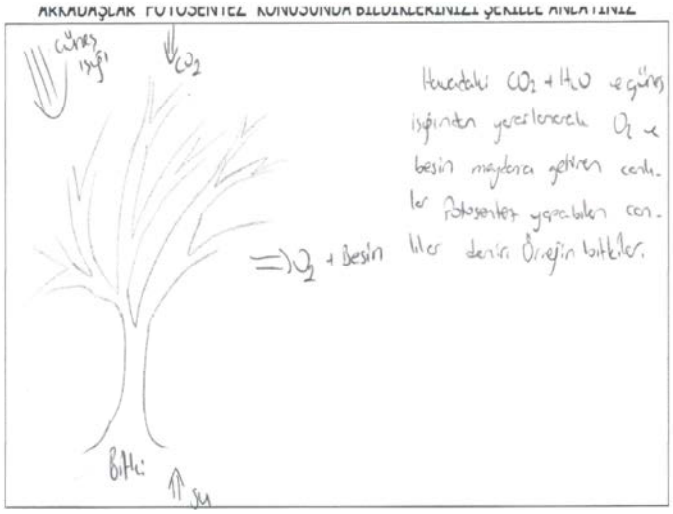


Fig. 2: *K13's response paper*

Sentence: *Those living beings that could produce O2 and nutrient by using CO2+H2O and sunlight are called photosynthesizing organisms (e.g. plants). Sunlight, plant, water, O2+Food, CO2*

than once is to avoid the risk of chain responses, because otherwise the student might write down concepts that her previous responses bring to her mind instead of the key concept. Such a situation harms the objective of the test.

At the second stage; participants are required to write down sentences in 20 seconds about the key concept. These sentences were analyzed one by one during the analysis of data, because the response sentence that is associated with the key concept may be a product of evocation that is not significantly correlated with the key concept. Besides, since a sentence is much more complex and advanced than a single word, the evaluation process is influenced by situations whether the sentence is scientific or not, or whether it involves misconceptions or not.

Drawing-Writing Technique: Using this technique, it was aimed to thoroughly examine the student teachers' conceptual structures on the concept of photosynthesis, because this technique is not only highly effective in obtaining natural and high-quality data about hidden opinions, understandings, attitudes and misconceptions regarding these technical concepts [59, 72, 124-133], but also it is an assessment method that is internationally

valid and that allows for comparison. In this respect, the participants were asked to freely state their opinions answering the question "*Express what you know about the concept of photosynthesis with figures"* in five minutes. Below is an example of students' response papers (Fig. 2).

Analysis of Data: Data obtained from each of the assessment instruments were analyzed separately. Before starting to analyze the data, the participants' response papers were assigned numbers from 1 to 44 in order to show whom the response belongs to. In general the data were analyzed based on the content analysis method. The main purpose in this method is to obtain common concepts and relations that can explain data through participants' responses. For this purpose, it is necessary to bring together similar data under certain concepts and categories.

The data obtained from the free word association test were analyzed using the techniques of number of words, number of responses and semantic relation [112]. Words with the same meaning were grouped under words recurred most frequently. Words, which were regarded as irrelevant, which were not associated with other words and which were stated only for once were excluded from the analysis [47 ,72,134-138]. However, in order to increase the validity and reliability of the research, these words are presented at the end of each category. Words were categorized by using semantic relation criteria and frequencies of words in each category were calculated. Many studies show that this type of data analysis produces reliable results [134,135,136].

In the drawing-writing technique, on the other hand, drawing-writing data regarding the concept of photosynthesis were analyzed using the content analysis method. By means of the drawing task, the students' ideas about the microscope were investigated, not the ability to draw it, so the precision in shape was ignored. It was a struggle to provide a scoring scale which gave minimum credit to the artistic quality of the drawing [132]. First, the participants' drawings related to the concept of photosynthesis were grouped under certain categories and sub-categories. Then, the cognitive structures demonstrated by the participants on the concept of photosynthesis were analyzed with respect to their levels. While determining these levels, data are grouped from level 1 to level 5. [54,71,139, 140].The level groups, which were formed with the purpose of evaluating participants' cognitive structures on the concept of photosynthesis through their drawings, are presented in Table 1.

Moreover, both in the free word association test and in the drawing-writing technique, the explanations provided by the participants for the concept of respiration within texts are presented in quotation marks in the following form: [" " (P13)]. In the drawing-writing technique, examples from participants' drawings are presented with respect to categories by indicating the number assigned to the participants (e.g. P1 or P7).

Validity and reliability are important in qualitative studies. For this reason, various efforts were made. In the research, two important processes were executed in order to ensure the validity of results: (a) Detailed explanations were provided on the processes of encoding data and analyzing data (how the conceptual category was reached), [141,142,143] (b) For each of the categories obtained in the research, an example response, which was thought to represent that category best, was assigned and presented both in "Findings" and "Alternative Conceptions" sections. Besides, these opinions were compared with the relevant literature and evaluated in the "Conclusion and Discussion" section.

In order to ensure the reliability of the research, on the other hand, codes and categories pertaining codes, which were produced by two researchers, were compared with the purpose of checking whether the codes given under the conceptual categories represent these conceptual categories or not. After the research data were encoded separately by two Biology experts, the researcher gave these lists of codes and themes their final forms. Consistency between the codes used independently by the researchers was determined by marking them as "Agreement" (when they used the same code for students' responses) or "Disagreement" (when they used different codes). In cases when a researcher ran

Table 1: Level groups formed to evaluate participants' cognitive structures on photosynthesis through their drawings

Levels	Drawings
Level 1:	No drawing
Level 2:	Non-representational-carton drawings (*drawings related to one or two dimensions of the concept*)
Level 3:	Drawings with alternative concepts (*drawings that are related to two or three dimensions of the concept and that include alternative conceptions*)
Level 4:	Partially correct drawings (*drawings that are related to three or more dimensions of the concept, but that include imperfect knowledge*)
Level 5:	Comprehensive representation drawings (*comprehensive drawings that are related to three or more dimensions of the concept*)

into a contradiction, encoding was performed by taking the opinion of the other researcher. The reliability of the data analysis conducted in the above-explained manner was calculated using the following formula: [Agreement/(Agreement + Disagreement) x 100] [104]. The mean reliability between the encoders was found at 97%.

On the other hand, NVivo9.3 software was used in forming the model on students' cognitive structures about the concept of photosynthesis.

RESULTS

This section was prepared by taking into consideration the assessment instruments. After dividing the findings with respect to the assessment instrument used to collect them, the alternative conceptions determined using both instruments were presented under relevant categories and in the final part, the model of biology student teachers' cognitive structures about the concept of photosynthesis was presented.

Findings Obtained from Free Word Association Test: Free word association test is one of the oldest and recently most popular alternative assessment instruments and it has been used in many researches in the field of science [47, 49, 63, 64, 66, 112, 114, 115, 134, 138, 144, 145]. As a result of the analysis of participants' cognitive structures regarding the concept of photosynthesis, a total of nine categories were formed. These categories and words given under them were listed and their frequency values were provided [47, 72, 134-138]. Words presented only for once, meaningless words and irrelevant words (49 words [12.59%]) were excluded from the analysis. So as not to harm the quality of the research, these words are not included in Table 1; however, they are presented in the comments section at the end of each category. As a result, the remaining 43 different words were divided into nine categories. Table 2 shows the categories and distribution of words by these categories. 340 response words were received in total.

In the analysis of the data obtained, most of student teachers' responses went under the category of "*molecules in the process of photosynthesis",* which thus emerged as the dominant category (f=122) While in this category most of the participants emphasized on the words *"carbondioxide", "oxygen", "nutrient", "glucose", "ATP"* and *"energy"*, some others wrote the words *"ATP use" and "ATP production"*. The words that were written in this category only for once by the participants and thus were excluded are the following: "*use of inorganic substance", "starch"* and *"protein"*.

In the second category, participants presented associations related to "*factors influencing photosynthesis*" (f=57). Most participants in this category wrote the words *"water" "light"* and *"sun"*. The words that were written in this category only for once by the participants and thus were excluded are *"pH", "evaporation" and "heat"*.

The third category was "*units where photosynthesis occurs*" (f=56). While most of the participants wrote *"chlorophyll", "chloroplast"* and *"stoma"*, some others wrote *"grana", "chlorophyll-a", "chlorophyll-b" and "thylakoid*". The words *"matrix", mesophyll layer", "pigment", cytoplasm", "P680", "P700" and wave length"* were excluded from this category.

In the fourth category, participants presented associations related to "*living beings that photosynthesize*" (f=34). They mostly focused on the words *"plant", "green parts of plants" and "leaves"* in this category. The words that were written in this category only for once by the participants and thus were excluded are *"bacteria", "photosynthetic bacteria", "flower", "body" and "tree"*.

In the fifth category, participants presented associations related to "*periods and times in which photosynthesis takes place"* (f=22). While most of them focused on the words *"light stage" and "dark stage"*, a lesser number wrote *"day"*. The words that were written in this category only for once by the participants and thus were excluded are the following*: "cyclical stage", "noncyclical stage"* and *"cycle"*.

In the sixth category, participants wrote the words "*photosynthesis and metabolism*", *"fad", "fad$_2$", "ferredoxin", "NAD", "NADH$_2$", "NADPH$_2$", " cytochrome"* and *"enzyme"*. On the other hand, the words that were written in this category only for once by the participants and thus were excluded are the following: *"reaction", "synthesizing"* and *"enzyme"*.

In the seventh category, participants presented associations related to "*photosynthesis-respiration"* (f=16). They focused on the words *"respiration" "krebs" and "ETS"*. The word that was written in this category only for once by the participants and thus was excluded is *"mitochondria"*.

In the seventh category, participants presented associations related to "*defining photosynthesis"* (f=9). It was observed that a very limited number of the participants wrote the words *"nutrient production", "chemical energy production" and "production"*.

Finally, the eight category was "*importance of photosynthesis"* (f=8). While most of the participants came up with the word "*continuation of life"*, a lesser

Table 2: Distribution of biology student teachers' cognitive structures about "photosynthesis" by categories

Categories	Concepts under categories and their frequencies	Total frequencies of categories
1. Molecules in the process of photosynthesis	"CO_2" (39)	122
	"O_2" (32)	
	"nutrient" (17)	
	"glucose ($C_6H_{12}O_6$)" (17)	
	"ATP" (6)	
	"energy" (5)	
	"ATP use" (2)	
	"ATP formation" (2)	
2. Factors influencing photosynthesis	"water" (25)	57
	"light" (17)	
	"sun" (15)	
3. Units where photosynthesis occurs	"chlorophyll" (25)	56
	"chloroplast" (12)	
	"stoma" (4)	
	"stroma" (4)	
	"grana" (3)	
	"chlorophyll-a" (3)	
	"chlorophyll -b" (3)	
	"thylakoid" (2)	
4. Living beings that photosynthesize	"plant" (20)	34
	"green parts of plants" (18)	
	"leaves" (14)	
	"blue-green algae" (2)	
5. Periods and times in which photosynthesis takes place	"light stage" (10)	22
	"dark stage" (10)	
	"day" (2)	
6. Enzymes in photosynthesis	"FAD" (2)	16
	"FAD_2" (2)	
	"ferredoxin" (2)	
	"NAD" (2)	
	"$NADH_2$" (2)	
	"$NADPH_2$" (2)	
	"cytochrome" (2)	
	"enzyme" (2)	
7.Photosynthesis-respiration	"respiration" (7)	16
	"ETS" (4)	
	"TCA" (3)	
	"krebs" (2)	
8. Defining photosynthesis	"nutrient production" (3)	9
	"chemical energy production" (3)	
	"production" (3)	
9. Importance of photosynthesis	"continuation of life" (5)	8
	"natural balance" (3)	
Total	43 words	340

number of them wrote "*natural balance"*. On the other hand, the words that were written in this category only for once by the participants and thus were excluded are the following: *"nature", "global warming", "greenhouse effect" and "atmosphere"*.

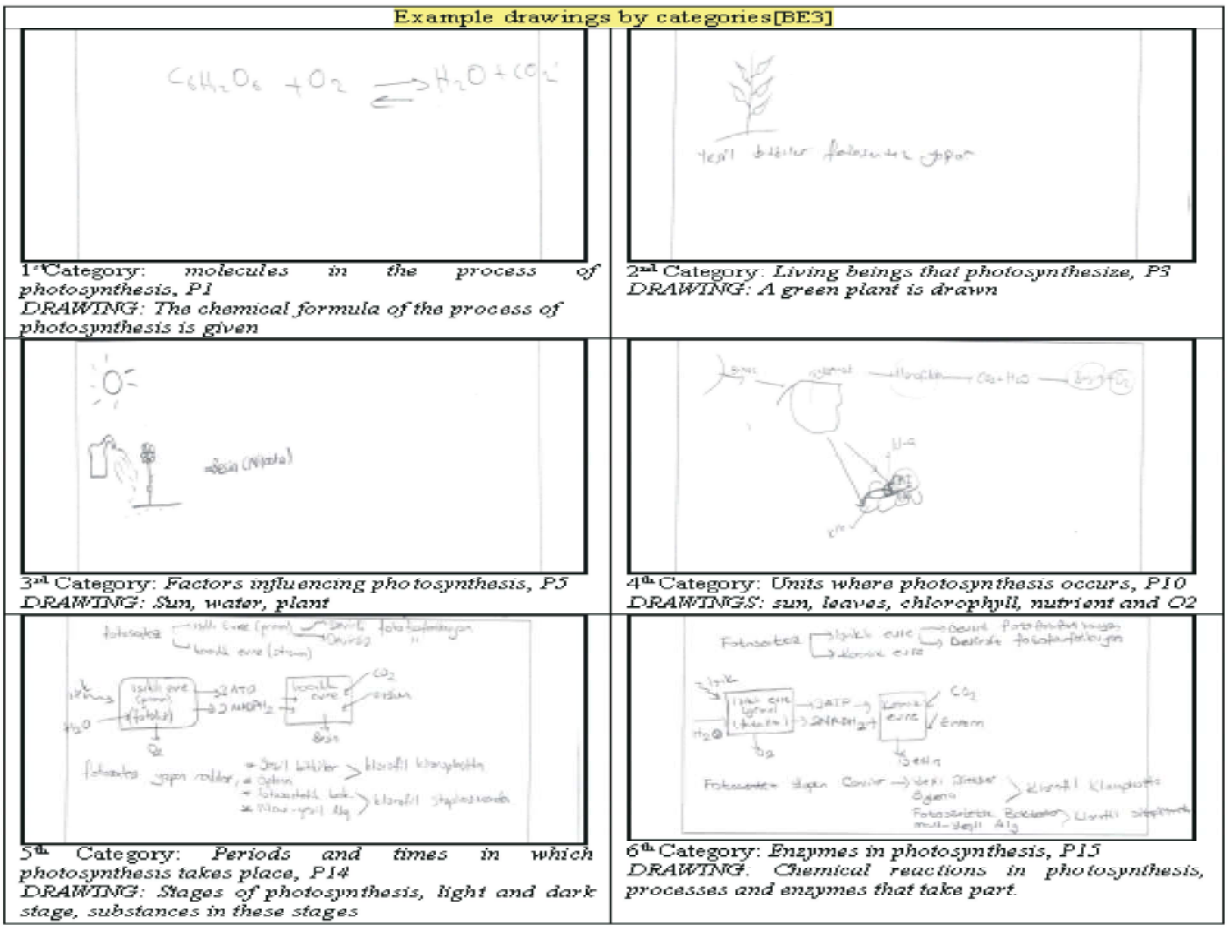
Findings Obtained from the Drawing-Writing Technique: It is seen that this technique, which is aimed at unveiling the details of cognitive structure, is frequently used in the field of science [52, 53, 55, 131, 146-150]. In this research, the drawing-writing technique produced eight categories. The following six categories were produced in the drawing technique: *molecules in the process of photosynthesis* (36), *living beings that photosynthesize* (35), *factors influencing photosynthesis* (30), *units where photosynthesis occurs* (27), *periods and times in which photosynthesis takes place* (4) and *enzymes in photosynthesis* (4). On the other hand, the following eight categories emerged in the writing technique: *molecules in the process of photosynthesis*

Table 3: Findings related to categories and sub-categories obtained using drawing-writing technique

Main category	Sub-category	Drawing (f)	Writing (f)
1. Molecules in the process of photosynthesis	CO_2	14	2
	O_2	10	4
	Food	6	8
	Glucose	2	3
	ATP	2	2
	CO_2 use	-	3
	O_2 release	-	2
	Sucrose	-	2
	Mineral substance	2	-
	Total	36	26
2.Living beings that photosynthesize	Green plants	19	2
	Leaves	5	2
	Euglena	3	3
	Plant	2	2
	Blue-green algae	2	2
	Photosynthetic bacteria	2	2
	Plants that have chlorophyll	-	3
	Living beings that have chloroplast	-	3
	Living beings that have chlorophyll Pigment	2	-
	Total	35	19
3.Factors influencing photosynthesis	Sunlight/daylight	16	8
	Water/water taken from soil	11	6
	Light	3	-
	Wave length of light	-	2
	Total	30	16
4.Units where photosynthesis occurs	Chlorophyll	10	2
	Chlorophyll -a	4	2
	Chlorophyll -b	4	2
	Chloroplast	3	2
	Grana	2	-
	Cytoplasm	2	-
	Granum	2	-
	Stroma		
	Total	27	8
5. Defining photosynthesis	Producing food for own	-	9
	Chemical incident	-	2
	Biological incident	-	2
	Water production	-	2
	Total	0	15
6. Periods and times in which photosynthesis takes place	Dark stage	2	4
	Light stage	2	3
	Cyclical photophosphorylation	-	2
	Noncyclical photophosphorylation	-	2
	Total	4	11
7. Enzymes in photosynthesis	$NADPH_2$	2	2
	Enzyme	2	-
	Total	4	2
8. Importance of photosynthesis	Continuation of life	-	2
	Total	0	2
	Total	132	105

(26), *living beings that photosynthesize* (19), *factors influencing photosynthesis* (16), *defining photosynthesis* (15), *periods and times in which photosynthesis takes place* (11), *units where photosynthesis occurs* (8), *enzymes in photosynthesis* (2) and *importance of photosynthesis* (2) (Table 3). The participants were given the opportunity to present their cognitive structures both through writing and through drawing.

Table 4: Examples obtained through drawing-writing technique on the concept of photosynthesis



It was observed that the Biology student teachers dominantly thought about concepts related to *"molecules in the process of photosynthesis"* in the drawing-writing technique drew relevant figures and wrote explanations. In this category, they drew figures mostly depicting *"CO_2"*. "*Molecules in the process of photosynthesis"* emerged as the dominant category in both the free word association test and the drawing-writing technique, which means that the participants' cognitive structures concentrated on this category.

On the other hand, the drawing findings fell under six categories [*molecules in the process of photosynthesis* (36), *living beings that photosynthesize* (35), *factors influencing photosynthesis* (30), *units where photosynthesis occurs* (27), *periods and times in which photosynthesis takes place* (4) and *enzymes in photosynthesis* (4)]. Table 4 shows examples from the drawings of participants related to photosynthesis.

On the other hand, analyses pertaining to the drawings of the biology student teachers on photosynthesis are presented in Table 5 under four relevant levels: *non-representative drawings* (13), *drawings with alternative conceptions* (12), *partial drawings* (9) and *conceptual representative drawings* (10) [54,71,139, 140]. In determining these levels, the data were grouped from level 1 to level 5. These levels demonstrate the participants' cognitive structures on photosynthesis.

It was determined that the drawings on the concept of photosynthesis are distributed by levels as follows: *non-representative drawings* (13), *drawings with alternative conceptions* (12), *partial drawings* (9) and *conceptual representative drawings (10)*. All participants presented drawings. It was determined that these drawings fell under six different categories; however, most of them were related to four categories (*living beings that photosynthesize, factors influencing photosynthesis, molecules in the process of photosynthesis and defining photosynthesis*).

Table 5: Analyses of drawings on photosynthesis

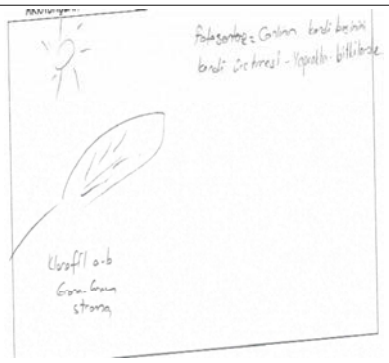
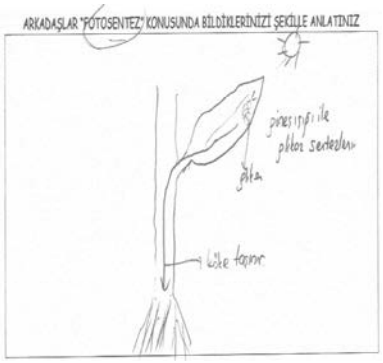
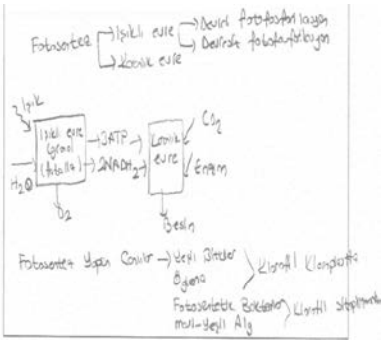
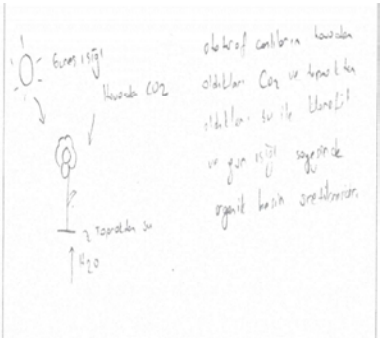
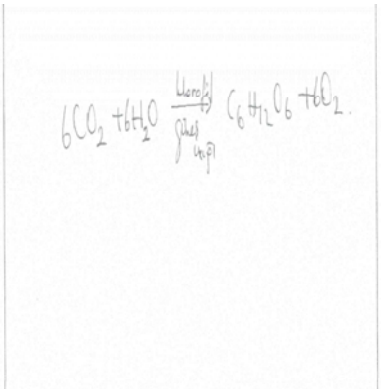
Levels	Example Drawings	
Level 1: No drawing		
Level 2: Non-Representational -carton drawing (n=13)	 P11 *DRAWING:* Green plant and Grana molecule. *WRITING:* Chlorophyll-a, Chlorophyll-b, Grana molecule.	 P27 *DRAWING:* Green plant and sun *WRITING*: Chlorophyll-a, Chlorophyll-b, Grana molecule, stroma. Photosynthesis: Green plants' production of their own nutrients.
Level 3: Drawings with alternative concepts (n=12)	 P6 *DRAWING:* Tree and sun *WRITING:* Green plants photosynthesize using the chlorophyll pigment. Sunlight comes together with CO2 and turns into nutrient.	 P8 *DRAWING:* Tree and sun *WRITING:* Sunlight and glucose are synthesized and transported to the root.
Level 4: Partially correct drawings (n=9)	 P15 *DRAWING:* Reactions that occur during photosynthesis. *WRITING:* Photosynthesis (light stage, dark stage). Light stage (Cyclical photophosphorylation, Noncyclical photophosphorylation). Chemical processes that occur during photosynthesis are written. Living beings that photosynthesize (green plants, euglena, photosynthetic bacteria, blue-green algea)	 P16 *DRAWING:* Flower and sun *WRITING:* It is autotrophic organisms' production of organic nutrients using CO2, water, chlorophyll and sunlight.

Table 5: Continued

Levels	Example Drawings	
Level 1: No drawing		
		
Level 5: Comprehensive representation drawings (n=10)	P12 *DRAWING:* The process of photosynthesis is shown. *WRITING*: Chemical substances related to the process are formulized.	P32 *DRAWING:* Flower, leaves, sun and the chemical process of photosynthesis. *WRITING:* Other organisms continuously release CO2. Photosynthesis occurs in all green parts of a plant; however leaves play a bigger role as they get lighter. Plants take CO2 and H2O and turn them into O2, this process is called photosynthesis. Photosynthesis also depends on the wave length of light as well as its density. Reactions of photosynthesis are divided into two: light stage and dark stage. Carbon is held during the dark stage.

This shows that ¼ of the participants expressed their cognitive structures about photosynthesis through non-representative drawings. When 12 other participants who presented drawings with alternative conceptions are added to this percentage, it appears that nearly half of the participant Biology student teachers expressed their cognitive structures about photosynthesis through non-representative drawings and drawings that include alternative conceptions. It means that they explained the subject with simple, vague and non-scientific drawings without thinking about the subject in length and breadth. Therefore, it is concluded that they express conceptual structures with personalized figures and that their academic cognitive structures are insufficient. It was observed that these drawings were mostly concentrated on the categories of *"living beings that photosynthesize, factors influencing photosynthesis, molecules in the process of photosynthesis and defining photosynthesis"*. On the other hand, ¼ of the participants presented their cognitive structures through conceptual representative drawings. That is, they managed to provide drawings that emphasize the details of the subject and that are scientifically valid. This shows that the participants in this group managed to form high-quality cognitive structures about photosynthesis.

The Alternative Conceptions of Student Teachers on Respiration Determined Through Free Word Association Test and Drawing-Writing Technique: It was determined, using the word association test and the drawing-writing technique, that participants have numerous alternative conceptions about the subject of photosynthesis. Analyses of alternative conceptions demonstrated by the participants about the concept of photosynthesis are presented with respect to assessment instruments.

Participants' Explanations Regarding the Category of *"Molecules in the Process of Photosynthesis"*;: *Example from the free word association test;*

"CO_2 and water are produced through photosynthesis" (P24;P42). It appears that the participant did not understand the process of photosynthesis. *"Glucose emerges in the process of photosynthesis"* (P1;P33). Photosynthesis produces not only glucose but also other nutrient molecules. It was determined that the participants had imperfect and incorrect knowledge.

A writing example from the drawing-writing technique;

"CO2 is taken O2 is revealed" (P22)

Participants' Explanations Regarding the Category of *"Living Beings That Photosynthesize"*;:

Example from the free word association test;

Plants' photosynthesis" (P29), *"green plants produce their nutrients this way"* (P30), *"Photosynthesis is carried out by plants"* (P31). Not only plants photosynthesize; primitive organisms such as blue-green algae and bacteria also photosynthesize. It was determined that the participant had imperfect knowledge. *"It occurs in plants' green leaves"* (P23;P39), *"...it generally occurs in green leaves that have chloroplast"* (P43). Photosynthesis occurs not only in plants' green leaves; instead it takes place in plants' different sections and different units of different organisms. It was determined that the participants had imperfect knowledge.

Writing examples from the drawing-writing technique;
"green plants photosynthesize" (P3).
"it is performed by autotrophic organisms" (P21)

Participants' Explanations Regarding the Category of *"Periods and Times in Which Photosynthesis Takes Place"*;

Example from the free word association test;
"plants photosynthesize during the day" (P7; P44). It was observed that the participants were unaware of photosynthesis at night.
Writing examples from the drawing-writing technique;
"...in the morning, nutrients and oxygen are produced; however, in the evening they take oxygen and give carbondioxide" (P28).

Participants' Explanations Regarding the Category of *"Photosynthesis-Respiration"*;

Example from the free word association test;
"Plants photosynthesize during the day and respire at night" (P6; P34). This is a very concerning alternative conception, because plants respire both during the day and at night.

Participants' Explanations Regarding the Category of *"Defining Photosynthesis"*;

Example from the free word association test;
"It is the synthesizing of nutrients and O_2 as a result of a reaction between water and CO_2" (P8; P9; P11; P14; P17; P27; P30; P37), *"plants that intake carbondioxide and water produce nutrients"* (P32). Light is a very important factor in photosynthesis. It was determined that the participants had imperfect and incorrect knowledge.

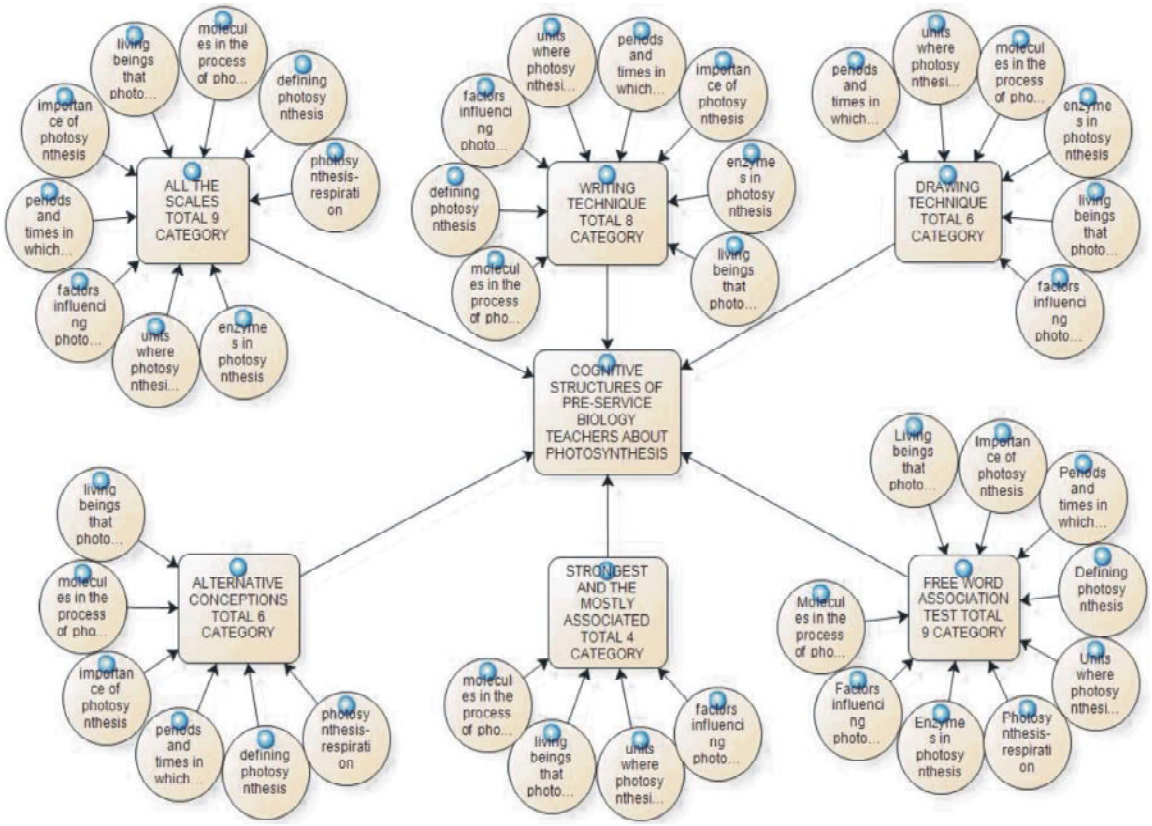
Writing examples from the drawing-writing technique;
"$H_2O+CO_2 \rightarrow$ light+chlorophyll $\rightarrow C_6H_{12}O_6+O_2$" (P6; P10).
"$C_6H_{12}O_6+O_2 \rightarrow H_2O+CO_2$" (P2).
"CO_2+su $\rightarrow O_2$
"$CO_2 \rightarrow$ Nutrient+ O_2" (P29; P41).
"Plants intake CO2 and turn it into O2, this process is called photosynthesis" (P31; P38).

Participants' Explanations Regarding the Category of *"Importance of Photosynthesis"*;

Writing examples from the drawing-writing technique;
"...oxygen is produced for the continuation of life" (P24).

It was determined, based on the examples presented above, that the pre-service biology teachers had imperfect and incorrect knowledge in the categories of *"molecules in the process of photosynthesis, living beings that photosynthesize, periods and times in which photosynthesis takes place, photosynthesis-respiration, defining photosynthesis and importance of photosynthesis"*. Besides, in the word association test, the incorrect knowledge that photosynthesis occurs during the day was observed. It was observed in the word association test that some participants fail to write proper sentences, whereas some others fail to turn their sentences into meaningful ones. On the other hand, in the drawing-writing technique, it was determined that the participants failed to effectively schematize their knowledge on the concept and to provide appropriate writing to support it. This finding points to the insufficiencies of biology student teachers' cognitive structures on the concept of photosynthesis.

Model 1 schematizes biology student teachers' cognitive structures on the concept of photosynthesis. As is seen in the model, the cognitive structures were determined with respect to the assessment instruments employed in this study. In this respect, the model involves detailed information about the following categories: categories obtained using the free word association test, categories obtained using the writing technique, categories obtained using the drawing technique, categories obtained using both of the assessment instruments, categories that emerged as dominant in both of the assessment instruments and categories in which alternative conceptions were found.



Model 1: *Cognitive structures of pre-service Biology teachers about photosynthesis*

DISCUSSION, CONCLUSION AND SUGGESTIONS

In this study, biology student teachers' cognitive structures about the concept of photosynthesis were determined. Departing from the idea that more than one assessment instruments must be used in a supportive manner in cognitive structure studies [54,60,151]; it was aimed to collect detailed information by using free word association test and drawing-writing technique in this research as data collection instruments. It was determined that the cognitive structures of the participants about photosynthesis carry both similarities and differences with respect to the assessment instruments. It was observed that the results obtained using different assessment instruments supported and enriched one another, because while a category could not be determined in one instrument, it could be determined in another. The responses given in the free word association test were grouped under the following 9 categories: *"molecules in the process of photosynthesis", "factors influencing photosynthesis", "units where photosynthesis occurs", "living beings that photosynthesize", "periods and times in which photosynthesis takes place", "enzymes in photosynthesis", "photosynthesis-respiration", "defining photosynthesis"* and *"importance of photosynthesis"*. On the other hand, 8 categories emerged in the drawing-writing technique: *"molecules in the process of photosynthesis", "living beings that photosynthesize", "factors influencing photosynthesis", "units where photosynthesis occurs", "defining photosynthesis", "periods and times in which photosynthesis takes place", "enzymes in photosynthesis"* and *"importance of photosynthesis"*. The categories obtained through both of the assessment instruments support, detail and explain one another. These findings show that detailed data can be collected on the conceptual structure of the same subject by using different assessment instruments that support one another. Therefore, this research demonstrates that ample data can be obtained by using different assessment instruments. It is notable that the data obtained through the free word association test are richer. It was determined that the participants failed to demonstrate their cognitive

structures in the drawing method as effectively as they did in the word association test, probably because they struggled to visualize their knowledge [132] and that their visual images were not adequately developed. The common and dominant categories emerged in both of the assessment instruments are *"molecules in the process of photosynthesis", "living beings that photosynthesize", "factors influencing photosynthesis"* and *"units where photosynthesis occurs"*. It was in fact desired and expected from biology student teachers to mention molecules related to the process of photosynthesis; however, it was determined that the correlations that they presented under the categories of *"defining photosynthesis"* and *"importance of photosynthesis"* were insufficient. Since these categories require the macro and micro-level correlation of photosynthesis and comprehension of its biochemical dimension, it is seen that the student teachers are not competent in the details of the subject.

On the other hand, through both of the assessment instruments, it was determined that nearly half of the participant biology student teachers have alternative conceptions in a total of six categories (*molecules in the process of photosynthesis, living beings that photosynthesize, periods and times in which photosynthesis takes place, photosynthesis-respiration, defining photosynthesis and importance of photosynthesis)*. The relevant literature also shows that participants have numerous imperfect and incorrect knowledge on photosynthesis and that they mostly mistake the concepts of photosynthesis and respiration for each other [3, 21,,20,23, 51,79, 81, 152]. For students experience learning difficulties stemming from their failure to concretize the relational nature of concepts due to the fact that the concept of photosynthesis involves the "macro, micro and symbolic" dimensions of thought [3]. This shows that biology student teachers experience difficulties in understanding the concept of photosynthesis along with the inputs, outputs, chemical events and relations inherent in the process.

When the alternative conceptions found in this study and those found in other studies in the literature are compared, they are mostly similar although there are also differences. In this study, it was determined under the category "*molecules in the process of photosynthesis"* that some participants have imperfect and incorrect knowledge such as *"CO_2 and water are produced through photosynthesis", "glucose emerges as a result of photosynthesis"* and *"CO2 is taken O2 is revealed"*. Similar results are found in the literature [74,76, 85,89]. It has been determined that participants experience difficulties in understanding the substance cycle during the process of photosynthesis and the dimensions of input-process-output [18, 26, 51, 76, 78, 80, 81, 83, 85]. At this point, it was determined that participants focus on molecules in the inputs and outputs of the process. The following are examples of molecules used most: ATP [85,25], glucose [18], nutrient production [89], light-sun [86], CO_2 [76,51], O2 [18,51].

The following imperfect and incorrect knowledge were determined in the category of *"living beings that photosynthesize":"It occurs in plants' green leaves"*, *"...it generally occurs in green leaves that have chloroplast"*, *"Plants' photosynthesis"*, *"green plants produce their nutrients this way"*, *"photosynthesis is performed by plants" and "it is performed by autotrophic organisms"*. Similarly, the incorrect knowledge that *"only green plants photosynthesize"* was found among science student teachers [78].

It was observed that the participants wrote "sunlight" and "light" as *"factors influencing photosynthesis";* however, they did not take these concepts into consideration while defining photosynthesis. Yip [153] , in the study on the importance and function of chloroplast in photosynthesis, observed that students are highly incompetent, as they defined the main function of chloroplast as absorbing solar energy for photosynthesis. However, they failed to comprehend the roles of chlorophyll and chloroplast and to figure out the optimal wavelength of light required for photosynthesis.

In the category *"periods and times in which photosynthesis occurs"*, the following imperfect and incorrect knowledge were provided: *"during the day"*, *"Plants photosynthesize during the day"* and *"...nutrients and oxygen are produced in the morning, however, oxygen is taken and carbondioxide is revealed in the evening"*. Similarly, Tekkaya and Balci [51] determined the incorrect knowledge among high school students that *"Plants photosynthesize during the day and they respire at night as sunlight is not available"*. In this study, in the category *"photosynthesis-respiration"* obtained from the free word association test, the incorrect knowledge that *"Plants photosynthesize during the day and respire at night"* was found similarly by Tekkaya and Balci [51].

In the category *"defining photosynthesis":* the following imperfect and incorrect knowledge were provided by the participants: *"It is the synthesizing of nutrients and O_2 as a result of a reaction between water and CO_2", "Plants that intake carbondioxide and water produce nutrients", "H_2O+CO_2 light+chlorophyll $C_6H_{12}O_6+O_2$", "$C_6H_{12}O_6+O_2$. → H_2O+CO_2" , "CO_2+su → O_2 "CO_2 → Nutrient+ O_2", "Plants' transformation of CO2 into O2 is called photosynthesis"*. Similar results were obtained among high school students by Tekkaya and Balcı [51] and among student teachers by Çokadar [18]. Moreover, the incorrect knowledge that water is absorbed by plants used in photosynthesis is found to be prevalent among nearly half of biology, chemistry and physics student teachers [83]. On the other hand, researchers have emphasized that in order for students to fully comprehend photosynthesis they need to combine the relations between energy transformation, observable aspects of plant growth and ecosystem [97, 96, 98]; and that they need to understand glucose cannot be produced during photosynthesis without any warning related to the rearrangement of water and carbondioxide [99]. It has been suggested that students have learning difficulties and confusions regarding whether luminous energy or thermal energy is needed for photosynthesis [1, 100] and how luminous energy turns into chemical energy during photosynthesis [1, 2, 101].

In the category *"importance of photosynthesis",* the imperfect and incorrect knowledge that *"...oxygen is produced for the continuation of life"* was found. In fact, the participant here tries to point to the fact that photosynthesis involves complex transformations and biochemical reactions and to the equilibrium in the ecological system such as ecology, physiology, digestion, respiration of all living beings, biosynthesis, biochemistry, transformation of energy and autotrophic nutrition [1, 74, 88,]; however, she fails to express this in a scientific manner.

As it is seen after an analysis of the findings of this study and other studies in the literature, learning difficulties, imperfect and incorrect knowledge and alternative conceptions about the concept of photosynthesis are common among primary school students [51], secondary school students [24, 74], high school students [77, 85], university students [60], student teachers [22, 83, 91, 92] and in-service teachers [89]. Given the fact that alternative conceptions and imperfect-incorrect knowledge can be altered only through a highly difficult process [31, 152, 154, 155] and that they persist from elementary school to university [86], effective teaching approaches must be utilized. It has been widely accepted that the quality of instruction plays a key role in students' learning outcomes [156]. Alzate and Puig [157] suggested that activities can be performed using effective teaching-learning approaches oriented towards conceptual change, after determining the mental presentations of students about photosynthesis. In this respect, teaching-learning practices, which allow students to learn by carrying out laboratory applications [94], in which concepts are visualized in printed materials, in which abstract concepts are concretized and in which students can learn by relating concepts to their daily lives, should be given priority; because photosynthesis is a subject that cannot be visually observed and thus needs to be concretized. It would be useful to benefit from technology in this process by offering computer-aided and/or simulated teaching, by paying special attention to the preparation of course books and ensuring the teaching of the subject through visualizations [153,158] and teaching the subject using a model [94]. That is, along with conventional methods used in biology education [159], employing computer-aided methods and techniques that can visualize knowledge will be helpful, because it was determined that the participants are incompetent in expressing their opinions through drawings. The visual dimension is of high importance in learning concepts and expressing what is learned [160,161,162]. Students should be encouraged to draw related to biological processes especially in laboratories in order to improve their cognitive imaginations. This is very important especially in a field like biology, in which the emphasis is on drawings and visualizations in order to concretize subjects.

Teachers should carefully monitor alternative conceptions, which may emerge at all educational levels and they should carry out effective teaching activities in order not only to prevent their emergence but also to alter existing ones. To this end, both before and during university education, pretests and posttests can be performed in order to detect alternative conceptions, students' misconceptions can be determined using conceptual tests and small group discussions, or other techniques such as open-ended questions, conceptual change texts, concept maps, concept caricatures, interviews, drawings, tests, analogies or computer-aided teaching [163-167].

The concept of photosynthesis points to a process that concerns not only plants but also all other living beings in the ecosystem. For this reason, teaching this subject by relating it to the daily life during teaching activities will concretize the subject for learners and facilitate learning, because for individuals to comprehend the relationships between what they learn at school and what they experience in their everyday lives contributes to their science literacy [168,169]. It was determined in this study that the participants had insufficient levels of correlating what they learned in different fields of science with the daily life, comprehending the relations between scientific and non-scientific concepts and being science literate [170-175]. It was also found that biology student teachers presented positive-negative correlations in their response words at the macro and micro levels; however, they failed to adequately construct these correlations. Satisfying students' biological, psychological and social needs in biology courses will increase their motivation to learn these courses.

In conclusion, learning concepts is one of the primary requirements for obtaining information on a subject. The biology course has a wide conceptual structure. It was determined in this research that biology student teachers have insufficient cognitive structures about the concept of photosynthesis. However, this insufficiency might have developed as early as the elementary school level. What matters is the elimination of these problems. Besides, learning concepts should be given importance starting from elementary education. Teacher training programs should be designed in a way to facilitate teacher candidates' conceptual developments, to improve their professional skills and to enable them to determine their students' learning difficulties [153]. Qualified teachers can be trained only if curricula are prepared with a higher consciousness, when the teacher candidate is enabled to become aware of her own individual characteristics and when she is enabled to find an answer to the question "How better can I learn?" Qualified teachers can only trained as a result of a high-quality education process.

This research, which yielded highly detailed findings, is capable of setting an example to future studies, which might be experimental or they might use other techniques such as two-stage multiple-choice tests, drawings, interviews, free word association test, structured grid, diagnostic tree, concept maps, conceptual change texts, analogy or prediction-observation-explanation. Moreover, competences of biology curricula in terms of concept learning/teaching can be addressed, because one of the reasons behind students' insufficient cognitive structures is problems in curricula.

REFERENCES

1. Marmaroti, P. and D. Galanopoulou, 2006. Pupils' understanding of photosynthesis: A questionnaire for the simultaneous assessment of all aspects. International Journal of Science Education, 28(4): 383-403.
2. Waheed, T. and A.M. Lucas, 1992. Understanding interrelated topics: Photosynthesis at age 14. Journal of Biological Education, 26(3): 193-200.
3. Bahar, M., A.H. Johnstone and M.H. Hansell, 1999. Revisiting learning difficulties in biology. Journal of Biological Education, 33: 84-86.
4. Cimer, A., 2012. What makes biology learning difficult and effective: Students' views? Educational Research and Reviews, 7(3): 61-71.
5. Hmelo-Silver, C.E. and R. Azevedo, 2006. Understanding complex systems: Some core challenges. The Journal of the Learning Sciences, 15: 53-61.
6. Inagaki, K. and G. Hatano, 2002. Young children's naïve thinking about the biological world (Essays in Developmental Psychology). New York: Psychology Press-Taylor and Francis Group.
7. Inagaki, K. and G. Hatano, 2006. Young children's conception of the biological world. Current Directions in Psychological Science, 15(4): 177-181.
8. Jones, M.G. and M.J. Rua, 2006. Conceptual representations of flu and microbial illness held by students, teachers and medical professionals. School Science and Mathematics, 108(6): 263-278.
9. Lazarowitz, R. and S. Penso, 1992. High school students' difficulties in learning biology concepts. Journal of Biological Education, 26(3): 215-224.
10. Lewis, J., J. Leach and C. Wood-Robinson, (2000). Chromosomes: The missing link-young people's understanding of mitosis, meiosis and fertilization. Journal of Biological Education, 34(4): 189-199.
11. Lukin, K., 2013. Exciting middle and high school students about immunology: An easy, inquiry-based lesson. Immunologic Research, 55(1-3): 201-209.
12. Prokop, P., M. Prokop and S.D. Tunnicliffe, 2007. Effects of keeping animals as pets on children's concepts of vertebrates and invertebrates. International Journal of Science Education, 30(4): 431-449.

13. Seymour, J. and B. Longdon, 1991. Respiration-that's breathing isn't it? Journal of Biological Education, 23(3): 177-184.
14. Simpson, W.D. and E.A. Marek, 1998. Understanding and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. Journal of Research in Science Teaching, 25: 361-374.
15. Udovic, D., D. Morris, A. Dickman, J. Postlethwait and P. Wetherwax, 2002. Workshop biology: Demonstrating the effectiveness of active learning in an introductory biology course. BioScience, 52(3): 272-281.
16. Tekkaya, C., O. Ozkan and S. Sungur, 2001. Biology concepts perceived as difficult by Turkish high school students. Science Education, 66(4): 531-538.
17. Treagust, D.F., 1988. Development and use of diagnostic tests to evaluate students' misconception in science. International Journal of Science Education, 10(2): 159-169.
18. Cokadar, H., 2012. Photosynthesis and respiration processes: Prospective teachers' conception levels. Education and Science, 37(164): 81-93.
19. Cakir, O.S., O. Geban and N. Yuruk, 2002. Effectiveness of conceptual change text-oriented ınstruction on students' understanding of cellular respiration concepts. Biochemistry And Molecular Biology Education, 30(4): 239-243.
20. Eisen, Y. and R. Stavy, 1988. Students' understanding of photosynthesis. The American Biology Teacher, 50(4): 209-212.
21. Griffard, P.B., 2001. The two-tier instrument on photosynthesis: What does it diagnose? International Journal of Science Education, 23(10): 1039-1052.
22. Harman, G., 2012. Knowledge and misconceptions of science student teachers about physical and chemical change. Journal of Education and Instraction Research, 1(3): 130-146.
23. Haslam, F. and D.F. Teagust, 1987. Diagnosingsecondarystudents' misconceptions of photosynthesis and respiration in plantsusing a two tier multiple choice instrument. Journal of Biological Education, 21(3): 203-211.
24. Keles, E. and P. Kefeli, 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.
25. Parker, J.M., C.W. Anderson, M. Heidemann, J. Merrill, B. Merritt, G. Richmond and M. Urban-Lurain, 2012. Exploring undergraduates' understanding of photosynthesis using diagnostic question clusters. Life Sciences Education, 11: 47-57.
26. Songer, C.J. and J.J. Mintzes, 1994. Understanding cellular respiration and analysis of conceptual change in college biology. Journal of Research in Science Teaching, 31(6): 621-637.
27. Driver, R. and J. Easley, 1978. Pupils and paradigms: A review of literature related to concept development in adolescent science students. Studies in Science Education, 5: 61-84.
28. Pines, A. and L. West, 1986. Conceptual understanding and science learning: an interpretation of research within sources-of knowledge framework. Science Education, 70(5): 583-604.
29. Tsai, C.C. and C.M. Huang, 2002. Exploring students' cognitive structures in learning science: A review of relevant methods. Journal of Biological Education, 36: 163-169.
30. Albanese, A. and M. Vicentini, 1997. Why do we believe that an atom is colorless? Reflections about the teaching of the particle model. Science & Education, 6: 251-261.
31. Posner, G., K. Strike, P. Hewson and W. Gertzog, 1982. Accommodation of a scientific conception. Toward a theory of conceptual change. Science Education, 66: 211-227.
32. Tsai, C.C., 1999. Overcoming junior high school students' misconceptions about microscopic views of phase change: A study of an analogy activity. Journal of Science Education and Technology, 8(1): 83-91.
33. Wandersee, J.H., J.J. Mintzes and J.D. Novak, 1994. Research on alternative conceptions in science. In: D.L. Gabel, (Ed.), Handbook of Research on Science Teaching and Learning, pp: 177-210. NY: Macmillan.
34. West, L.H.T. and P.J. Fensham, 1974. Prior knowledge and the learning of science: A review of Ausubel's theory of this process. Stud. Science Education, 1: 61-81.
35. Doran, R.L., 1972. Misconception of selected science concepts held by elementary school students. Journal of Research in Science Teaching, 9(2):127-137.

36. Driver, R., 1989. Students' conceptions and the learning of science. International Journal of Science Education, 11: 481-490.
37. Driver, R. and J. Easley, 1978. Pupils and paradigms: a review of literature related to concept development in adolescent science students. Studies in Science Education, 5: 61-84.
38. Mike, M. and D.F. Treagust, 1998. A pencil and paper instrument to diagnose students' conceptions of breathing, gas exchange and respiration. Australian Science Teachers Journal, 44(2): 55-60.
39. Skelly, K.M. and D. Hall, 1993. The development and validation of a categorization of sources of misconceptions in chemistry. Paper presented at the Third International Seminar on Misconceptions and Educational Strategies in science and Mathematics, Ithaca.
40. Smith, E.L., T.D. Blakeslee and C.W. Anderson 1993. Teaching strategies associated with conceptual change learning in science. Journal of Research in Science Teaching, 30(2): 111-126.
41. Gilbert, J.K., C. Boulter and M. Rutherford, 1998a. Models in explanations, part 1, Horses for courses? International Journal of Science Education, 20: 83-97.
42. Gilbert, J.K., C. Boulter and M. Rutherford, 1998b. Models in explanations, part 2, Whose voice? Whose ears? International Journal of Science Education, 20: 187-203.
43. Gilbert, J.K. and C.J. Boulter, 2000. Learning Science Through Models and Modeling. In: K. Tobin and B. Frazer (Eds). The International Handbook of Science Education, pp: 53-66. Dordrecht: Kluwer.
44. Bahar, M., 2003. Misconceptions in biology education and conceptual change strategies. Educational Sciences: Theory & Practice, 3(1): 55-64.
45. Bahar, M., Z. Nartgun, S. Durmus and B. Bicak, 2006. Traditional and Alternative Assessment and Evaluation of Teachers' Manual. Ankara: Pegem A Publishing.
46. Ercan, F., A. Tasdere and N. Ercan, 2010. Observation of cognitive structure and conceptual changes through word association tests. Journal of Turkish Science Education, 7(2): 138-154.
47. Kurt, H., 2013. Biology student teachers' cognitive structure about "Living thing". Educational Research and Reviews, 8(12): 871-880.
48. Ozcan, S., 2010. Determination of opinions of Science student teachers on environmental problems using different techniques. Unpublished master thesis. Abant Izzet Baysal University, Bolu, Turkey.
49. Yalvac, G.H., 2008. Impact of cooperative learning approach upon student teachers' mental structures on environment. Unpublished Master's Thesis, Abant İzzet Baysal, Bolu, Turkey.
50. Odom, A.L. and L.H. Barrow 1995. Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction. Journal of Research in Science Teaching, 32: 45-61.
51. Tekkaya, C. and S. Balci, 2003. Determination of students' misconceptions concerning photosynthesis and respiration in plants. Hacettepe Journal of Education, 24: 101-107.
52. Ainsworth, S., V. Prain and R. Tytler, 2011. Drawing to learn in science. Science Education, 333: 1096-1097.
53. Cetin, G., M. Ozarslan, E. Isik and H. Eser, 2013. Students' views about health concept by drawing and writing technique. Energy Education Science and Technology, Part B, 5(1): 597-606.
54. Cinici, A., 2013. From caterpillar to butterfly: A window for looking into students' ideas about life cycle and life forms of insects. Journal of Biological Education, DOI:10.1080/00219266.2013.773361.
55. Nyachwayaa, J.M., A.R. Mohameda, G.H. Roehriga, N.B. Woodb, A.L. Kernc and J.L. Schneiderd, 2011. The development of an open-ended drawing tool: An alternative diagnostic tool for assessing students' understanding of the particulate nature of matter. Chemistry Education Research and Practice, 12(2): 121-132.
56. Patrick, P.G. and S.D. Tunnicliffe, 2010. Science Teachers' drawings of what is inside the human body. Journal of Biological Education, 44(2): 81-87.
57. She, H.C., 2004. Facilitating changes in ninth grade students' understanding of dissolution and diffusion through DSLM instruction. Research in Science Education, 34: 503-525.
58. Yayla, R.G. and G. Eyceyurt, 2011. Mental models of pre-service science teachers about basic concepts in chemistry. Western Anatolia Journal of Educational Sciences, 2011: 285-294.
59. Zoldosova, K. and P. Prokop, 2007. Primary pupils" preconceptions about child prenatal development. Eurasia Journal of Mathematics, Science and Technology Education, 3(3): 239-246.
60. Kose, S., 2008. Diagnosing student misconceptions: Using drawings as a research method. World Applied Sciences Journal, 3(2): 283-293.
61. Osborne, R.J. And M.M. Cosgrove, 1983. Children's conceptions of the changes of state of water, Journal of Research in Science Teaching, 20(9): 825-838.

62. Martinez, M.N., I. Solano and E.J. Gomez, 2001. Characteristic of the methodology used to describe student's conceptions. International Journal of Science Education, 23(7): 663-690.
63. Ad, V.N.K. and N. Demirci, 2012. Prospective teachers' levels of associating environmental problems with science fields and thermodynamics laws. Ahi Evran University Journal of Kirsehir Educatioan Faculty, 13(3): 19-46.
64. Dove, J.E., L.A. Everett and P.F.W. Preece, 1999. Exploring a hydrological concept though children's drawings. International Journal of Science Education, 21(5): 485-497.
65. Koseoglu, F. and E. Bayir, 2011. Examining cognitive structures of chemistry teacher candidates about gravimetric analysis through word association test method. Trakya Üniversitesi Eðitim Fakültesi Dergisi, 1(1): 107-125.
66. Polat, G., 2013. Determination of the cognitive structures of year secondary school students through word association test techniques. Necatibey Faculty Education Electronic Journal of Science and Mathematic Education, 7(1): 97-120.
67. Novak, J.D. and D.B. Gowin, 1993.Learning how to learn. Cambridge University Press, New York, 1984.
68. Horton, P.B., A.A. McConney, M. Gallo, A.L. Woods, G.J. Senn and D. Hamelin, 1993. An investigation of the effectiveness of concept mapping as an instructional tool. Science Education, 77(1): 95-111.
69. Liew, C.W. and D.F. Treagust, 1998. The effectiveness of predict-observe-explain tasks in diagnosing students' understanding of science and in identifying their levels of achievement. Paper Presented at the Annual Meeting of The American. Educational Research Association, San Diego.
70. Champagne, A.B., L.E. Klopfer and R.F. Gunstone, 1982. Cognitive research and the design of science instruction. Educational Psychologist, 17: 31-53.
71. Bahar, M., M. Ozel, P. Prokop and M. Usak, 2008. Science student teachers' ideas of the heart. Journal of Baltic Science Education, 7(2): 1648-3898.
72. White, R.T. and R.F. Gunstone, 1992. Probing understanding. London: The Falmer Press.
73. Driver, R., A. Squires, P. Rushworth and V. Wood-Robinson, 1994. Making sense of secondary science: Research into children's ideas. London: Routledge.
74. Lin, C. and R. Hu, 2003. Students' understanding of energy flow and matter cycling in the context of the food chain, photosynthesis and respiration. International Journal of Science Education, 25(12): 1529-1544.
75. Kao, H.L., 2007. A study of aboriginal and urban junior high school students' alternative conceptions on the definition of respiration. International Journal of Science Education, 29(4): 517-533.
76. Gunes, T., N.S. Dilek,. M. Hoplan and O. Gunes, 2012. Misconceptions of elementary school 8th grade students about photosynthesis and respiration. Journal of Educational and Instructional Studies in the World, 2(1): 42-47.
77. Yuruk, N. and O. Cakir, 2000. Determination of misconceptions about aerobic respiration and anaerobic respiration of high school students. Hacettepe Journal of Education, 18: 185-191.
78. Kose, S. and M. Usak, 2006. Determination of prospective science teachers' misconceptions: Photosynthesis and respiration in plants. International Journal of Environmental and Science Education, 1(1): 25-52.
79. Anderson, C.W., T.H. Sheldon and J. Dubay, 1990. The effects of instruction on college nonmajors' conceptions of respiration and photosynthesis. Journal of Research in Science Teaching, 27(8): 761-776.
80. Hogan, K. and J. Fisherkeller, 1996. Representing students' thinking about nutrient cycling in ecosystems: Bidimensional coding of a complex topic. Journal of Biological Education, 33: 941-970.
81. Kose, S., A. Ayas and M. Usak, 2006. The Effect of Conceptual Change Texts Instructions on Overcoming Prospective Science Teachers' Misconceptions of Photosynthesis and Respiration in Plants. International Journal of Environmental and Science Education, 1(1): 78-103.
82. Yenilmez, A. and C. Tekkaya, 2006. Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach. Journal of Science Education and Technology, 15(1): 81-87.
83. Mak, S.Y., D.Y. Yip and C.M. Chung, 1999. Alternative conceptions in biology related topics of integrated science teachers and implications for teacher education. Journal of Science Education and Technology, 8(2): 161-170.

84. Griffiths, A. K. and B.A.C. Grant, 1985. High school students' understanding of food webs: Ýdentification of a learning hierarchy and related misconceptions. Journal of Research in Science Teaching, 22: 421-436.
85. Barak, J., B. Sheva and M. Gorodetsky, 1999. As 'process' as it can get: students' understanding of biological processes. International Journal of Science Education, 21: 1281-1292.
86. Canal, P., 1999. Photosynthesis and 'inverse respiration' in plants: An inevitable misconception?, International Journal of Science Education, 21(4): 363-371.
87. Lin, C. and R. Hu, 2010. Assessing learning progression of energy concepts across middle school grades: The knowledge integration perspective. Science Education, 94: 665-688.
88. Jin, H. and C.W. Anderson, 2012. A learning progression for energy in socio-ecological systems. Journal of Research in Science Teaching, 49(9): 1149-1180.
89. Lenton, G.M. and J.J. McNeil, 1993. Primary school teachers' understanding of biological concepts: Selected research findings. British Journal of In-Service Education, 19(2): 27-34.
90. Griffard, P.B. and J.H. Wandersee, 2001. The two-tier instrument on photosynthesis: What does it diagnose? International Journal of Science Education, 23(10): 1039-1052.
91. Tekkaya, C., Y. Capa and O. Yilmaz, 2000. Prospective teachers' misconceptions concerning general biology concepts. Hacettepe Journal of Education, 18: 140-147.
92. Brown, M.H. and R.S. Schwartz, 2009. Connecting photosynthesis and cellular respiration: Preservice teachers' conceptions. Journal of Research in Science Teaching, 46: 791-812.
93. Chi, M., 2001. Why do students fail to understand complex dynamic concepts? Paper delivered to American Education Research Association, Seattle. April 10-14, 2001.
94. Ross, P., D. Tronson and R.J. Ritchie, 2006. Modelling photosynthesis to increase conceptual understanding. Journal of Biological Education, 40(2): 84-88.
95. Ray, A.M. and P.M. Beardsley, 2008. Overcoming student misconceptions about photosynthesis: a model- and inquiry-based approach using aquatic plants, science activities. Classroom Projects and Curriculum Ideas, 45(1): 13-22.
96. Ryoo, K. and M.C. Linn, 2012. Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis? Journal of Research in Science Teaching, 49(2): 218-243.
97. Kesidou, S. and J.E. Roseman, 2002. How well do middle school science programs measure up? Findings from Project 2061's curriculum review. Journal of Research in Science Teaching, 39(6): 522-549.
98. Stern, L. and J.E. Roseman, 2004. Can middle-school science textbooks help students learn important ideas? Journal of Research in Science Teaching, 41(6): 538-568.
99. Mohan, L., H. Chen and W.C. Anderson, 2009. Developing a multi-year learning progression for carbon cycling in socio-ecological systems. Journal of Research in Science Teaching, 46(6): 675-698.
100. Carlsson, B., 2002. Ecological understanding 1: Ways of experiencing photosynthesis. International Journal of Science Education, 24(7): 681-699.
101. Johnson, P., 2000. Children's understanding of substances, Part 1: Recognizing chemical change. International Journal of Science Education, 22: 719-737.
102. Gall, M.D., W.R. Borg and J.P. Gall, 2002. Educational Research: An Introduction (7th ed.). White Plains: Pearson/Allyn and Bacon.
103. Hitchcock, G. and D. Hughes, 1995. Research and the Teacher, (2nd Edition), London: Routledge.
104. Miles, M.B. and A.M. Huberman, 1994. Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks, California: SAGE.
105. Verma, G.K. and K. Mallick, 1999. Researching Education: Perspectives and Techniques. Philadelphia: Open University Press.
106. Cohen, L. and L. Manion, 1997. Research Methods in Education. London: Routledge.
107. Patton, M.Q., 1990. Qualitative Evaluation and Research Methods. USA: Sage.
108. Punch, K.F., 2005. Introduction to Social Research-Quantitative and Qualitative Approaches. London: Sage.
109. Coyne, I., 1997. Sampling in qualitative research. Purposeful and theoretical sampling: merging or clear boundaries? Journal of Advanced Nursing, 26(3): 623-630.
110. Given, L.M., 2008. The Sage Encyclopedia of Qualitative Research Methods. Sage: Thousand Oaks, CA.

111. Knight, S.L., J. Nolan, G. Lloyd, F. Arbaugh, J. Edmondson and A. Whitney, 2013. Quality teacher education research: How do we know it when we see it? Journal of Teacher Education, 64(2): 114-116.
112. Atasoy, B., 2004. Science Learning and Teaching. Ankara: Asil Publisher.
113. Bahar, M. and F. Kilicli, 2001. Investigating the bonds between the principles of Ataturk through the method of word association test. X. National Congress of Educational Sciences, Turkey.
114. Bahar, M. and N.S. Ozatli, 2003. Investigating high school freshman students' cognitive structures about the basic components of living things through word association test method. Journal of the Institute of Science and Technology of Balikesir University, 5(1): 75-85.
115. Cardellini, L. and M. Bahar, 2000. Monitoring the learning of chemistry through word association tests. Australian Chemistry Research Book, 19: 59-69.
116. Kempa, R.F. and C.E. Nicholls, 1983. Problem solving ability and cognitive structure-an explanatory investigation. European Journal of Science Education, 5: 171-184.
117. Bahar, M., A.H. Johnstone and R.G. Sutcliffe, 1999. Investigation of students' cognitive structure in elementary genetics through word association tests. Journal of Biological Education, 33: 134-141.
118. Sato, M. and P. James, 1999. "Nature" and "Environment" as perceived by university students and their supervisors. International Journal of Environmental Education and Information, 18(2): 165-172.
119. Shavelson, R.J., 1972. Some aspects of the relationship between contentstructure and cognitive structure in physics instructions. Journal ofEducational Psychology, 63(3): 225-234.
120. Ashcraft, H.M., 1978. Property dominance and typicality effects in propertystatement verification. Journal of Verbal Learning and Verbal Behavior, 17(2): 155-164.
121. Bahar, M. and H.M. Hansell, 2000. The relationship between somepsychological factors and their effect on the performance of grid questionsand word association tests. Educational Psychology, 20(3): 349-364.
122. Kounios, J. and P.J. Holcomb, 1992. Structure and process in semantic memory: Evidence from event-related brain potentials and reaction times. Journal of Experimental Psychology: General, 121(4): 459-479.
123. Gussarsky, E. and M. Gorodetsky, 1990. On the concept "Chemical equilibrium: The associative framework. Journal of Research in Science Teaching, 27(3): 197-204.
124. Backett-Milburn, K. and L. McKie, 1999. A critical appraisal of the draw and write technique. Health Education Research Theory and Practice, 14(3): 387-398.
125. Borthwick, A., 2011. Children's perceptions and attitudes towards their mathematics lessons. In C. Smith, (Ed.), British Society for Research into Learning Mathematics, 31: 37-42.
126. Christensen, P. and A. James, 2000. Research with Children. London: Falmer Press.
127. Guichard, J., 1995. Designing tools to develop the conception of learners. International Journal of Science Education, 17: 243-253.
128. Ozden, M., 2009. Primary student teachers' ideas of atoms and molecules: Using drawings.Education 129(4): 635-642.
129. Patrick, P.G. and S.D. Tunnicliffe, 2010. Science teachers' drawings of what is inside the human body. Journal of Biological Education, 44(2): 81-87.
130. Pridmore, P. and G. Bendelow, 1995. Images of health: Exploring beliefs of children using the 'draw-and-write' technique. Health Education Journal, 54(4): 473-88.
131. Prokop, P., J. Fancüvicüva and S.D. Tunnicliffe, 2009. The effect of type of instruction on expression of children's knowledge: How do children see the endocrine and urinary system?" International Journal of Environmental and Science Education, 4(1): 75-93.
132. Reiss, M.J., S.D. Tunnicliffe, A.M. Andersen, A. Bartoszeck, G.S. Carvalho, S.-Y. Chen, R. Jarmana, *et al*., 2002. An international study of young peoples' drawings of what is inside themselves. Journal of Biological Education, 36(2): 58-64.
133. Rennie, L.J. and T. Jarvis, 1995. English and Australian children's perceptions about technology. Research Science Technology Education, 13(1): 37-52.
134. Daskolia, M., E. Flogaitis and E. Papageorgiou, 2006. Kindergarten teachers' conceptual framework on the ozone layer depletion. Exploring the associative meanings of a global environmental issue. Journal of Science Education and Technology, 15(2): 168-178.
135. Kostova, Z. and B. Radoynovska, 2008. Word association test for studying conceptual structures of teachers and students. Bulgarian Journal of Science and Education Policy, 2(2): 209-231.

136. Kostova, Z. and B. Radoynovska, 2010. Motivating students' learning using word association test and concept maps. Bulgarian Journal of Science and Education Policy, 4(1): 62-98.
137. Torkar, G. and B. Bajd, 2006.Trainee teachers' ideas about endangered birds. Journal of Biological Education, 41(1): 5-8.
138. Wagner, W., J. Valencia and F. Elejabarrieta, 1996. Relevance, discourse and the hot stable core of social representation-A structural analysis of word association. British Journal of Social Psychology, 35: 331-351.
139. Bartoszeck, A.B., D.Z. Machado and M. Amann-Gainotti, 2008. Representations of internal body image: A study of preadolescents and adolescent students in Araucaria, Paraná, Brazil. Ciências & Cognição, 13(2): 139-159.
140. Reiss, M.J. and S.D. Tunnicliffe, 2001. Students' understandings of human organs and organ systems. Research in Science Education, 31: 383-399.
141. Hruschka, D.J., D. Schwartz, D.C. St. John, E. Picone-Decaro, R.A. Jenkins and J.W. Carey, 2004. Reliability in coding open-ended data: Lessons learned from HIV behavioral research. Field Methods, 16(3): 307-331.
142. Marvasti, A.B., 2004. Qualitative Research in Sociology. London: Sage Publications Ltd.
143. Roberts, P. and H. Priest, 2006. Reliability and validity in research. Nursing Standard, 20: 41-45.
144. Hovardas, T. and K.J. Korfiatis, 2006. Word associations as a tool for assessing conceptual change in science education. Learning and Instruction, 16: 416-432.
145. Isikli, M., A. Tasdere and N.L. Goz, 2011. Investigation teacher candidates' cognitive structure about principles of Ataturk through word association test. Usak University Journal of Social Science, 4(1): 50-72.
146. Garcia-Barros, S., C. Martínez-Losada and M. Garrido, 2011. What do children aged four to seven know about the digestive system and the respiratory system of the human being and of other animals? International Journal of Science Education, 33(15): 2095-2122.
147. Pluhar, Z.F., B.F. Piko, S. Kovacs and A. Uzzoli, 2009. Air pollution is bad for my health: Hungarian children's knowledge of the role of environment in health and disease. Health and Place, 15: 239-246.
148. Shepardson, D.P., B. Wee, M. Priddy and J. Harbor, 2007. Students' mental models of the environment. Journal of Research in Science Teaching, 44(2): 327-348.
149. Stafstrom, C.E., K. Rostasy and A. Minster, 2002. The usefulness of children's drawings in the diagnosis of headache. Pediatrics, 109(3): 460-472.
150. Yorek, N., M. Sahin and I. Ugulu, 2010. Students' representations of the cell concept from 6 to 11 grades: Persistence of the "Fried-Egg Model". International Journal of Physical Sci., 5(1): 15-24.
151. Strommen, E., 1995. Lions and tigers and bears, Oh my! Children's conceptions of forests and their inhabitants. Journal of Research in Science Teaching, 32: 683-698.
152. Ozay, E. and H. Oztas, 2003. Secondary students' interpretations of photosynthesis and plant nutrition. Journal of Biological Education, 37(2): 68-70.
153. Yip D.Y., 1998. Teachers' misconceptions of the circulatory system. Journal of Biological Education, 32(3): 207-215.
154. Donovan, M.S. and J.D. Bransford, 2005. How Students Learn: Science in the Classroom. National Academies Press.
155. Reinfried, S., 2006. Conceptual change in physicalgeography and environmental sciencesthrough mental model building: The example of groundwater. International Research of Geography and Environmental Education, 15(1): 41-61.
156. Kuijpers, J.M., A.A.M. Houtveen and T. Wubbels, 2010. An integrated professional development model for effective teaching. Teaching and Teacher Education, 26(8): 1687-1694.
157. Alzate, O.E.T. and N.S. Puig, 2007. High-school students' conceptual evoluation of the respiration concept from the Perspective of Giere's Cognitive Science Model. International Journal of Science Education, 29(2): 215-248.
158. Barrass, R., 1984. Some misconceptions and misunderstandings perpetuated by teachers and textbooks of biology. Journal of Biological Education, 18(3): 201-206.
159. Sundberg, M.D., J.E. Armstrong and E.W. Wischusen, 2005. A reappraisal of the status of introductory biology laboratory education in U. S. colleges and universities. American Biology Teacher, 67: 525-529.

160. Gilbert, J., 2005. Catching the Knowledge Wave: The Knowledge Society and the Future of Education E-Learning & Distance Education Resources, Tony Bates Associates Ltd.
161. Gilbert, J.K., M. Reiner and M. Nakhleh, 2008. Visualization: Theory and Practice in Science Education. Springer: Surrey.
162. Kozma, R. and J. Russell, 2005. Modelling Students Becoming Chemists: Developing Representational Competence. In: J.K. Gilbert, (Ed.), Visualization in Science Education, pp: 121-145. Dordrecht: Springer.
163. Beeth, M.E., 1998. Teaching science in fifth grade: Instructional goals that support conceptual change. Journal of Research in Science Teaching, 35(10): 1091-1101.
164. O' Connell, B., I. Beaman, P. De Lange and K. Smyrnios, 2002. An experiment to assess the learning benefits of employing accounting software in the classroom. Review of Business Information Systems, 7(1): 49-57.
165. Keogh, B. and S. Naylor, 1999. Concept cartoons, teaching and learning in science: An evaluation. International Journal of Science Education, 21(4): 431-446.
166. Naylor, S., S. Keogh and B. Downing, 2007. Argumentation and primary science. Research in Science Education, 37: 17-39.
167. Wang, T. and T. Andre, 1991. Conceptual change text versus traditional text questions versus no questions in learning about eletricity.Contemporary Educational Psychology, 16: 103-116.
168. Harlen, W., 2002. Links to everyday life: The roots of scientific literacy.Primary Science Review, 71: 8-10.
169. Andrée, M., 2003. Everyday-life in the science classroom: A study on ways of using and referring to everyday-life. Paper presented at the ESERA Conference. Noordwijkerhout, Netherlands.
170. Enginar, İ., A. Saka and E. Sesli, 2002. High School second grade students' levels of ability to associate the knowledge, which they acquire in biology class, with current events. 5th National Science and Mathematics Education Congress, Ankara.
171. Kurt, H., B. Kaya, A. Ates and S. Kilic, 2009. The biological literacy of biology teacher candidates. Selcuk University Journal of Ahmet Kelesoglu Education Faculty, 27: 17-30.
172. Ozmen, H., 2003. Chemistry student teachers' levels of ability to associate their Interest on the concepts of acid and base with daily events. Kastamonu Journal of Education, 11(2): 317-324.
173. Palmer, D.H., 1999. Exploring the link between students' scientific and nonscientific conceptions. Science Education, 83: 639-653.
174. Tasdemir, A. and M. Demirbas, 2010. Elementary school students' levels of ability to associate the concepts they study in the topics of the science and technology class with the daily life. International Journal of Human Science, 7(1): 125-148.
175. Yigit, N., Y. Devecioglu and H.S. Ayvaci, 2002. Elementary school science students' levels of association of the concepts of science with the facts and events in the daily life. 5th National Science and Mathematics Education Congress, Ankara.