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Determining Biology Student Teachers' Cognitive Structure on the Concept of "Diffusion" Through the Free Word-Association Test and the Drawing-Writing Technique

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Abstract

The aim of the current study is to investigate student biology teachers' cognitive structures related to "diffusion" through the free word-association test and the drawing-writing technique. As the research design of the study, the qualitative research method was applied. The data were collected from 44 student biology teachers. The free word-association test and the drawing-writing technique were used as data collection instruments. The data were subject to content analysis and divided into categories through coding. In the analysis, the categories were formed and determined through the results of word-association test and drawing-writing test which were completed by the student biology teachers. With the help of these categories, the cognitive structures of student biology teachers were explained. The data collected through the study were divided into 8 categories *(defining diffusion, diffusion environments, diffusion-forms of substance transfer, places and structures where diffusion occurs, substances in diffusion and their characteristics, importance of diffusion in plants, examples of diffusion and factors influencing diffusion speed)*. The common and dominant category in both assessment instruments is "defining diffusion". On the other hand, it was determined that student biology teachers had alternative concepts related to diffusion. At the end of the article, comprehensive suggestions are presented on the subject.

Keywords: diffusion, free word association test, drawing-writing technique, cognitive structure, alternative concepts

1. Introduction

Learning occurs as a result of an interaction between what the student learns and the concepts already existing in her mind (Posner, Strike, Hewson & Gertzog, 1982). For this reason, determining and revealing the existing concepts in students' cognitive structures is of importance for learning (Hewson & Hewson, 1981). It is highly difficult to account for students' cognitive structures that are formed as a result of learning. However significant data can be obtained by unveiling their opinions through key concepts, and thus individuals' cognitive structures can be revealed (Gilbert, Boulter & Rutherford, 1998a; Gilbert, Boulter & Rutherford, 1998b; Gilbert & Boulter, 2000). Researches on concepts demonstrate individuals' cognitive structures pertaining 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 (Bahar, Johnstone & Hansell, 1999; Cimer, 2012; Jones & Rua, 2006; Lukin, 2013; Lazarowitz & Penso, 1992; Prokop, Prokop, Tunnicliffe & Diran, 2007; Seymour & Longdon, 1991; Simpson & Marek, 1988; Udovic, Morris, Dickman, Postlethwait & Wetherwax, 2002; Treagust, 1988). For this reason, Biology is among the courses in which students struggle to learn; due to their failure in comprehending the unity at the level of biological organization, in understanding the micro and macro level relations among concepts, and in making sense of abstract subjects. In this process, they struggle to learn those concepts that point to the micro and macro relations inherent in biological events.

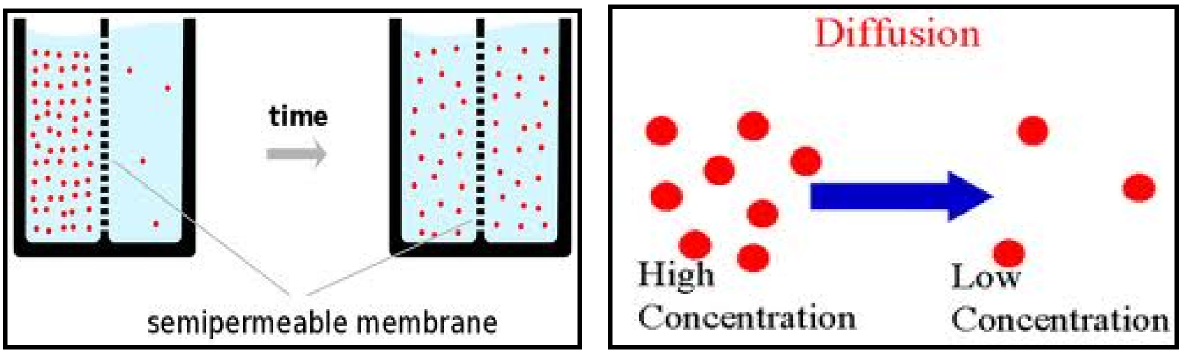


Figure 1.

One of the essential concepts in biology is "DIFFUSION". Diffusion can roughly be defined as molecules' movement from a high-concentration area to a low-concentration one due to their kinetic energies (Figure 1). Cook, Carter and Wiebe (2008) suggest that diffusion is one of the main concepts that help us understand cells and their relations with their environments, exchange of matters between living organisms during equilibrium and water transportation, essential operations of life, and certain biological events in living bodies. The concept of diffusion is closely linked with concepts in other fields of science. Researchers suggest that one must know the scientific concepts of solution, solubility and molecular movement in order to be able to accurately comprehend the concept of diffusion (Odom & Kelly 2001). On the other hand, learning the subject of diffusion is of importance for learning many other biological subjects. The concept of diffusion explains functional events in biology both at micro and macro levels, that is, both at cellular and organ levels. It is one of prioritized conditions in substance transfer in cells and cellular systems. An accurate comprehension of the concept of diffusion is essential for the learning of numerous biological incidents such as digestion, gas exchange and excretion. Furthermore, the concept should also be known in order to comprehend the relational structures of the concepts of substance, energy and biological organization. Researches show that diffusion is among concepts which students struggle to conceptually learn and about which students develop alternative conceptions (Artun & Costu, 2013; Christianson & Fisher 1999; Kose, 2007; Odom 1995; Odom & Barrow 1995a, b; Odom & Kelly 2001; Panizzon 1998; Panizzon, 2003; She, 2004; Tekkaya, Capa & Yilmaz 2000; Tekkaya, 2003; Tweedy & Hoese 2005; Tomažič & Vidic, 2012; Westbrook & Marek, 1991). Among the reasons of this difficulty in understanding are that it is an abstract subject and its operation occurs at the cellular level that is not visible to the naked eye.

In researches conducted; whereas She (2004) found that 9th grade students' cognitive structures are inadequate as 80% of them stated that paint molecules either diffuse in water or move randomly. However, Cakilcioglu, Bahsi and Turkoglu (2007) found that pre-service science teachers have alternative conceptions *related to the definition and speed of diffusion*, Odom and Barrow (1995b) determined that high school students have alternative conceptions related to "*Kinetic energy of matter*", "*Matter's granular structure and random movement", "Concentration and flexibility", "Impact of life force upon osmosis and diffusion", "Cell membranes", "Diffusion process*" and "*Osmosis process",* Akgun (2009) determined that pre-service science teachers have an alternative conception that "color of water changes since ink is dissolved in water". It was also determined that pre-service classroom teachers (Artun & Costu, 2011) and science teachers (Bilen, Kose & Usak, 2011) have similar alternative conceptions.

The alternative conceptions of high school students regarding "*Kinetic energy of matter*", "*Matter's granular structure and random movement", "Concentration and flexibility", "Impact of life force upon osmosis and diffusion", "Cell membranes", "Diffusion process*" and "*Osmosis process"* were determined (Odom, 1995; Odom & Barrow, 1995a; Odom & Barrow, 1995b; Odom & Kelly, 2001; Tomažič & Vidic, 2012). It was found that pre-service biology teachers have alternative misconceptions that "o*smosis is the incident in which water molecules move from a hypertonic environment to a hypotonic one, which are semi-permeably separated"*, and "*water in the central vacuole of a plant cell, which is left in a hypertonic environment, is absorbed by salt molecules located in the outside environment"* (Aykurt & Akaydin, 2009).

As it is seen in the examples selected from the relevant literature, students have many alternative conceptions regarding the subject of diffusion. While various methods are employed in order to determine conceptual learning, especially those techniques labeled 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, Nartgun, Durmus & Bicak, 2006; Ercan, Tasdere & Ercan, 2010; Kurt, 2013) and alternative conceptions they develop. In this respect, in order to determine the cognitive structures and alternative conceptions related to the concept of diffusion; two-step multiple-choice tests (Odom & Barrow, 1995; Tekkaya, 2003), drawings (Ainsworth, Prain & Tytler, 2011; Cetin, Ozarslan, Isik & Eser, 2013; Cinici, 2013; Nyachwayaa et. al., 2011; Patrick & Tunnicliffe 2010; She, 2004; Yayla & Eyceyurt, 2011; Zoldosova & Prokop 2007), interviews (Kose, 2008), free word association test, (Ad & Demirci, 2012; Dove, Everett & Preece, 1999; Ercan & Tasdere, 2010; Koseoglu & Bayir, 2011; Kurt, 2013), structured grid, diagnostic tree, concept maps, conceptual change texts, analogy, prediction-observation-explanation and other techniques can be used (Bahar Ozel, Prokop & Usak, 2008; White & Gunstone, 1998). In this research, the free word association test and drawing-writing technique were employed.

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

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

2) What are the alternative conceptions of biology student teachers on the concept of diffusion?

2. Method

In this research, the qualitative research method was employed (Hitchcock & Hughes, 1995; Miles & Huberman 1994; Patton, 1990; Silverman, 2000). According to Yildirim and Simsek (2000), qualitative research is a method which is aimed at being able to see a phenomenon from the viewpoints of relevant individuals and at revealing the processes pertaining to these viewpoints. The main purpose in qualitative research method is to present a descriptive and realistic picture of the subject rather than producing generalisable results through numbers.

2.1 Study Group

A total of 44 fourth and fifth year Biology teaching students from Necmettin Erbakan University participated in this study in the 2011-2012 Academic Year. 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. This study benefited from purposive sampling. Some criteria were taken into consideration in order to minimize the problems in purposive sampling (Given, 2008; Knight et. al., 2013; Patton, 1990). 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. The participants studied about diffusion before and during university studies. Furthermore, the participants were 4th and 5th year biology students who are about to start teaching. It is determined if the participants need to learn diffusion, how their cognitive structures are, and if they have alternative concepts on this issue. Before starting the research, the participants were given information about it. This information includes the subject and aim of the study, manual for filling in scales, rules and regulations, and the time length.

2.2 Data Collection Instruments

Using free word association test and drawing-writing technique in this research as data collection instruments, it was aimed to collect detailed information regarding biology student teachers' conceptual structures on the subject of "*Diffusion*". Information on these assessment instruments is given below:

2.2.1 The Free Word Association Test

It 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, and whether the links between concepts in individuals' long-term memories are adequate or not (Atasoy, 2004; Bahar & Kilicli, 2001; Bahar & Ozatli, 2003; Cardellini & Bahar, 2000). This technique is based on the assumption of giving responses to free stimulant words without limiting the ideas coming to the mind (Bahar, Johnstone & Sutcliffe 1999; Sato & James, 1999). In the current research, the concept of "*diffusion*" was selected as the stimulant, and presented to the participants in the following format. Figures 2 show an example response given by a participant (P38) in the word association test.

KEY CONCEPT: DIFFUSION

Diffusion-1: ………………………

Diffusion-2: ………………………

Diffusion-3: ………………………

Diffusion-4: ………………………

Diffusion-5: ………………………

SENTENCE:………….

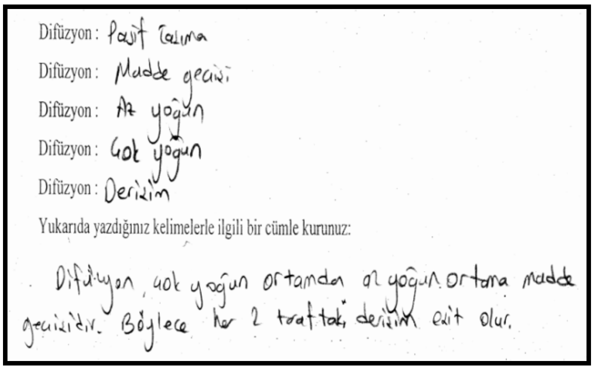


Figure 2. P38's response paper

Words in the answer sheet: passive transfer, matter exchange, high concentration, low concentration, concentration

Sentence in the answer sheet: Diffusion is transition of substances from high- to low-concentration environments. This way, concentration becomes equal in both sides.

As is seen in the Figure 2, 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 20 seconds in this research (Gussarsky & Gorodetsky, 1990). 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 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.

2.2.2 Drawing-Writing Method

It was aimed with the drawing-writing technique to thoroughly examine biology student teachers' opinions on the concept of diffusion (Rennie & Jarvis, 1995). Because this technique is highly effective in obtaining natural and high-quality data about hidden opinions, understandings and attitudes regarding these technical concepts (Backett-Milburn & Mckie, 1999; Cinici, 2013; Pridmore & Bendelow, 1995; Reiss & Tunnicliffe 2001; White & Gunstone, 1992). In this respect, the participants were asked to freely state their opinions answering the question "*Express what you know about the concept of diffusion with figures"* in five minutes. Below is an example of students' response papers (Figure 3).

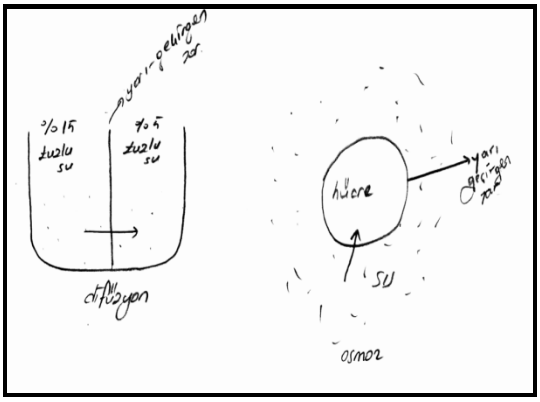


Figure 3. The participant drawing (P30) depicting how diffusion is

The participant mentions, "transition, semi-permeable membrane, salt water, high concentration–low concentration, cell, water, osmosis".

2.3 Analysis of Data

Before starting to analyze the data, the participants' response papers were assigned numbers from 1 to 44. The data were analyzed based on the content analysis method. To this end, similar data were brought together under certain concepts and themes, and they were organized in a way the reader can understand (Yildirim & Simsek, 2006).

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 for once were excluded from the analysis. Words were categorized by using semantic relation criteria, and frequencies of words in each category were calculated (Daskolia, Flogaitis & Papageorgiou, 2006; Kostova & Radoynovska, 2008; Kostova & Radoynovska, 2010).

In the drawing-writing technique, on the other hand, drawing-writing data regarding the concept of diffusion were analyzed using the content analysis method. By means of the drawing task, the students' ideas about the diffusion 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 diffusion were grouped under certain categories and sub-categories. Then, the cognitive structures demonstrated by the participants on the concept of diffusion 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, Machado & Amann-Gainotti, 2008; Cinici, 2013; Reiss & Tunnicliffe, 2001). The level groups, which were formed with the purpose of evaluating participants' cognitive structures on the concept of diffusion through their drawings, are presented in Table 1.

Table 1. Level groups formed to evaluate participants' cognitive structures on diffusion through 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)*

Moreover, both in the free word association test and in the drawing-writing technique, participants' explanations of diffusion within texts are presented in quotation marks in the following form: [" " (P11)]. 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. P3 or P33).

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), (Hitchcock & Hughes, 1995; Hruschka et al., 2004; Marvasti, 2004; Miles & Huberman 1994; Roberts & Priest, 2006; Silverman, 2001), (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 (Yildirim & Simsek, 2006).

In order to ensure the reliability of the research, on the other hand, codes and categories pertaining codes, which were produced by two Biology experts, 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 researchers gave these lists of codes and themes their final forms. Consistency between the codes used independently by two biology experts 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: [Agreement / (Agreement + Disagreement) x 100] (Miles & Huberman, 1994). Average reliability between coders was found to be 90% for the free word association test and 93% for the draw-write technique.

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

3. Findings

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

3.1 Findings Obtained from Free Word Association Test

As a result of the analysis of participants' cognitive structures regarding the concept of diffusion, a total of seven categories were formed. These categories and words given under them were listed. Words presented only for once (29 words [14.64%]) were excluded from the analysis (Daskolia et al., 2006; Kostova & Radoynovska, 2008; Kostova & Radoynovska, 2010; Kurt, 2013; Torkar & Bajd, 2006; Wagner, Valencia & Elejabarrieta, 1996; White & Gunstone, 1992). These words were removed from the Table 2, but they were presented in the comments section at the end of each category. As a result, the remaining words were divided into seven categories. Table 2 shows these words and categories. 169 words were received in total.

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

Categories	Concepts under categories and their frequencies	Total frequencies of categories
1.Defining diffusion	"water transition" "transition" "spread" "permeability" "matter exchange"	42
2.Diffusion environments	"high concentration and low concentration" "concentration" "salty water" "conditions of environment" "equilibrium" "pressure"	41

	"concentration difference"	
	"passive transfer"	
	"energy"	
3.Diffusion-forms of matter transfer	"osmosis"	29
	"active transfer"	
	"cell membrane"	
4. Places and structures where diffusion occurs	"cell"	24
	"pore"	
	"membrane"	
	"substance"	
5.Substances in diffusion and their characteristics	"small molecule"	18
	"big substance "	
	"transfer"	
6.Importance of diffusion in plants	"shrinkage"	9
7.Examples of diffusion	"cologne"	
	"perfume"	4
Total	*27 words*	*169*

In the analysis of the data obtained, most of biology student teachers' responses went under the category of "*defining diffusion",* which thus emerged as the dominant category (n=42). While in this category most of the participants emphasized on the words *"transition of water", "transition"* and *"spread",* some others wrote the words *"permeability"* and *"matter exchange"*. The words that were written in this category only for once by the participants and thus were excluded are the following: "*movement", "vitality", "wall", "cellular exchange"* and *"food intake"*.

In the second category, participants presented associations related to "*diffusion environments*" (n=41). While most participants wrote the words *"high concentration-low concentration", "concentration", "salty water", "conditions of environment"* and *"equilibrium",* a lesser number of participants wrote *"pressure"* and *"concentration difference"*. The words that were written in this category only for once by the participants and thus were excluded are the following: *"hypertonic" and "hypotonic"*.

The third category was "*diffusion-forms of matter transfer*" (n=29). While most of the participants wrote *"passive transfer", "energy"* and *"osmosis"*, some others wrote *"active transfer"*. The word *"ATP"* was excluded from this category.

In the fourth category, participants presented associations related to "*places and structures where diffusion occurs*" (n=24). They focused on the words *"cell membrane" and "cell"* in this category. The word *"intestine"* was written for once and thus excluded from analysis.

In the fifth category, participants presented associations related to "*substances in diffusion and their characteristics"* (n=18). While most of them focused on the words *"substance" and "small molecule"*, a lesser number wrote *"big substance"*. The words that were written in this category only for once by the participants and thus were excluded are the following*: "substance transfer speed", "weight of substance"* and *"granules"*.

The sixth category was "*importance of diffusion in plants*" (n=9). They wrote *"transfer"* and *"contraction"* as response words under this category. The words that were written in this category only for once by the participants and thus were excluded are the following: *"capillarity", "cohesion", "adhesion", "root", "turgor"* and *"external pressure"*.

The seventh category was "*examples of diffusion*" (n=4). It was seen that a very little number of participants wrote the words "*cologne*" and *"perfume"*. The words that were written in this category only for once by the participants and thus were excluded are the following: *"inky water"* and *"spray"*.

3.2 Findings Obtained through Drawing-Writing Technique

The drawing-writing technique produced six categories. The following five categories were produced in the drawing technique: *defining diffusion* (23), *substances in diffusion and their characteristics* (10), *examples of diffusion* (7), *places and structures where diffusion occurs* (6) and *diffusion environments* (4); and the following four categories were produced in the writing technique *defining diffusion* (14), *factors influencing diffusion speed* (4), *substances in diffusion and their characteristics* (2) and *places and structures where diffusion occurs* (2) (Table 3).

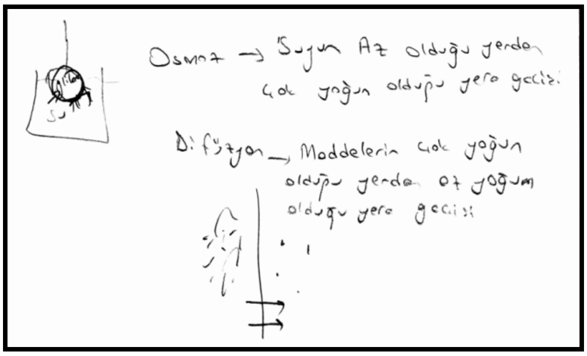
Table 3. Findings related to categories and sub-categories obtained using drawing-writing technique

Main Category	Sub-Category	Drawing (n)	Writing (n)
1.Defining Diffusion	Movement of substances from a high-concentration environment to a low-concentrated one	17	8
	Movement of water from high- to low-concentration	2	-
	Transition from high to low	-	2
	CO2 passage through cell membrane	2	-
	O2 passage through cell membrane	2	-
	Leaving cell in an environment with higher concentration than the cell itself	-	2
	Passive transfer of substances from a high- to low-concentration environment	-	2
	Total	***23***	***14***
2.Substances in Diffusion and Their Characteristics	Water	6	-
	Matter	2	-
	Glucose	2	-
	Small molecule	-	2
	Total	***10***	***2***
3. Places and Structures where Diffusion Occurs	Intestine	2	2
	Intestinal membrane	2	-
	Semi-permeable membrane	2	-
	Total	***6***	***2***
4. Examples of Diffusion	Spray on perfume	3	-
	Cologne	2	-
	Inky water	2	-
	Total	***7***	***0***
5. Diffusion Environments	Salty water	4	-
	Total	***4***	***0***
6. Factors influencing Diffusion Speed	Heat	-	2
	Molecule size	-	2
	Total	***0***	***4***
	Total	50	20

It was observed that the biology student teachers mostly thought about concepts related to *"defining diffusion"* in both techniques drew relevant figures and wrote explanations. In the category of "*defining diffusion*", they talked mostly about *"substances' movement from high- to low-concentration zones"*, and presented drawings. Table 4 shows examples from what the biology student teachers drew on the concept of diffusion.

Table 4. Examples obtained through drawing-writing technique on the concept of diffusion

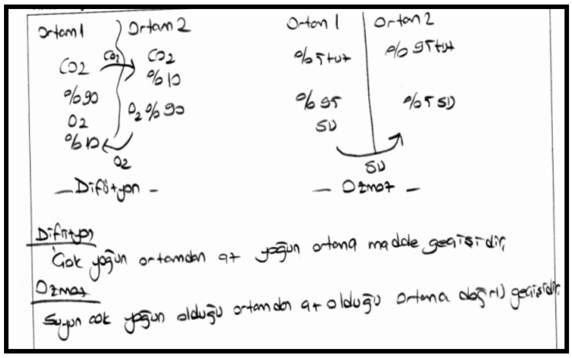
Example drawings by categories



1.*Category: Defining Diffusion*

The participant drawing (P2) depicting how defining diffusion (and osmosis) is.

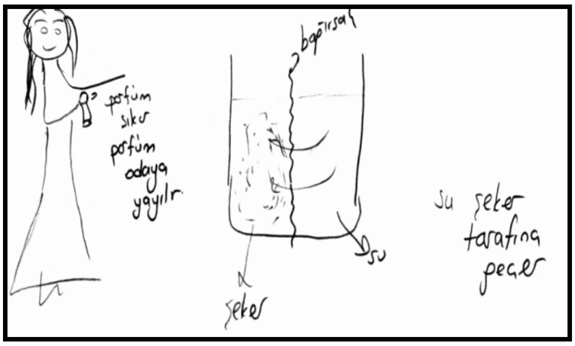
The participant mentions, ”Diffusion is transition of substances from high- to low-concentration environments”.



2.*Category: Substances in Diffusion and their Characteristics*

The participant drawing (P17) depicting how diffusion’s (and osmosis) substance is.

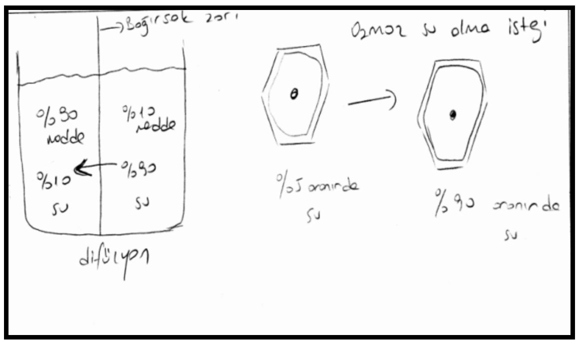
The participant mentions, ”Diffusion is transition of substances from high-to low-concentration environments” and “water, salt”.



4.*Category: Examples of Diffusion*

The participant drawing (P8) depicting what diffusion examples is.

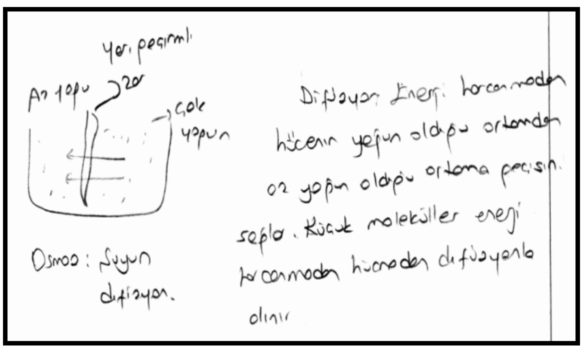
The participant mentions,” Perfume is sprayed and then it spreads over the room”, “Water passes to the side of sugar” and “Diffusion; transition of water, intestine membrane”.



3.*Category: Places where Diffusion Occurs*

The participant drawing (P18) depicting where diffusion occurs is.

The participant mentions, ”diffusion, intestine membrane transition of water”.



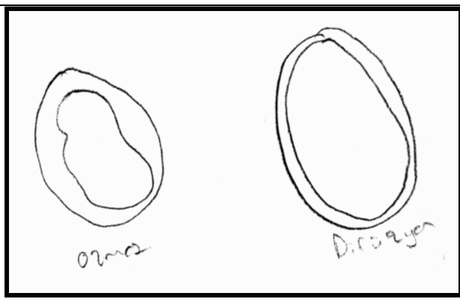
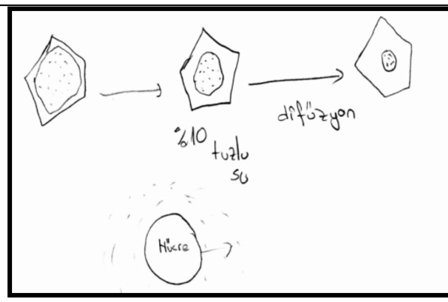
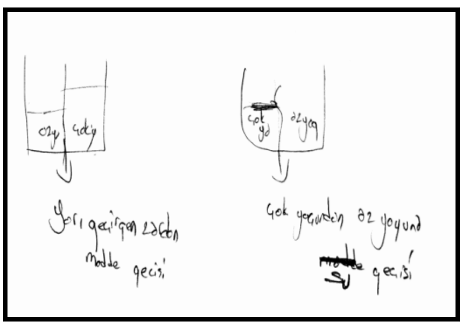
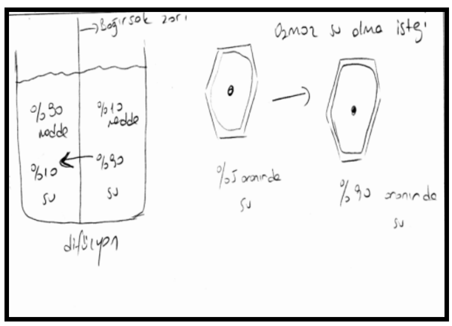
6. *Category: Factors influencing Diffusion Speed*

No drawing sample is given.

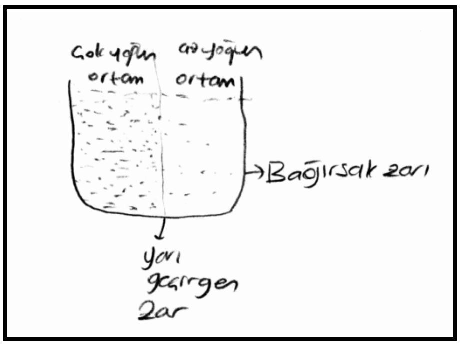
5.Category: Diffusion Environments The participant drawing (P19) depicting how a high- to a low-concentration zone are. The participant mentions "Diffusion enables the cell to move from a high- to a low-concentration zone without spending energy. Small molecules are taken through diffusion without spending energy".	

Moreover, analyses pertaining to the drawings of the biology student teachers are presented in Table 5 under the following five relevant levels: *no drawing* (4), *non-representative drawings* (6), *drawings with alternative conceptions* (12), *partial drawings* (8) and *conceptual representative drawings* (13). In determining these levels, the data were grouped from level 1 to level 5 (Bahar et. al., 2008; Bartoszeck, Machado & Amann-Gainotti 2008; Cinici, 2013; Reiss & Tunnicliffe, 2001).

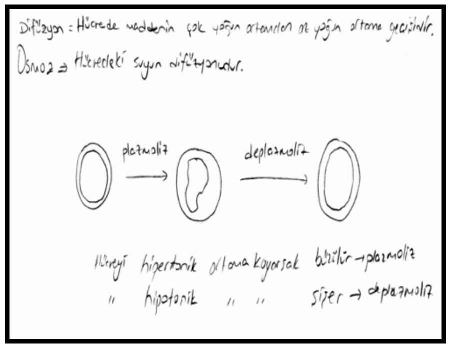
Table 5. Analyses of drawings on diffusion with respect to cognitive levels

Categories	Drawing examples	
Level 1: *No drawing (n=4)*		
Level 2: *Non-Representative drawings (n=6)*	 The participant drawing (P1) depicting how diffusion (and osmosis) occurs is.	 The participant drawing (P29) depicting how diffusion and cell is. The participant mentions, "salt water, cell, Transition from high to low concentration environment".
Level 3: *Drawings with alternative conception (n=12)*	 The participant drawing (P11) depicting how diffusion is. The participant mentions, "Substance transition through semi-permeable membrane. Transition from high to low concentration environment".	 The participant drawing (P18) depicting how diffusion occurs is. The participant mentions, "diffusion, intestine membrane transition of water".

Level 4: Partial drawings (n=10)

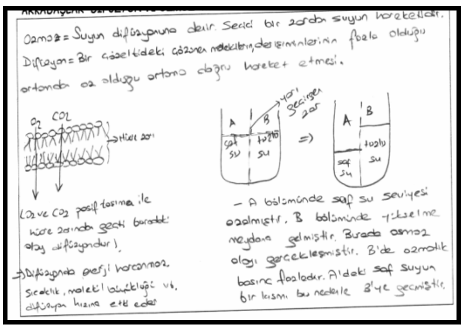


The participant drawing (P5) depicting how diffusion is.
The participant mentions, "Diffusion: In intestine membrane, substance transition through semi-permeable membrane. Transition from high to low concentration environment".

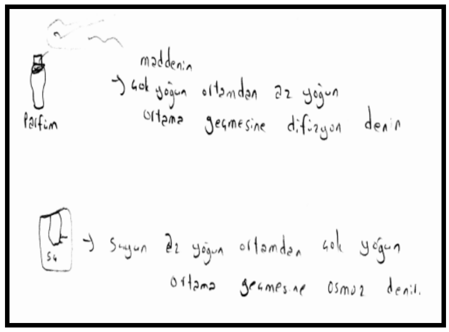


The participant drawing (P25) depicting how diffusion (and osmosis) is.
The participant mentions, "Cell contracts if we put it in a hypertonic environment "Plasmolysis" and "Cell swells if we put it in a hypotonic environment. "Deplasmolysis".

Level 5: Conceptual representative drawings (n=12)



The participant drawing (P31) depicting how diffusion in cell is.
The participant mentions, "Diffusion is the transition of a solvated substance in a solution from a high to a low concentration environment.
O2 and CO2 passed through the cell membrane through passive transfer.
Diffusion does not consume energy. Heat and molecular size are influential.
Mixture of salty water and pure water in an environment".



The participant drawing (P32) depicting how diffusion occur-spraying perfume erythrocyte is.
The participant mentions, "It is transition of substances from high to low concentration environments. Spraying perfume in a room".

As Table 5 shows, four biology student teachers at level 1 did not draw anything on the concept of diffusion. It was determined that six participants provided non-representative drawings at level 2. Twelve participants presented drawings with alternative conceptions at level 3. Ten participants at level 4 presented partial drawings, and twelve participants at level 5 presented conceptual representative drawings. This shows that the biology student teachers' cognitive structures about the concept of diffusion are insufficient, because the drawings presented by nearly half of the participants were non-representative drawings (*no drawing* + *non-representative drawings* + *drawings with alternative conceptions*), whose scientific references cannot be fully understood. This shows that the biology student teachers' cognitive structures about the concept of diffusion are insufficient. 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 determined that the participant biology student teachers presented both conceptual representative drawings and drawings with imperfect knowledge on the subject of diffusion.

Assessing the data obtained in the research, the model about the cognitive structures of biology student teachers on the subject of diffusion was produced (Figure 4). As is seen in the model, the cognitive structures of the participants about the concept of diffusion emerged in relation to a total of eight categories.

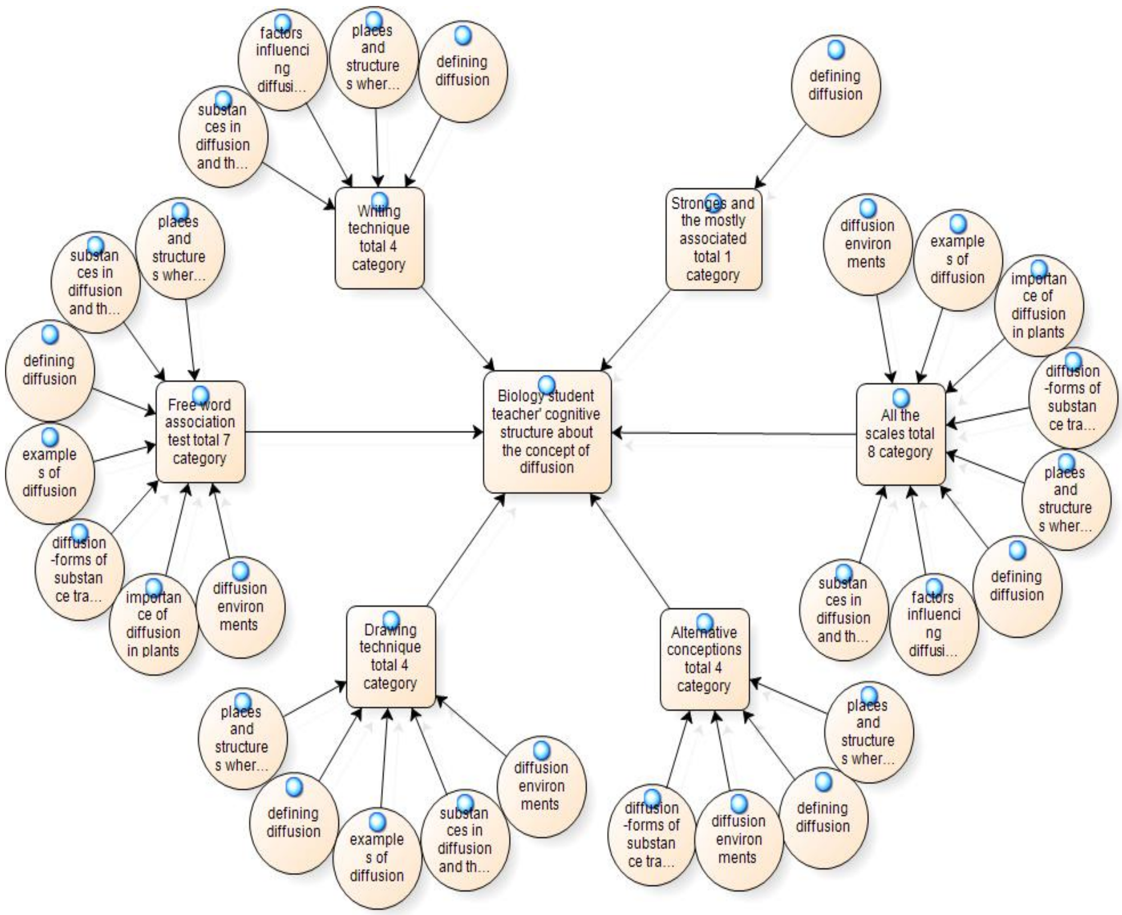


Figure 4. Cognitive structure of biology student teachers about diffusion

3.3 Biology Student Teachers' Alternative Conceptions of Diffusion

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*" (Doran, 1972; Driver & Easley, 1978; Driver, 1989; Mike & Treagust, 1998; Rowlands, Graham, Berry & McWilliams, 2007; Skelly & Hall, 1993; Smith, Blakeslee & Anderson 1993) are among these terms. In this study, the term "*alternative conception*" was used. Below, analyses of alternative conceptions presented by the participants about the concept of diffusion are presented with respect to assessment instruments.

Participants' explanations regarding the category of *"defining diffusion"*;

Example from the free word association test;

"Spread of water in a high-concentration environment" (P2; P29). Diffusion is the transition of substances from high- to low-concentration environments, not spread of water. It was determined that the participants had imperfect and incorrect knowledge.

"Diffusion is simply transition of substances" (P11; P38). It was determined that the participants had imperfect knowledge.

Examples from the drawing-writing technique;

"Transition of a liquid from a high- to a low-concentration environment is called diffusion" (P13).

"It is passive transportation of substances from a low to a high concentration environment" (P16).

"Diffusion is leaving a substance in an environment that is more concentrated than the substance itself" (P21).

Participants' explanations regarding the category of *"diffusion environments"*;

An example from the free word association test;

"Diffusion is substance transition from a low to a high concentration environment" (P15; P40). Diffusion is transition of substances from high to low concentration environments. It was determined that the participants had incorrect knowledge.

Participants' explanations regarding the category of *"diffusion-forms of substance transfer"*;

An example from the free *word association test;*

"Intercellular exchange occurs through diffusion" (P19; P43). Intercellular exchange occurs not only through diffusion but also through active transfer. It was determined that the participants had imperfect and incorrect knowledge.

Participants' explanations regarding the category of *"places and structures where diffusion occurs"*;

Examples from the drawing-writing technique;

"Water intake and disposal" (P23).

It was determined, based on the examples presented above, that the biology student teachers had imperfect and incorrect knowledge in the categories of *"defining diffusion, diffusion environments, diffusion-forms of substance transfer, and places and structures where diffusion occurs"*. Moreover, imperfect and incorrect knowledge was found also in the participants' response words such as *"water transition"* in the category of *"defining diffusion"*, *"energy"* and "*active transfer*" in the category of "*diffusion-forms of substance transfer*, *"cell membrane"* and *"cell"* in the category of "*places and structures where diffusion occurs, "big substance"* in the category of *"substances in diffusion and their characteristics"*. Therefore, it could be argued that some participants' cognitive structures lack conceptual validity. It was also observed that some participants fail to write proper sentences. Some others also fail to turn their sentences into meaningful ones. These are other indicators of students' low cognitive levels.

4. Conclusion and Discussion

At the end of the research, important findings were obtained both through the free word association test and the drawing-writing technique. In this framework, participants' cognitive structures about the concept of diffusion were brought under 7 categories in the free word association test. These categories are *"defining diffusion", "diffusion environments", "diffusion-forms of substance transfer", "places and structures where diffusion occurs", "substances in diffusion and their characteristics", "importance of diffusion in plants", and "examples of diffusion"*. On the other hand, a total of 6 categories emerged in the drawing-writing technique. These categories are the following: *"defining diffusion", "substances in diffusion and their characteristics", "places and structures where diffusion occurs", "examples of diffusion", "diffusion environments" and "factors influencing diffusion speed"*. 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 common and dominant category in both assessment instruments is *"defining diffusion"*. This finding suggests that the participants had tended to form their cognitive structures mostly in line with memorizing, because this way they could answer questions with *WHAT IS....?* or *PLEASE DEFINE?*. It was determined that the participants managed to associate less words and to provide more imperfect explanations in the categories of *"importance of diffusion in plants", "examples of diffusion"* and *"factors influencing diffusion speed"*, which require a more detailed cognitive structure.

On the other hand, it was determined that the participants failed to adequately express their cognitive structures through the drawing-writing technique. However, visuality is of high importance in learning concepts and expressing what has been learned (Gilbert, 2005; Gilbert, Reiner & Nakhleh, 2008; Kozma & Russell, 2005). This finding might have stemmed not only from students' incompetence in expressing their opinions with visuals but also from the lack of visually-rich learning of diffusion experienced by the participants. For this reason, both books and teachers' classroom presentations should include visuals as much as possible so that students may learn easier.

It was determined that nearly a quarter of the participants had imperfect and incorrect knowledge. Studies in the literature show that alternative conceptions are widespread among participants on the subject of diffusion (Artun & Costu, 2013; Christianson & Fisher 1999; Kose, 2007; Odom 1995; Odom & Barrow 1995a, b; Odom & Kelly 2001; Panizzon, 1998; Panizzon, 2003; She, 2004; Tekkaya et. al., 2000; Tekkaya, 2003; Tweedy & Hoese 2005; Tomažič & Vidic, 2012; Westbrook & Marek, 1991). In this study, participants' alternative conceptions were determined using two assessment instruments. The following are examples of imperfect and incorrect knowledge presented by the participants of this study: in the free word association test - *"water transition", "spread of water in a concentrated environment"* and *"diffusion simply is substance transition"* in the categories of *"defining diffusion"* and *"diffusion environments"*; in the drawing-writing technique *"Transition of a liquid from a high- to a low-concentration environment is called diffusion", It is passive transportation of substances from a low to a high concentration environment", and "Diffusion is leaving a substance in an environment that is more concentrated than the substance itself"*. In the relevant literature, She (2004) and Cakilcioglu et. al. (2007) similarly found alternative conceptions regarding the definition of diffusion.

On the other hand, the following alternative conceptions were determined in the category of "*diffusion-forms of substance transfer", "energy", "active transfer"* and *"intercellular exchange occurs through diffusion"*. Cakilcioglu et. al. (2007) found the alternative conception of high school students that *"diffusion cannot occur without ATP"*. While the incorrect answers of "*cell membrane" and "cell"* emerged in the category of "*places and structures where diffusion occurs*", the imperfect and incorrect knowledge that "*intake and disposal of water in a cell"* emerged in the drawing-writing technique. Cakilcioglu et. al. (2007) found the following imperfect and incorrect knowledge among high school students: *"Diffusion occurs only in a living cell", "Diffusion does not occur in an environment without membrane" and "Diffusion is bidirectional"*. Similarly, Odom and Kelly (2001) found that cognitive structures of high school students about cell membrane are not at desired levels.

One of the important findings of this research is that the participants produced a low number of associated words/sentences with the category of "*importance of diffusion in plants*". The following alternative conception was found among high school students: "*osmosis and diffusion stop after a plant cell dies, because the cell has no function anymore"* (Odom & Kelly, 2001). This shows that the participants failed to adequately learn the subject of diffusion in plants, because it was observed here that the participants compared a living organism with a cell as if it is a living person. When someone dies, many observable physiological functions such as breathing and beating of heart stop. However, when an organism dies, macro-level functions stop, but the process continues at the micro level for hours, and even for days.

In conclusion, it was determined that students' knowledge of diffusion is mostly concentrated on the dimension of defining diffusion. They cannot relationally comprehend the subject at micro and macro levels. They do not adequately think about the subject of diffusion in plants. The imperfect and incorrect knowledge of biology student teachers on the concept of diffusion indicates that certain points need to be addressed in the education process. In the literature, the utilization of special teaching techniques is suggested in order to prevent the emergence of alternative conceptions on the concept of diffusion (and osmosis) (Friedrichsen & Pallant, 2007; Meir, Perry, Stal, Maruca & Klopfer, 2005; Sagner & Brecheisen, 2001; She 2004; Williamson & Abraham, 1995).

In order to determine alternative conceptions in the form of pretest and posttest before and after the teaching of subjects both before and during the university period; an effective environment might be formed using conceptual tests and small group discussions, open-ended questions might be asked to students, and conceptual change texts, concept maps, concept caricatures, interviews, drawings, tests, analogies and computer-aided teaching methods might be employed (Beeth 1998; De Lange, 2009; Keogh & Naylor, 1999; Naylor, Keogh & Downing, 2007; Wang & Andre, 1991).

Biology curricula and course books should be revised. Teachers can teach subjects by visualizing them with figures. Students in these courses should be able to learn abstract concepts through concretizations and daily life examples. Given the fact that students struggle to eliminate alternative conceptions even when they receive education (Donovan & Bransford, 2005), it is apparent that concept learning is a process that needs to be taken seriously and thus students should be supported to develop appropriate cognitive strategies.

Moreover, Biology courses should be taught in laboratory environments and they should be supported by technologies such as simulation as much as possible.

On the other hand, through arranging researches of concept like this as interviews, achievement test, experimental researches etc., collection of different data can be provided.

To conclude; the main reason is that the students try to establish relationships between the concepts and their daily usages. However, these concepts are mostly not related with the scientific equivalents, and that hinders learners to learn new concepts properly. Determining pre-knowledge of learners is necessary to change the false believes about why and how an action takes place, and renew the curriculum of science courses (Dekkers & Thijs, 1998; Osborne & Wittrock, 1983). The concepts are not concrete item, action or creatures. The concepts are abstract idea units categorized under some groups.

On the other hand, learning is a broad subject related to many cognitive learning theories. This study can be planned as an experimental study. In this sense, the study can be prepared linked with many cognitive learning theories such as IPT, Gagne‟s condition of learning theory, constructivist theory, Torrance‟s creativity framework, Piaget'in Cognitive Development theory, and Bandura's Social cognitive theory. However, this study aims to determine individual cognitive situations of biology teachers in terms of diffusion. It can be suggested to have another study about the contribution of learning-teaching process.

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