

Full Length Research Paper

On the concept of “Respiration”: Biology student teachers’ cognitive structures and alternative conceptions

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In researches, the subject of respiration has been determined to be among subjects about whom 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 respiration. 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. At the end of the research, the cognitive structures of the participant biology student teachers about the concept of respiration consisted of the words and drawings they presented in the free word association test and the drawing-writing technique. The data were grouped under the following nine categories: “*respiratory organs and their structures*”, “*molecules that take part in respiration and their transformations*”, “*types of respiration*”, “*defining respiration*”, “*respiratory-carrying system*”, “*purpose of respiration*”, “*respiratory diseases and their causes*”, “*respiratory-digestive system*” and “*respiration-living species*”. In both of the assessment instruments, the categories of “*respiratory organs and their structures*” and “*molecules that take part in respiration and their transformations*” emerged as the common and dominant categories. Besides, almost all 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 many categories defined in both of the instruments. At the end of this paper, comprehensive suggestions related to the subject are presented.

Key words: Respiration, cognitive structure, free word association test, drawing-writing technique, alternative conception, drawing level.

INTRODUCTION

The concept of respiration refers to one of the vital systems in living beings. Respiration is among the common characteristics that are indicators of life for all living beings. For this reason, at all levels in all science courses that focus on living beings, students have to

learn scientific information and construct their cognitive structures about the concept of respiration. In courses, the expression “respiration in living beings” is used in a widespread fashion. However, research has been demonstrating that students experience difficulties in

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learning, and constructing their cognitive structures about, the subject of systems, which is among the healthy life characteristics of living beings (Bahar et al., 1999; Cimer, 2012; Hmelo-Silver and Azevedo, 2006; Inagaki and Hatano, 2002, 2006; Jones and Rua, 2006; Lazarowitz and Penso, 1992; Lewis et al., 2000; Lukin, 2013; Prokop et al., 2007a,b; Seymour and Longdon, 1991; Simpson and Marek, 1988; Udovic et al., 2002; Tekkaya et al., 2001; Treagust, 1988). It is emphasized in the literature that students experience difficulties in learning the subject of respiration and that they have many relevant alternative conceptions (Anderson et al., 1990; Bishop et al., 1985; Eisen and Stavvy, 1988; Haslam and Treagust, 1987; Seymour and Longdon, 1991; Tekkaya and Balci, 2003).

There are many reasons why students fail to adequately construct their cognitive structures about the subject of respiratory systems. However, in this study, the main importance is attached to the features of the subject, because features of the subject to be learned are among the main factors that influence learning. One of the main reasons of students' inability to adequately comprehend the concept of respiration is their inability to comprehend the micro- and macro-level relations pertaining to the subject (Ben-Zvi et al., 2013; Hmelo-Silver et al., 2000; Hmelo-Silver and Pfeffer, 2004; Hmelo-Silver and Azevedo, 2006). This is because the concept of respiration refers to a complex process which differs from single-cell organisms to animals and plants. The facts that this process contains numerous concepts and that each of these concepts are linked with one another render this structure much more complex. It is emphasized in the literature that students fail to form their cognitive structures, to concretize abstract aspects, and to establish a link with their daily lives related to this complex structure (Anagun et al., 2010; Enginar et al., 2002; Er et al., 2013; Kurt et al., 2009; Palmer, 1999; Saxe, 1991; Tasdemir and Demirbas, 2010; Yigit et al., 2002). However, endowing students with the skill of linking the events and phenomena in their daily lives with the science course brings about meaningful learning (Smith and Siegel, 2004; Martin, 1997) and positive attitudes towards science (Andree, 2003; Hannover and Kessel, 2004). Another main problem stems not only from the detailed nature of the subject of respiration at the micro and macro levels, but also from its links with micro- and macro-level abstract subjects such as energy production and the circulatory system. This is why students fail to draw a full picture of the subject in their minds (Knippels et al., 2005; Krawczyk, 2007; Lukin, 2013; Quinn et al., 2009; Smith, 1991; Sinan and Karadeniz, 2010; Wynne et al., 2001).

One of the most important factors in the learning process is students' failure to correlate-in their minds-the concepts in their cognitive structures about the subject. 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 (Pines and West, 1986; Tsai and Huang, 2002) does not only help teachers develop teaching strategies, but also help carry out researches on students' conceptual changes. Conceptual knowledge is of high importance for learning scientific concepts, systems and the micro and macro level relations among systems. On the other hand, wrong prior knowledge always negatively affects learning and can be altered only through a careful and high-quality teaching process (Finley and Stewart, 1982; Posner et al., 1982; Wandersee et al., 1994; West and Fensham, 1974). Biology teachers should make use of the results of cognitive structure researches while designing their teaching practices in order to contribute to students' formation of high-quality cognitive structures. 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 (Gilbert et al., 1998a, 1998b, 2000), 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.

While various methods are employed in order to determine conceptual learning, those techniques labelled as alternative measurement and evaluation techniques are frequently used. 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 (Bahar, 2003; Bahar et al., 2006; Ercan et al., 2010; Kurt, 2013; Ozcan, 2010; Yalvac, 2008) and alternative conceptions they develop. In this respect, in order to determine the cognitive structures and alternative conceptions related to the concept of respiration, two-step multiple-choice tests (Odom and Barrow, 1995; Tekkaya, 2003), drawings (Ainsworth et al., 2011; Cetin et al., 2013; Cinici, 2013; Nyachwayaa et al., 2011; Patrick and Tunnicliffe, 2010; She, 2004; Yayla and Eyceyurt, 2011; Zoldosova and Prokop, 2007), interviews (Kose, 2008), free word association test (Ad and Demirci, 2012; Dove et al., 1999; Ercan et al., 2010; Koseoglu and Bayir, 2011; Kurt, 2013; Polat, 2013; Yalvac, 2008), structured grid, diagnostic tree, concept maps, conceptual change

texts, analogy, prediction-observation-explanation and other techniques can be used (Bahar et al., 2008; White and Gunstone, 1992). In this research, the free word association test and drawing-writing technique were employed.

These measurement techniques listed above are employed both in determining the scientific cognitive structures about concepts that students are supposed to have and in the non-scientific cognitive structures that students are not supposed to have. During the process of learning, individuals may incorporate non-scientific concepts along with scientific ones into their 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 (Doran, 1972; Driver, 1989; Driver and Easley, 1978; Mike and Treagust, 1998; Skelly and Hall, 1993; Smith et al., 1993). 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, because alternative conceptions may direct students to incorrect conclusions while learning and negatively affect their accurate construction of new information in their minds (Albanese and Vicentini, 1997; Tsai, 1999).

Cognitive structure researches on respiration in living beings

When the researches conducted on the concept of respiration are reviewed, it is seen that the subject is highly complex and has many dimensions as it pertains to all living beings from humans to single-cell organisms. It has been determined that the dimensions of respiration and the concepts under these dimensions differ by species. In researches, generally, it is indicated that students experience difficulties in comprehending the subjects of "photosynthesis" and "respiration" (Bahar et al., 1999; Waheed and Lucas, 1992); they mistake one for the other (Ozay and Oztas, 2003) and they struggle to understand the correlation between respiration and vital biological functions (e.g. circulation) common among living beings (Songer and Mintzes, 1994). One of the striking research findings is that students at all educational levels have alternative conceptions on the subjects of "photosynthesis" and "respiration", although they are taught beginning from the primary school (Tekkaya et al., 2000; Tekkaya and Balci, 2003). A detailed analysis of the researches in the literature shows that there are many alternative conceptions. It is believed that it would be appropriate to present the review of these studies under the categories of respiration in human biology and

respiration in plant biology, because it is observed that most of the studies focus on one of the above two categories.

Respiration in human biology: Incidents in human biology are interrelated at the levels of anatomy, physiology and biochemistry. It is of high importance to be able to think of the system that provides the basis for the mechanisms maintaining these systems and that explains their relations, and to be able to attain a cognitive structure that requires thinking at that level. For example, since respiration occurs at the cellular level along with the level of organism (Liu and Hmelo-Silver, 2009), it is among the subjects that students struggle to comprehend.

While Hmelo-Silver et al. (2000) found that 6th grade students have problems related to their learnings of human respiration system, Ben-Zvi et al. (2013) determined that 2/3 of high school students stated that the obligatory role in both circulation and respiration systems is the transition of CO₂ and O₂, that they group concepts related to life (*concepts related to structures* such as "cell nucleus, nerves and bones", *concepts related to processes* such as *cellular processes* like "diffusion and cellular respiration" and *organismic processes* like "growing and breathing"), yet they fail to relate them at the microscopic level.

Garcia-Barros et al. (2011) determined that children at the ages of 4-7 are aware of the organs in their bodies related to the intake of air and food that they give examples from organs of animals they know; however, their knowledge on the respiratory system is limited. On the other hand, Gultepe et al. (2008) found that 6th grade students have alternative conceptions regarding the human respiratory system such as "air taken from outside goes to the stomach", "breathing can only be executed through the mouth", "no water outflow occurs during the respiration", "venous blood goes out and arterial blood goes in", "water enters alveoli", "oxygen goes in and water goes out". Abimbola (1986) found the following alternative conceptions among high school students related to human respiration: "During breathing, oxygen is taken in and carbondioxide is given off", "oxygen serves in the body as the energy source", "the body uses air/oxygen in order to oxidize food during digestion", "blood ossifies if the body does not have air", and "air is used as a liquid form for blood"; whereas Tekkaya et al. (2000) determined that student teachers have the misconception that "respiration takes place in lungs while cellular respiration, which is a different happening, takes place in tissues".

Kao (2007) states that high school students have important alternative conceptions regarding the chemical process dimension of respiration and that these conceptions differ between students living in urban and rural areas. The alternative conceptions that Kao has determined are the following: under the theme *continuity and*

necessity of respiration, “microorganisms do not have respiratory organs such as lungs or trachea; this is why they cannot realize respiration”, “oxygen is the raw material required for blood production”, under the theme respiration gas, “lungs filter O₂ and intake O₂ for CO₂ production that is released during respiration”; and under the theme aerobic respiration, “O₂ may support CO₂ release and breathing” and “O₂ is a sort of nutrition and it contributes to development”.

These studies show that participants from all levels experience difficulties in learning the subject of respiration and that they have alternative conceptions.

Respiration in plant biology: Respiration in plants focuses on the concept of photosynthesis, which 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 (Marmaroti and Galanopoulou, 2006). The relationship between cellular respiration and photosynthesis renders these concepts almost inseparable, and makes it one of the most difficult subjects in biology (Waheed and Lucas, 1992). The difficulty of these subjects lies in the complex transformations and biochemical processes that they involve, and their connections with many other subjects in curricula such as ecology, physiology, biochemistry, transformation of energy, autotrophic nutrition, and so forth (Marmaroti and Galanopoulou, 2006). While these processes are misunderstood by students most of the time, cellular respiration is perceived by many students as synonymous with breathing (Seymour and Longden, 1991; Lin and Hu, 2003). 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 (Marmaroti and Galanopoulou, 2006). 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 (Tekkaya et al., 2001). It has been reported that students experience difficulties in understanding the subjects of respiration and photosynthesis due to their lack of knowledge in chemistry (Marmaroti and Galanopoulou, 2006), in learning the chemical process aspect of respiration apart from being a physical process (Kao, 2007), 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.

Jin and Anderson (2012) investigated the conceptual structures of secondary and high school students regarding processes that have socioeconomic aspects such as photosynthesis, digestion, biosynthesis, cellular respiration, oxidation and energy. Students wrote that it provides 90% of human energy and all the energy in

living systems. They also wrote that the primary reason behind global climate change is the imbalance between these systems. Lin and Hu (2003) determined that secondary school students fail to comprehend and correlate energy concepts embedded in energy-production processes, that they have misconceptions related to photosynthesis, respiration and energy flow in the food chain, and that they fail to transfer their knowledge to energy conservation. Capa and Yilmaz (2000) and Brown and Schwartz (2009) 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”.

Kao (2007) states that high school students have important alternative conceptions regarding the chemical process dimension of respiration in plants and that these conceptions differ between students living in urban and rural areas. The alternative conceptions that Kao has determined are the following: under the theme continuity and necessity of respiration, “trees can live during photosynthesis, because it serves as respiration”, “trees can live without respiration if food is stored when leaves reserve light”; under the theme respiration gas, “plants store O₂ during the night and release it during the day”, “plants need oxygen at night since they cannot photosynthesize during that time”; and under the theme aerobic respiration, “plants need O₂ at night for nutrition production” and “O₂ can be used as a raw material in photosynthesis”.

Yuruk and Cakir (2000), in the study they carried out with high school students, determined the following alternative conceptions: “plants cannot respire”, “germinated seed needs energy while photosynthesizing”, and “fungi photosynthesize in illuminated environments”. Similarly, Kose and Usak (2006) 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”. Gunes et al. (2012), 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”. On the other hand, in studies conducted with the participation of science student teachers and high school students, the following alternative conceptions were found: “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” (Cakir et al., 2002; Harman, 2012; Kose et al., 2006; Kose and Usak, 2006; Songer and Mintzes, 1994; Tekkaya and Balci, 2003; Yenilmez and Tekkaya, 2006).

These findings indicate 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 and respiration. However, understanding the relationships between the macro- and micro-level biological systems is of importance for biological literacy (Brown and Schwartz, 2009). It is observed in studies that participants fail to adequately notice these 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 occurs simultaneously. For example, while the cellular respiration in plants occurs in more than ecological level and more than one complex systems, students fail to comprehend these continuous and simultaneous complex processes (Brown and Schwartz, 2009; Chi, 2001).

Biology teachers are among the most important ones who are responsible for teaching the concept of respiration to students. As it is seen in the research examples presented above from the relevant literature, participants have numerous alternative conceptions on both respiration and photosynthesis. However, no cognitive structure research was found, which was carried out with the participation of biology student teachers, on the concept of respiration. Using free word association test and drawing-writing technique, cognitive structures and alternative conceptions of biology student teachers can be revealed. 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 respiration 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 "respiration" by using the techniques of free word association and drawing-writing. Answers were sought to the following questions:

1. What cognitive structures do biology student teachers have, according to the free word association test, on the concept of respiration?
2. What cognitive structures do biology student teachers have, according to the drawing-writing technique, on the

concept of respiration?

3. What are the alternative conceptions of biology student teachers on the concept of respiration?

METHODOLOGY

Research design

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 (Gall et al., 2006; Hitchcock and Hughes, 1995; Miles and Huberman 1994; Verma and Mallick, 1999). A qualitative research approaches the subject with an interpretative and natural perspective 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 (Cohen and Manion, 1997; Ekiz, 2009; Patton, 1990; Punch, 2005). The qualitative research method was preferred in this study, since the cognitive structures of biology student teachers on the concept of respiration are presented in detail using the free word association test and the drawing-writing technique in this research.

Study group

This study benefited from purposive sampling. For this reason, the study comprised 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. 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. Some criteria were taken into consideration in order to minimize the problems in purposive sampling (Coyné, 1997; Given, 2008; Knight et al., 2013). 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. Moreover, the student biology teachers were informed by the researcher of the aim of the study and how to complete the measurement tool.

Data collection instruments

In this research, departing from the idea that more than one assessment instruments must be used in a supportive manner in cognitive structure studies (Cinici, 2013; Kose, 2008; Strommen, 1995), it was aimed to collect detailed information regarding biology student teachers' conceptual structures on the concept of "respiration", by using free word association test and drawing-writing technique in this research as data collection instruments. Information on these assessment instruments is given as follows.

Free word association test: This technique, which is based on the assumption of giving responses to independent stimulant words without limiting the ideas coming to the mind (Bahar et al., 1999; Sato and James, 1999), is one of the oldest methods and has been used in numerous researches (Ad and Demirci, 2012; Atasoy, 2004; Bahar and Ozatli, 2003; Cardellini and Bahar, 2000; Daskolia et al., 2006; Dove et al., 1999; Hovardas and Korfiatis, 2006; Isikli et al., 2011; Kurt et al., 2013a; Kurt, 2013b, 2013c; Polat, 2013; Wagner et al., 1996; Yalvac, 2008). It is among the most widely

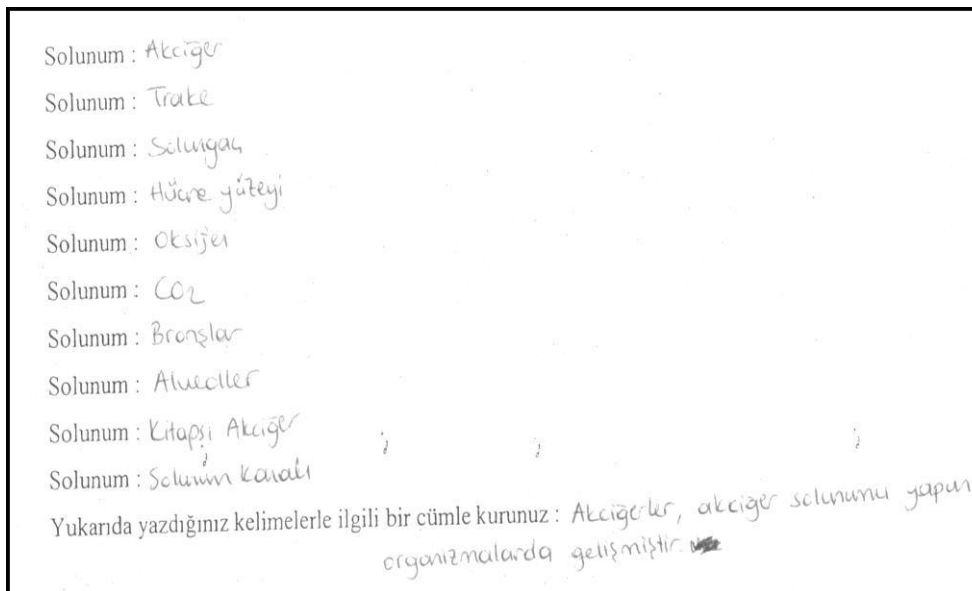


Figure 1. Response paper of P28. WORDS: Lung, Trachea, Gill, Cell surface, Oxygen, CO₂, Bronchia, Alveoli, Book Lung, Respiration Canal. SENTENCE: Lungs are developed in organisms with lung respiration). KEY CONCEPT: RESPIRATION. Respiration -1 ; Respiration -2. Respiration -10: SENTENCE.

used techniques with the purpose of determining individuals' cognitive structures about concepts, analyzing the links between concepts in these structures, and whether the links between concepts in individuals' long-term memories are adequate or not. In this research, the concept of "respiration" was selected as the stimulant for the word association test, and presented to the participants in the following format. Figure 1 shows an example response given by a participant (P28) in the word association test.

As is seen in Figure 1, the word association test consists of two stages. *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 of 40 s in this research (Gussarsky and Gorodetsky, 1990). 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 "respiration" in 40 s. The reason the key concept was written more 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 s 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 respiration, because this technique is highly effective in obtaining natural and high-quality data about hidden opinions, understandings, attitudes and misconceptions regarding these technical concepts (Backett-Milburn and Mckie, 1999; Christensen and James, 2000; Guichard, 1995; Pridmore and Bendelow, 1995; Rennie and Jarvis, 1995; White and Gunstone, 1992). This

technique is observed to be used in many studies in science (Ainsworth et al., 2011; Cetin et al., 2013; Garcia-Barros, 2011; Nyachwayaa et al., 2011; Pluhar et al., 2009; Prokop et al., 2009, 2009; Shepardson et al., 2007; Stafstrom, 2002; Yayla and Eyceyurt, 2011; Yorek et al., 2010). In this respect, the participants were asked to freely state their opinions answering the question "Express what you know about the concept of respiration with figures" in five minutes. Below is an example of students' response papers (Figure 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. The data, in general, were analyzed based on the content analysis method. The main purpose in this method is to obtain concepts and relations that can explain data. For this purpose, similar data were brought together under certain concepts and themes.

The data obtained from the free word association test were analyzed using the techniques of number of words, number of responses and semantic relation (Atasoy, 2004). 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 once were excluded from the analysis (Daskolia et al., 2006; Kostova and Radoynovska, 2008, 2010; Kurt, 2013; Torkar and Bajd, 2006; Wagner et al., 1996; White and Gunstone, 1992). 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 (Daskolia et al., 2006; Kostova and Radoynovska, 2008, 2010).

In the drawing-writing technique, on the other hand, drawing-

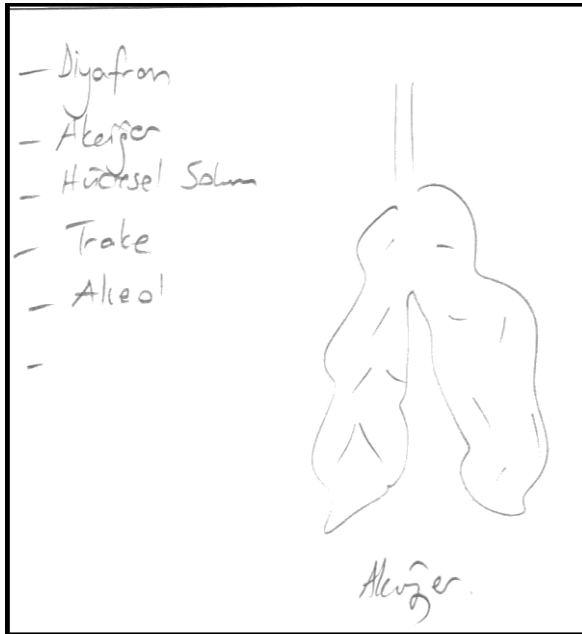


Figure 2. P27's response paper. WORDS: Diaphragm, Lung, Cellular respiration, trachea, Alveoli. The figure shows a lung.

writing data regarding the concept of respiration 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 (Reiss et al., 2002). First, the participants' drawings related to the concept of respiration were grouped under certain categories and sub-categories. Then, the cognitive structures demonstrated by the participants on the concept of respiration were analyzed with respect to their levels. While determining these levels, data are grouped from level 1 to level 5 (Bahar et al., 2008; Bartoszeck et al., 2008; Cinici, 2013; Reiss and Tunnicliffe, 2001). The level groups, which were formed with the purpose of evaluating participants' cognitive structures on the concept of respiration 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: [" " (P4)]. 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).

On the other hand, 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), (Hruschka et al., 2004; Marvasti, 2004; Roberts and Priest, 2006)

(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 in the "Findings" 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 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: $[\text{Agreement} / (\text{Agreement} + \text{Disagreement}) \times 100]$ (Miles and Huberman, 1994). The mean reliability between the encoders was found at 90%.

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

FINDINGS

In this section, findings are divided into two according to the method. Then, alternative conceptions of participants on the subject of respiration, which were determined through both methods, are presented.

Findings obtained from free word association test

As a result of the analysis of participants' cognitive structures regarding the concept of respiration, a total of eight categories were formed. These categories and words given under them were listed and their frequency values were provided. Words presented only for once, meaningless words and irrelevant words (68 words [18.78%]) were excluded from the analysis (Daskolia et al., 2006; Kostova and Radoynovska, 2008, 2010; Kurt, 2013; Torkar and Bajd, 2006; Wagner et al., 1996; White and Gunstone, 1992). These words are presented in the comments section at the end of each category. As a result, the remaining 41 different words were divided into eight categories. 294 words were received in total (Table 2).

In the analysis of the data obtained, most of student teachers' responses went under the category of "*respiratory organs and their structures*", which thus emerged as the dominant category ($f=168$). While in this category most of the participants emphasized on the words "*lung*", "*bronchi*", "*alveoli*", "*trachea*", "*mouth*", "*nose*", "*windpipe*", "*bronchiole*", "*gill*" and "*diaphragm*", some others wrote the words "*throat*", "*bronchiole*", "*skin*", "*tracheitis*", "*bronchus*" and "*stoma*". The words that were written in this category only for once by the participants and thus were excluded are the following: "*trachea pipes*" and "*malpighian tubule*". These results indicate that the participants correlated the concept of respiration mostly with "*respiratory organs and their structures*".

In the second category, participants presented associations related to "*molecules that take part in respiration and their transformations*" ($f=49$). While most participants wrote the words "*oxygen*" and "*carbondioxide*", a lesser number of participants focused on both particular and general concepts like "*air*", "*diffusion*" and "*carbon-oxide*". The only word that was written in this category

Table 1. Level groups formed to evaluate participants' cognitive structures on respiration through their drawings .

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

only for once by the participants and thus was excluded is "water". According to these findings, it can be concluded that the cognitive structures of the participants on "molecules that take part in respiration and their transformations" are limited.

The third category was "types of respiration" (f=22).

While most of the participants wrote "respiration with O₂", "respiration without O₂" and "coetaneous respiration", some others wrote "cellular respiration". The words "external respiration", "internal respiration" and "respiration in insects" were excluded from this category. It was observed that the cognitive structures of biology student teachers on types of respiration lack conceptual validity.

In the fourth category, participants presented associations related to "defining respiration" (f=20). They mostly focused on the words "inhaling", "breathe" and "inhaling-exhaling" in this category. It was observed that the cognitive structures of biology student teachers related to defining respiration lack conceptual validity.

In the fifth category, participants presented associations related to "respiratory-carrying system" (f=12). While most of them focused on the word "haemoglobin", a lesser number wrote "vessel", "blood" and "artery". The words that were written in this category only for once by the participants and thus were excluded are the following: "capillary vessel" and "blood pressure".

The sixth category emerged as "purpose of respiration" (f=11). The participants came up with the following words under this category: "energy" and "vital activity".

In the seventh category, participants presented associations related to "respiratory diseases and their causes" (f=9). While most of them focused on the words "asthma" "cigarette" and "bronchitis", the words that were written in this category only for once by the participants and thus were excluded are "lung failure", "respiratory insufficiency", "pharyngitis", and "pneumonia".

Finally, the eight category was "respiratory-digestive system" (f=5). The word that the participants came up with under this category is "pharynx".

Findings obtained from the drawing-writing technique

The drawing-writing technique produced seven categories. The following categories were produced in the drawing technique: *respiratory organs and their structures* (39), *molecules that take part in respiration and their transformations* (32), *respiration-species* (14), *defining respiration* (12), *types of respiration* (8) and *purpose of respiration* (6). On the other hand, the following categories emerged in the writing technique: *molecules that take part in respiration and their transformations* (30), *defining respiration* (19), *types of respiration* (18), *respiratory organs and their structures* (6), *respiratory carrying system* (6), *purpose of respiration* (5) and *respiration-species* (4) (Table 3).

It was observed that the Biology student teachers dominantly thought about concepts related to "molecules that take part in respiration and their transformations" in the drawing-writing technique, drew relevant figures and wrote explanations. In the category of "molecules that take part in respiration and their transformations", they drew figures mostly depicting "O₂" and "CO₂". In the free word association test, "respiratory organs and their structures" emerged as the dominant category, whereas "molecules that take part in respiration and their transformations" emerged as the dominant category in the drawing-writing technique. Table 4 shows examples from what the student teachers drew on the concept of respiration.

On the other hand, analyses pertaining to the drawings of the Biology student teachers on respiration are presented in Table 5 under five relevant levels. In determining these levels, the data were grouped from level 1 to level 5 (Bahar et al., 2008; Bartoszeck et al., 2008; Cinici, 2013; Reiss and Tunnicliffe, 2001). These levels demonstrate the participants' cognitive structures on respiration.

It was determined that the drawings on the concept of respiration are distributed by levels as follows: *non-*

Table 2. Distribution of biology student teachers' cognitive structures about "respiration" by categories.

| Categories | Concepts under categories and their frequencies | Total frequencies of categories |
|---|---|---------------------------------|
| Respiratory organs and their structures | "lung" (42) | 168 |
| | "bronchi" (27) | |
| | "alveoli" (18) | |
| | "trachea" (13) | |
| | "mouth" (10) | |
| | "nose" (10) | |
| | "windpipe" (10) | |
| | "bronchiole" (9) | |
| | "gill" (7) | |
| | "diaphragm" | |
| | (6) "throat" (4) | |
| | "bronchiole" (3) | |
| | "skin" (3) | |
| "tracheitis" (2) | | |
| "bronchus" (2) | | |
| "stoma" (2) | | |
| Molecules that take part in respiration and their transformations | "oxygen (O ₂)" (31) | 49 |
| | "carbondioxide (CO ₂)" (10) | |
| | "air" (3) | |
| | "diffusion" (3) | |
| | "carbonmonoxide (CO)" (2) | |
| Types of respiration | "respiration with O ₂ " (8) | 22 |
| | "respiration without O ₂ " (6) | |
| | "coetaneous respiration " | |
| | (5) "cellular respiration" (3) | |
| Defining respiration | "inhaling" (8) | 20 |
| | "breathe" (5) | |
| | "inhaling-exhaling" | |
| | (4) "exhaling" (3) | |
| Respiratory-carrying system | "haemoglobin" (5) | 12 |
| | "vessel" (3) | |
| | "blood" (2) | |
| | "artery" (2) | |
| Purpose of respiration | "energy" (4) | 11 |
| | "vital activity" (4) | |
| | "life" (3) | |
| Respiratory diseases and their causes | "asthma" (4) | 9 |
| | "cigarette" (3) | |
| | "bronchitis" (2) | |
| Respiratory-digestive system | "pharynx" (5) | 5 |
| Total | 41 words | 294 |

representative drawings (28), *drawings with alternative conceptions* (14) and *partial drawings* (2). On the other hand, there were no participants who did not present any

drawing or who presented a conceptual representative drawing. While *non-representative drawings* were found in four categories (*molecules that take part in respiration*

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

| Main category | Sub-category | Drawing (f) | Writing (f) |
|---|----------------------------|--|-------------|
| 1. Molecules that take part in respiration and their transformations | O ₂ | 9 | 9 |
| | CO ₂ | 9 | 7 |
| | air (clean/polluted) | 2 | 7 |
| | water | 2 | 3 |
| | glucose | 2 | 2 |
| | food | 2 | 2 |
| | private | 2 | - |
| | lactic acid | 2 | - |
| | ethyl alcohol | 2 | - |
| | <i>Total</i> | 32 | 30 |
| 2. Respiratory organs and their structures | lung | 22 | 4 |
| | nose | 2 | 2 |
| | windpipe | 3 | - |
| | bronchia | 3 | - |
| | bronchiole | 3 | - |
| | alveoli | 2 | - |
| | mouth | 2 | - |
| | heart | 2 | - |
| | <i>Total</i> | 39 | 6 |
| | 3. Defining respiration | O ₂ -CO ₂ transformation | 3 |
| inhaling-exhaling | | 5 | 2 |
| inhaling | | 2 | 4 |
| exhaling | | 2 | 2 |
| food+O ₂ =CO ₂ +water | | - | 2 |
| C ₆ H ₁₂ O ₆ +6O ₂ =6CO ₂ +6H ₂ O+38ATP | | - | 2 |
| <i>Total</i> | | 12 | 19 |
| 4. Types of respiration | aerobic respiration | 2 | 2 |
| | anaerobic respiration | 2 | 2 |
| | lactic acid fermentation | 2 | 2 |
| | ethyl alcohol fermentation | 2 | 2 |
| | cellular respiration | - | 2 |
| | tracheal respiration | - | 2 |
| | coetaneous respiration | - | 2 |
| | gill respiration | - | 2 |
| | lung respiration | - | 2 |
| | <i>Total</i> | 8 | 18 |
| 5. Respiration-species | human | 5 | - |
| | plant | 3 | 2 |
| | brewers yeast bacteria | 2 | - |
| | microorganisms | - | 2 |
| | O ₂ producers | 2 | - |
| | O ₂ consumers | 2 | - |
| | <i>Total</i> | 14 | 4 |
| 6. Purpose of respiration | ATP | 4 | - |
| | oxidizing food | - | 3 |
| | energy | 2 | - |
| | continuation of life | - | 2 |

Table 3. Contd.

| | | | |
|--------------------------------|------------------|-----|----|
| | <i>Total</i> | 6 | 5 |
| | cleaning blood | - | 2 |
| | capillary vessel | - | 2 |
| 7. Respiratory-carrying system | aorta | - | 2 |
| | <i>Total</i> | 0 | 6 |
| <i>Total</i> | | 111 | 88 |

and their transformation, respiration-species, respiratory organs and defining respiration), drawings with alternative conceptions were also found in four categories (molecules that take part in respiration and their transformation, respiration-species, respiratory organs and types of respiration) and partial drawings were found in two categories (molecules that take part in respiration and their transformation, respiratory organs and defining respiration).

This shows that $\frac{3}{4}$ of the participants expressed their cognitive structures about respiration through non-representative drawings. When 14 other participants who presented drawings with alternative conceptions are added to this percentage, it appears that a very high percentage of the participant Biology student teachers expressed their cognitive structures about respiration 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 category of "molecules that take part in respiration and their transformation". On the other hand, the fact that none of the participants presented conceptual representative drawings indicated that they failed to adequately comprehend the subject and that their cognitive structures are insufficient.

The alternative conceptions of student teachers on respiration determined through free word association test and drawing-writing technique

Below, analyses of alternative conceptions demonstrated by the participants about the concept of respiration are presented with respect to assessment instruments. Analyses show that the participants have alternative conceptions in all categories.

Participants' explanations regarding the category of "respiratory organs and their structures"

Example from the free word association test;

"The respiratory organs required for life are lungs, nose, skin etc." (P37). Respiratory organs differ from one living being to another. The participant here thinks of respiratory organs in terms of only one species.

A writing example from the drawing-writing technique;

"Respiration occurs at the cytoplasm organelle of the cell" (P22).

Participants' explanations regarding the category of "types of respiration"

Example from the free word association test;

"Respiration has two types: aerobic and anaerobic" (P5; P12; P13; P21; P41). The purpose of respiration is production of energy. It is incorrect to define respiration by these terms. Since such a division is presented in the acquisitions specified in curricula and since professors taught the subject in these terms at the university, participants maintained this incorrect knowledge "Living beings carry out aerobic and anaerobic respiration" (P43). Living beings can respire in different types, which are not limited to the above two. The participant's incorrect knowledge is unveiled here. "Plants respire at night" (P44). This is a very common alternative conception among the participants. Scientifically, plants respire both during day and night.

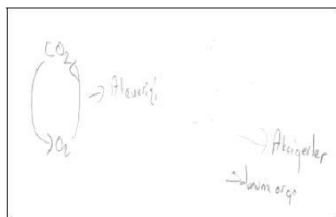
Writing examples from the drawing-writing technique;

"There are two types of respiration: aerobic and anaerobic. Living beings continue their lives through aerobic respiration" (P15).

Participants' explanations regarding the category of "defining respiration"

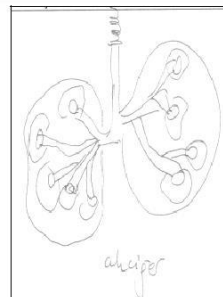
Example from the free word association test,

"Inhaling is a must for the continuation of life" (P17; P42). The participants here equate respiration with inhalation. Inhalation also requires exhalation. It was determined that the participants had imperfect and incorrect knowledge;

Table 4. Examples obtained through drawing-writing technique on the concept of respiration.**Example drawings by categories**

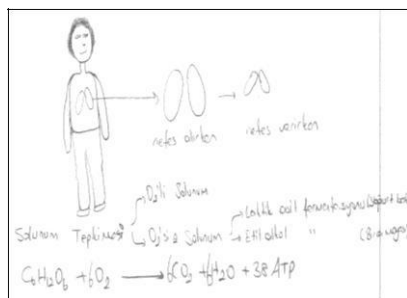
1. Category: Molecules that take part in respiration and their transformations, P11

DRAWING: O₂ and CO₂ exchange is depicted and lung is demonstrated as a respiratory organ.



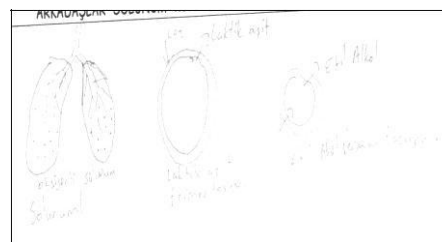
2. Category: Respiratory organs and their structures, P12

DRAWING: Lung is depicted.



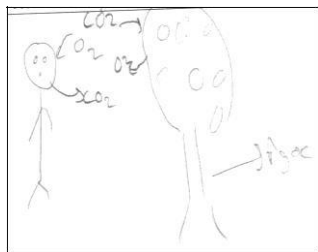
3. Category: Defining respiration, P14

DRAWING: It is depicted that lungs expand when a person inhales, and contract when she exhales. Formulae of aerobic and anaerobic respiration are given.



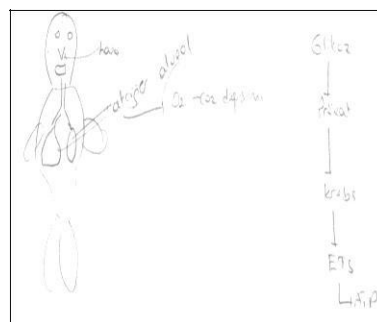
4. Category: Types of respiration, P6

DRAWINGS: It depicts that aerobic respiration occurs in lungs, and fermentation (lactic acid, ethyl alcohol, CO₂ need)



5. Category: Respiration-species, P1

DRAWING: Human and tree are depicted, demonstrating that while humans inhale O₂ and exhale CO₂, trees do the exactly opposite.



6. Category: Purpose of respiration, P10

DRAWING: Respiration and energy production is depicted, demonstrating that humans inhale air through their noses that it goes all the way to lungs-alveoli and that O₂ and CO₂ exchange occurs. An energy production scheme is also provided (Glucose-Privat-Krebs-ETS-ATP).

Writing examples from the drawing-writing technique; "CO₂+H₂O=O₂+C₂H₆O" (P26).

"Food +O₂----mitochondria=38ATP+H₂O+heat" (P20).

"While inhaling, the rib cage expands and the diaphragm is filled with air" (P3).

"Respiration is transforming oxygen into carbondioxide and producing energy" (P18).

"Food+O₂=CO₂+H₂O

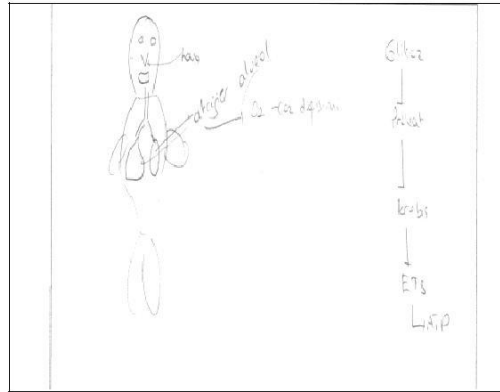
"It is the act of taking O₂ into the body and giving CO₂ off the body through lungs" (P30).

Table 5. Analyses of drawings on respiration.

| Levels | Example of drawings |
|--|--|
| <p>Level 1: No Drawing</p> | <p>No drawing</p> |
| <p>Level 2: Non-representational- carton drawings (n=28)</p> | <div data-bbox="680 489 1018 852"> </div> <p data-bbox="566 856 1073 968"> P23's DRAWING: Human breathing and lung. WRITING: Respiration is the act of inhaling free oxygen in the air and exhaling it in the form of carbondioxide. </p> |
| <p>Level 3: Drawings with alternative concepts (n=14)</p> | <div data-bbox="634 1010 1062 1398"> </div> <p data-bbox="566 1409 1109 1543"> P17's DRAWING: Humans' O₂ inhalation and CO₂ exhalation. The vice versa for green plants. WRITING: Respiration is the act of inhaling free oxygen in the air and exhaling it in the form of carbondioxide. </p> <div data-bbox="1154 1010 1604 1377"> </div> <p data-bbox="1154 1388 1604 1543"> K20's DRAWING: Aerobic respiration: A exhalation. Anaerobic respiration: Brewer's yeast bacter WRITING: Respiration is the act of oxidizi that we intake from outside, and thus prod heat. </p> |

Table 5. Contd.

Level 4:
Partially correct drawings
(n=2)



P10's DRAWING: Respiration and energy production is depicted, demonstrating that humans inhale through their noses, the air goes to lungs-alveoli, and O₂ and CO₂ are exchanged.

WRITING: An energy production scheme is also provided (Glucose-Private- Krebs-ETS-ATP) and O₂ and CO₂ are written.

Solumun denince delima hayvanlarda mevsimle gelen solumun gelişi. Omuz, gök ve omurgasız hayvanlarda deri, trake, solungaç, akciğer gibi solumun organları var. Ayrıca insanda solumun organı akciğerdir. Biri nefes alıp vererek solumun olayını gerçekleştirir. Soluk vermede diyafram ve kaburgalar arası kaslar gevşer, göğüs boşluğu genişler. Akciğer içi basıncı dışarı soluk almede diyafram ve kaburgalar arası kaslar kasılır. Göğüs boşluğu genişler. Akciğer içi basıncı azalır. Ayrıca solumun denince delima akciğerler gelir.

$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$

Akciğer etkilenmez
ve solumunda dışarı CO₂ çıkarılır

P32's DRAWING: On a depiction of lung, it is written and alveoli.

WRITING: What comes to my mind first is respiratory different respiratory organs such as skin, trachea, respiratory organ is lung. Respiration occurs as exhaling, the muscles between diaphragm and ribs of the chest cavity contracts. The lung's internal respiration brings lungs to my mind. Formulae are

Level 5: Comprehensive No drawing representation drawings

"The organism carries out the act of respiration through O₂ taken from outside" (P31).

Participants' explanations regarding the category of "molecules that take part in respiration and their transformation"

Writing examples from the drawing-writing technique;
"CO₂ is the main source of respiration" (P22)

Participants' explanations regarding the category of "respiration-species";

Writing examples from the drawing-writing technique;
"Not all living organisms respire" (P25).

Participants' explanations regarding the category of "purpose of respiration"

Writing examples from the drawing-writing

technique;
"They can continue through oxidizing"

Participants' category of "re"

Writing example technique;
"Lungs are eff"

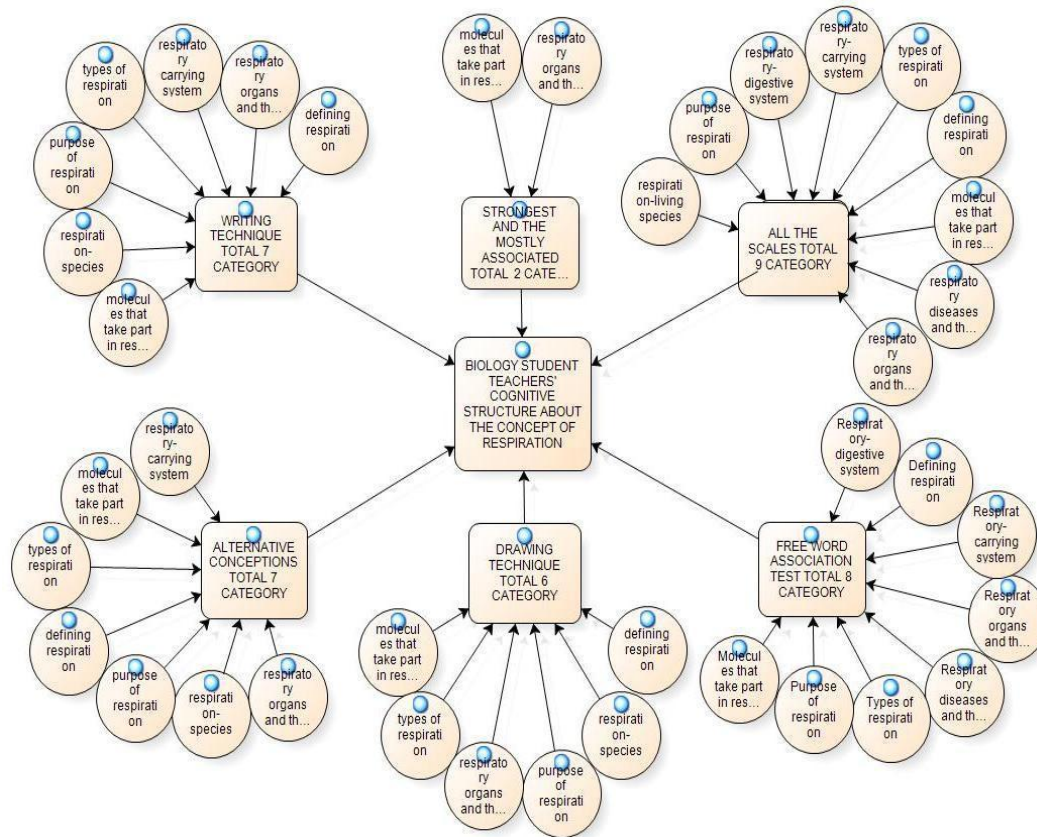


Figure 3. Cognitive structures biology student teachers' about respiration

beings, as they transfer clean air to cells" (P16).

It was determined, based on the above-presented responses given to the free word association test; the participant biology student teachers have alternative conceptions in the categories of "respiratory organs and their structures, types of respiration and defining respiration". On the other hand, in the drawing-writing technique, it was determined that the participants have numerous alternative conceptions in the categories of "molecules that take part in respiration and their transformation, respiratory organs their structures, types of respiration, respiration-species, purpose of respiration", and "respiratory-carrying system".

Assessing these data, the model about the cognitive structures of Biology student teachers on the subject of respiration was produced (Figure 3). According to the analysis results, while 8 categories were defined in the free word association test regarding the participants' cognitive structures about respiration, 7 categories were also defined in the drawing-writing technique. As is seen in the model, the cognitive structures of the participants about the concept of respiration emerged in relation to a total of 9 categories. On the other hand, through both assessment instruments, two categories were determined in which the conceptual structure is the most intense, and

it was also determined that alternative conceptions fall under a total of seven categories.

DISCUSSION, CONCLUSION AND SUGGESTIONS

There is no consensus in the relevant literature on cognitive structure and the conceptual change that is required for the formation of cognitive structure (Chi et al., 1994; Franco et al., 1999; Vosniadou, 1994; Vosniadou and Brewer, 1992, 1994; Vygotsky, 1995). However, a consensus exists on the necessity of a conceptual change for the formation of cognitive structure (Dagher, 1994; diSessa and Sherin, 1998; Duit et al., 1998; Duschl and Gitomer, 1991; Siegler, 1995; Stavridou and Solomonidou, 1998; Tyson et al., 1997), and on the necessity of reshaping the art of teaching in order to be able to ensure conceptual change (Gilbert et al., 1998a, b; Schnotz and Preuss, 1997). In the field of science, which involves numerous concepts and micro- and macro-level relationships, and in which the process differs by species, students experience significant difficulties in learning concepts in subjects. Therefore, students' conceptual changes go in wrong directions and they may carry the alternative conceptions, which emerge as a result of imperfect learning, with themselves

throughout all educational levels. This research was designed with the purpose of determining biology student teachers' cognitive structures and alternative conceptions on the concept of respiration.

It is suggested that the difficulties in learning concepts in the course of biology stem from the fact that they cover the "macro, micro and symbolic" dimensions of thought (Bahar et al., 1999). There are macro and micro dimensions in the subjects of energy flow and matter cycle. Besides, the symbolic dimension is also included as the concepts in the above dimensions are abstract. Photosynthesis and respiration serve as a bridge between organic and inorganic life (Lin and Hu, 2003). While studies focus on how to better learn these complex subjects, it is generally emphasized that the focus should be on determining the interrelated concepts embedded in knowledge, on the integration, function and process of biological knowledge (Barak et al., 1999; Hogan and Fisher, 1996; Leach et al., 1996; Waheed and Lucas, 1992).

The responses given in the free word association test were grouped under the following eight categories: ("respiratory organs their structures", "molecules that take part in respiration and their transformation", "types of respiration", "defining respiration", "respiration-species", "purpose of respiration", "respiratory diseases and their causes", "respiratory-digestive system" and "respiratory-carrying system"). On the other hand, seven categories were determined through the drawing-writing technique ("molecules that take part in respiration and their transformation", "respiratory organs their structures", "defining respiration", "types of respiration", "respiration-species", "purpose of respiration", and "respiratory-carrying system"). While a total of nine categories were produced through both techniques, the categories of "respiratory organs their structures" and "molecules that take part in respiration and their transformation" were found to be the common and dominant ones. The categories obtained through both assessment instruments support, detail and clarify each other. This shows 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.

The findings show that alternative conceptions exist in a total of seven categories of the participants' cognitive structures. This is a highly important result, because it shows that the scientific validity of the cognitive structures of the biology student teachers is limited, and that these cognitive structures are formed with imperfect and incorrect knowledge.

In the categories obtained, it was found that the participants established fewer connections with the concept of respiration in the categories of "defining respiration" and "purpose of respiration", and that more than 1/3 of them had imperfect and incorrect knowledge. Similarly, it was

determined that student teachers had imperfect and incorrect knowledge on the subject of the definition-purpose of respiration and photosynthesis (Harman, 2012), and university students on the subject of respiration in plants and definition-purpose of photosynthesis (Kose, 2008). In both of the assessment instruments, the following imperfect and incorrect opinions were found among the participants: "breathing is a must for the continuation of life" and "food+ O₂ in mitochondria= 38ATP+H₂O+1s1", "respiration is the transformation of oxygen into carbondioxide and oxidation of food", "food+O₂=CO₂+H₂O", "it is the incident of taking O₂ into the body and giving CO₂", "the living being carries out the act of respiration through the O₂ taken from outside". Similar findings were obtained by Abimbola (1986) among high school students ("oxygen is taken and carbondioxide is give through breathing", "air breaks the nutrition in lungs and energy is revealed"), and by Cakir et al., (2002) among high school students ("inhaling oxygen and exhaling carbondioxide is called respiration").

It was determined in the category of *respiratory organs and their structures*", both through the free word association test and through the drawing-writing technique, that the participants have imperfect and incorrect knowledge such as "the respiratory organs required for life are lungs, nose, skin etc." and "respiration occurs at the cytoplasm organelle of the cell". Similarly, Gultepe, Yildirim ve Sinan (2008) found imperfect and incorrect knowledge among sixth grade students that "only mouth is used for inhaling" and "air is taken in through the nose and discharged through the mouth".

Similarly, in the category of "types of respiration" which was common in both of the assessment instruments, the following imperfect and incorrect knowledge were determined: "Respiration is divided into two: aerobic and anaerobic", "living beings carry out aerobic and anaerobic respiration", "plants respire at night" and "there are two types of respiration: aerobic and anaerobic. Living beings continue their lives through aerobic respiration". These processes cause misunderstanding and confusion among students. Besides, most students see cellular respiration as synonymous to inhaling and exhaling (Seymour and Longden, 1991; Lin and Hu, 2003). Similarly, imperfect and incorrect knowledge were determined among science student teachers by Kose and Usak (2006) ("respiration in plants occurs only during night"), among high school students by Kao (2007) ("plants need O₂ at night for nutrition production"), and among high school students by Cakir et al. (2002) ("plants respire at night").

In this study, in the category of "molecules that take part in respiration and their transformation" obtained in the drawing-writing technique, participants had the imperfect and incorrect knowledge that "CO₂ is the main source of respiration". In contrast, Brown and Schwartz (2009) determined that some student teachers define "photosynthesis as a process for oxygen production", whereas some others gave answers such as "role of

carbondioxide as a component of photosynthesis”, *“oxygen and carbondioxide exchange is the cycle between humans and plants”* and *“cellular respiration is the mechanism for the release of carbondioxide”*. Marmaroti and Galanopoulou (2006) determined that students perceive plant respiration as the reverse of gas exchange in animals” respiration and photosynthesis as a type of respiration.

In the category of *“respiration-species”*, an important incorrect knowledge that *“not all living organisms respire”* was determined. It is a serious misconception, because all living organisms respire for energy. In the category of *“purpose of respiration”*, on the other hand, it was determined that they failed to relate the concept of energy as one of them said *“they can continue their lives by obtaining energy by oxidizing oxygen in their lungs”*, whereas Lin and Hu (2010) 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.

In the category of *“respiratory-carrying system”*, the imperfect and incorrect knowledge that *“lungs are effective in respiration in human beings, as they transfer clean air to cells”* was found. Similarly, imperfect and incorrect knowledge were observed under this category by Hmelo-Silver et al. (2000) among sixth grade students, by Ben-Zvi Assaraf et al. (2013) among high school students, by Abimbola (1986) among high school students and by Gultepe et al. (2008) among secondary school students.

These results indicate that the knowledge of biology student teachers on the concept of respiration is inadequate, and their knowledge is highly imperfect-incorrect and full of alternative conceptions. This finding obtained through the assessment instruments and the findings obtained through an evaluation of the participants’ drawings by levels support each other, as the drawings of almost all participants were *non-representative drawings or drawings with alternative conceptions*. This finding points to the necessity of perfecting the imperfect knowledge of student teachers, acquired either before or during their university education.

Given the fact that alternative conceptions and imperfect-incorrect knowledge can be altered only through a highly difficult process (Donovan and Bransford, 2005; Posner et al., 1982; Reinfried, 2006), and that they persist from elementary school to university (Canal, 1999); effective teaching approaches must be utilized. It has been widely accepted that the quality of instruction plays a key role in students’ learning outcomes (Kuijpers et al., 2010). Alzate and Puig (2007) suggested that activities can be performed using effective teaching-learning approaches oriented towards conceptual change, after determining the mental presentations of students about respiration. In this respect, teaching-learning practices, which allow students to learn by carrying out laboratory

applications, 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. It would be further useful to benefit from technology in this process by offering computer-aided and/or simulated teaching.

On the other hand, biology course books should be prepared with special attention, because imperfect and incorrect knowledge that could be included in books might lead students to developing alternative conceptions (Barrass, 1984). At this point, teachers, curriculum development specialists and units authorized with books in education systems should be very careful.

Since the concept of respiration is also related to people’s daily lives, presenting information 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 (Harlen, 2002; Andrée, 2003). It has been determined in researches that students insufficiently relate what they learn at difference science courses with their daily lives and comprehend the relationships between scientific and non-scientific concepts (Enginar et al., 2002; Kurt et al., 2009; Palmer, 1999; Tasdemir and Demirbas, 2010; Yigit et al., 2002). It has also been determined that biology student teachers have made positive and negative correlations in their responses related to respiration; however, they failed to do so adequately. In this respect, the words and drawings-writings presented by the student biology teachers reflect their academic conceptions on respiration, the extent to which they relate these concepts with the daily life, and their abilities to explain academic concepts using everyday language etc. However, what is important here is the ability to correctly construct the academic concept and to express it in an academically correct manner. One of the reasons lying behind student biology teachers’ difficulties in comprehending the subject of respiration stems from the characteristics of concepts that the subjects of biology course involve; because these concepts cover the “macro, micro and symbolic” dimensions of thought (Bahar et al., 1999). Concretization of the abstract dimension of the subject of respiration will help students comprehend the connections between the biological systems at the micro and macro levels. This is of high importance for biological literacy (Brown and Schwartz, 2009).

In conclusion, teaching and learning of concepts should be given importance beginning from the elementary education level. 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 (Yip, 1998). 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?"

On the other hand, future researches 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.

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