JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898

TURKISH STUDENT BIOLOGY TEACHERS' CONCEPTUAL STRUCTURES AND SEMANTIC ATTITUDES TOWARDS MICROBES

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Abstract. *The aim of the current study is to investigate student biology teachers' cognitive structures related to "microbe". The mixed research design was applied in this study. The data were collected from 44 student biology teachers. The free word-association test, the drawing-writing technique and the semantic differential attitude scale were used as data collection instruments. The data were subject to content analysis and divided into categories through coding. With the help of these categories, the cognitive structures of student biology teacher were explained. These categories were determined as definition of microbes, microbial variety and activity, immunity. It was determined that student biology teachers' semantic attitudes towards microbe were at a neutral level in terms of mean scores of all adjectives considered; however based on each and every adjective, they mostly perceive microbes as infectious, contagious, and dirty. Moreover, the data collected through two data collection instruments indicated that student teachers had misconceptions about microbes considering the themes determined.*

Key words: *cognitive structure, microbe, misconception, semantic differential attitudes.*

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Introduction

Microbial processes play a fundamental role in many biological domains. The importance of microorganisms can hardly be overestimated if the understanding of human life and the biosphere in general are considered. Therefore the subject is of great importance for education. There are many concepts that exist particularly in different disciplines and that students find it difficult to form their conceptual structures. One of these concepts is the concept of "microbes". The concept of microbes is one of the important concepts that concern many disciples such as medicine, industrial, training, agricultural, technology, etc. Since this concept concerns many disciplines, it causes students to have difficulty in forming conceptual structures related to the concept of microbes. The reasons why students are successful or unsuccessful in learning concepts are the leading issue in educational research for an effective learning. In this sense concepts need to be structured appropriately in students' minds (Tartar & Koray, 2005). In this vein, teachers play an important role in students' learning concepts. Teachers of biology, which is related to many disciplines, adopt great responsibility for students' forming and learning the appropriate conceptual structures related to the concept of microbes. Therefore, it is believed that determining student biology teachers' conceptual structures about the concept of microbes and their attitudes toward, will serve as an effective means of leading them to form quality cognitive structures.

Particularly in recent years, the effect of constructivist learning on educational contexts has revived conceptual understanding and different methods and strategies to be used in determining conceptual change. In this context, the researchers canalized in techniques that measure not only students' existing knowledge but also the relationships between their various existing

knowledge and concepts, cognitive structures (Greca & Moreira, 2000), whether they form meaningful learning through linking new knowledge with existing knowledge (Novak, 2002) and to what extent they understand the similarities between the knowledge that they construct in their minds and how the events occur in the natural world. In addition, some other techniques have assumed importance, which determine students' cognitive structure and the relationships between the concepts in this structure, as well as find out whether these relationships are enough (Bahar et al., 2006). To this end, some strategies have been developed to induce and measure conceptual understanding and change. Bahar (2003) provides these strategies as follows: word association, structured grid, diagnostic tree, concept maps, texts of conceptual change, analogy, and predict-observe-explain. On the other hand, alternative techniques such as surveys, interviews, concept maps, fortune lines, and word association tests are used to determine students' opinions, understanding, or attitudes towards a specific issue (Bahar et al., 2008; White & Gunstone, 1992).

In the current study, student biology teachers' conceptual structures related to microbe, were investigated through versatile perspectives using the free word-association test, the drawing-writing technique in addition to the semantic differential attitude scale. Accordingly, the extend of misconceptions causing negative impact in concept learning and misconceptions were determined and discussed in the last section of the study since the concept of microbes is one of the particular issues causing students to have difficulty in understanding and that includes many misconceptions although it is one of the most important concepts in biology.

The Studies Conducted on Conceptual Structures of Microbe Concept

Considering the related literature, there are many studies conducted to investigate students' conceptual structures about the concept of microbes. It was determined that these studies conducted at each level of education focused on issues such as the structure of microbes, characteristics, types, effects on human health, methods of prevention, views on microbes, and conceptual structures about microbes.

The studies conducted on pre-school and primary school students determined the concepts of microbes observed in preschool children, disease and the mechanism of how microbes infect the body (Ergazaki et al., 2010; Kalish, 1996a, b; Kalish, 1997), children's concepts of microorganisms and microbial activities (Byrne & Sharp, 2006; Byrne et al., 2009; Byrne & Grace, 2010), primary school students' risk perceptions about microorganisms, their basic knowledge and views (Karadon & Sahin, 2010), primary school students' conceptual structures about fungi and misconceptions (Bulunuz et al., 2008), primary school students' concepts of food and health (Turner, 1997).

The studies conducted on middle and high school students focused on middle school students' conceptual structures about microbes (Uzunkaya & Ozgur, 2011), middle school students' conceptual structures about immune system (Bilaloglu, 2006), middle school students' conceptual structures about microorganisms (Bandiera, 2007), middle school students' conceptual structures about diseases (Mahajan & Chunawala, 1999), and high school students' conceptual structures about microbes (Rene & Guilbert 1994).

It was also determined that there were other studies conducted to investigate students' conceptual structures about microbes, views, and misconceptions at various levels of education and in different countries. In this vein, detailed studies were conducted on issues such as developing an educational tool on primary and middle school students' hygiene and use of antibiotics (Lecky et al., 2011), primary, secondary, and high school students' conceptual structures about microorganisms and microbial activities (Byrne, 2011), and microbiophobia (Williams & Gillen, 1991). Kinchin (2005) determined university students' conceptual structures about bacteria, viruses, and fungi. In general, it was determined that while the studies were conducted on the participants at each level of education, the studies conducted on university students were very few.

On the other hand, a great majority of the studies conducted on microbes discussed only misconceptions. One of the fundamental reasons for this is that misconceptions contribute to students' academic failure. Misconceptions are not based on scientific facts and lead to difficulties in acquiring

scientific knowledge. As a result, misconceptions make it more difficult to learn the concept of microbes concerning a variety of disciplines. Determining students' misinformation and lack of learning in their previous knowledge plays a crucial role in preventing future misconceptions (Seloni, 2005), and stressing the points that need special care while acquiring new knowledge.

It was determined in the studies conducted that the participants of each level of education had very different misconceptions about microbes. In this vein, it was determined that while the participants adopted alternative views on the size of microorganisms and morphology, they associated microorganisms with terrifying animals, and viewed them as the small forms of such animals as insects, snakes, worms, ants, and spiders. Moreover, microbes were believed to have hands, legs, or face, head, hair like humans and animals, and look like the devil (Byrne et al., 2009; Jones & Rua, 2006; Maxted, 1984; Simonneaux, 2000; Uzunkaya & Ozgur, 2011; Vasquez, 1985). The participants viewed microorganisms as ugly-bad-smelly and expressed their views through linking microbes with the things in their environment such as garbage cans and rotten things (Jones & Rua, 2006; Simonneaux, 2000; Uzunkaya & Ozgur, 2011).While the activities of microorganisms were mostly viewed as the cause of people's diseases, dangerous, harmful and even fatal (Byrne et al., 2009; Uzunkaya & Ozgur 2011; Vasquez, 1985), it was also determined that there were many misconceptions about many issues such as the mechanisms of infection, vaccination, drugs use, not being able to discriminate bacteria and viruses, and lack of understanding the process of recovery (Au & Romo, 1996; Byrne & Grace, 2010; Inagaki & Hatano, 1993; Jones & Rua, 2008; Kalish, 1996a; Prout, 1985). It was also revealed that children and students had misconceptions about several other issues such as the roles of microorganisms in balance of nature (Leach et al., 1996) and technological practices related to microbes (Bazile, 1994; Byrne & Sharp, 2006; Simonneaux, 2000).

In the detailed studies conducted on this issue, Uzunkaya (2007) determined that 6th grade students had misconceptions about the issues of microorganisms, such as in *which environment they are available, their effects, the existence of microorganisms in our bodies, viruses' vitality, how microorganisms infect our bodies, natural and passive immunity, prevention by vaccination against disease and use of antibiotics.* In another study conducted by Byrne (2011) to investigate primary, middle and high school students' conceptual structures about microorganisms through drawing and brainstorming activities, it was determined that students viewed microorganisms as formless, cells of bacteria, eukaryotic cells, similar to animals, similar to humans, abstract shapes (dot, spot, line, caricature) *in terms of morphology*; as microorganisms, microbes, bacteria, viruses, and fungi/mold *in terms of premises*; as small drawings, small, and microscopic/needs to be enlarged to be seen in its real dimensions *in terms of size and magnitude;* living and cell structure, life stages, living and non-living in *terms of vitality;* everywhere, in/on humans, in dirty/unhygienic environment, animals *in terms of location;* developing immunity, some being pathogen, and all being pathogen *in terms of microbial activity*. Karadon and Sahin (2010) determined that while 53.0% of the primary school students viewed microorganisms as dirty, pollutant, and harmful, 37.4% could not provide any examples of microorganisms. Moreover, while a great majority of the students believed that microorganisms were harmful rather than useful, they also stated that they felt bad when they heard of the concepts of microbes or microorganisms. Secondary school students had the misconception that there were not any microorganisms in our bodies and that microorganisms could be divided into two categories, namely, useful and harmful (Bandiera, 2007); primary school students shared the misconception that mold and yeast were not living organisms (Bulunuz et al., 2008). In another study conducted by Nguyen and Rosengren (2004) on pre-school children's parents regarding the concept of disease, it was determined that a majority of parents had misconceptions about causes and symptoms of diseases. Several studies indicate that use of microscopes by middle and high school students proven its effect in students' better learning of microorganism's morphology through overcoming the misconceptions about microscopic living things that cannot be seen and encouraging meaningful learning (Jones et al., 2003a, b) and that models can be used in teaching key concepts about microbes and improving learning (Weersing et al., 2010). Accordingly, while direct observation of abstract living things that cannot be seen or providing explanations through models improves learning, it can also be effective in decreasing the number of misconceptions and alternative concepts.

As indicated in the related literature, almost all of the studies conducted on this issue included the participants of educational institutions excluding universities. In this vein, to the best knowledge of

the author, there is not any study conducted to determine student teachers' and teachers' conceptual structures about microbes. The results of the current study are important, considering that the participants included particularly student biology teachers.

In the following section, the tests of free word association, and the drawing-writing technique, and the scale of semantic differential attitudes were discussed, providing examples from the related literature, and later other examples were provided of the studies conducted particularly on microbes through using these techniques.

Free Word-Association Test

Free word-association test is one of the most general and the oldest techniques that investigate students' cognitive structure. Used in many studies (Bahar et al., 1999; Bahar & Ozatli, 2003; Kurt et al., 2013; Nakiboglu, 2008; Ozatlı & Bahar, 2010) this technique is quite efficient in revealing individuals' cognitive structures and conceptual changes (Hovardas & Korfiatis, 2006). Free word-association test is a data collection technique used to determine individual's conceptual structures related to a concept. When the related literature is revised, it is observed that there are also important studies in biology conducted using free word-association tests. In this context, through word association tests, students', student teacher, and teachers' cognitive structures related to different concepts were revealed. In the studies conducted in biology; while Kostova and Radoynovska, in (2008) investigated the cognitive structures related to "cell" and "biodiversity" of teachers and high school students with varying levels, to find out their cognitive structures and levels of knowledge, Kostova and Radoynovska, in (2010), studied high school students through the concept "humankind", Dikmenli, in (2010a), investigated student biology teachers through "biodiversity", Dikmenli, in (2010b), through the concepts "science" and "scientist", Uzun et al. (2010) investigated "biodiversity" concept structures of student teachers of different disciplines, Dikmenli, in (2010c), investigated university biology students through "global warming" and Trumper, in (1997b), studied primary school students through the concept of "energy" to find out these participants' cognitive structures and levels of knowledge. Through applying free-word association tests, the studies, while investigating students', student teachers', and teachers' conceptual structures, revealed that they also had alternative concepts.

Concerning the literature review conducted, there is not any study conducted to investigate the participants' conceptual structures about the concept of microbes using the free word association test. Therefore, it is believed that the results of the current study will fill this gap in the related literature.

Drawing-Writing Technique

Drawing-writing technique is an efficient technique used to reveal students' learning thoroughly. This technique is very crucial in that it helps collect natural and high quality data on students' hidden thoughts, understanding, points of view, attitudes, etc. (Garland, 2005; Levin & Bus, 2003; Pridmore & Bendelow, 1995). Furthermore, since drawing technique is more convenient in terms of time management than the other methods such as writing and behavior scales used to reveal opinions, understanding, and attitudes changes, and it enables collecting data from various perspectives, drawing technique is very effective. It is also efficient as it can be easily internalized (Atasoy et al., 2007).

There are many studies conducted at almost each and every level of education in biology with participation of students, student teachers, and teachers using the *drawing technique*. In this vein, in these studies, several issues were investigated such as primary school teachers' views on energy (Kruger, 1990), primary school students' views on environment and conceptual models (Barraza, 1999; Alerby, 2000), primary school students' views on headache (Stafstrom et al., 2002), primary school students' conceptual understanding of energy save (Edens & Potter, 2003), primary school students' perceptions of the concepts of health and illness (Piko & Bak, 2006), high school students' levels of conceptual understanding of the subject of cell (Yorek, 2007), high school students' mental models of environment (Shepardson et al., 2007), university students' misconceptions related to respiration in plants and photosynthesis (Kose, 2008), the images of teacher, scientist, and veterinary in primary school students'

minds (Losh et al., 2008), primary school students' statements regarding endocrine and excretory systems (Prokop et al., 2009), university freshmen chemistry students' levels of conceptual understanding of chemical reactions (Nyachwayaa et al., 2011), science education student teachers' mental models of basic chemistry issues (Yayla &Eyceyurt, 2011), high school students' images of biology, and biology scientists (Korkmaz, 2011), university students' levels as for environment and environmental consciousness (De Carvalho Maffia et al., 2011), and high school students' views on health (Cetin et al., 2013). In these respective studies, the misconceptions regarding the concepts studied were determined, and the participants' mental models were revealed.

As a result of the literature review, it can be stated that the *drawing technique* was the most commonly used technique used to determine the participants' conceptual structures about the concept of microbes. Concerning the studies conducted in this context, Jones and Rua (2006) investigated how students', teachers', and doctors' knowledge about the concept of microorganisms differed from each other. While the drawings indicated that there were such categories as viruses, bacteria, animal cells and others (disease, caricature, insect, protozoan, and unclassified), the data obtained through the semi-structured interviews revealed that there were categories as *size, reproduction,* and *structure*. Moreover, the same researchers determined 5th, 8th, and 11th grade students', teachers', and doctors' conceptual structures about microbial diseases and the flu (Jones & Rua 2008). Ergazaki et al. (2010) investigated pre-school children's' views on the concept of microbes. In this context, the researchers asked questions such as; *what is a microbe? Where do microbes exist? Are they good or bad, living or non-living things? and What do microbes look like in the drawings?* As a result of the study, it was determined that the participants did not relate the concept of microbes to health and hygiene, their location in our bodies and other environment, and to the idea that there were good microbes, and they drew pictures of microbes similar to humans and animals.

There are also many studies conducted using *drawing-writing technique*. In this regard, these studies were conducted on issues such as illness and health for high school students (Piko & Bak, 2006), water cycle and environment for primary school students (Dove et al., 1999), health education for high school students (Backett-Milburn & McKie, 1999), air pollution for primary school students (Pluhar et al., 2009) and heart for science education student teachers (Bahar et al., 2008). Moreover, using this technique, Lenton and McNeil (1993) investigated primary school teachers' levels of understanding the biological concepts of gas exchange in photosynthesis and respiration processes.

Attitudes towards the Concept of Microbe

In literature, attitude is defined as "the core of human individuality", "the permanent organization of an individual's motivational, emotional, perceptional and mental processes towards an event or a psychological object", "positive or negative sensual intensity", and "learned tendency" (Bohner & Wanke, 2002; Fishbein & Ajzen, 1975; Muller, 1986; Tezbasaran, 1996). Attitudes, through cognitive, emotional and behavioral dimensions, play an important role in individuals' learning (Anderson 1988; Bagozzi and Burnkrant 1985; Bloom 1979). Accordingly, it is important for individuals to acquire the real facts while adopting attitudes as these facts will play a great role in this process (Verplanken & Hofstee, 1998). It is a long and important process to lead individuals to adopt and change attitudes since cognitive, emotional, and behavioral factors affect how individuals adopt attitudes. At this point, the attitudinal and behavioral patterns are composed of four factors: Action, target towards action, content towards action and time. The general or special pattern of these four factors also forms the attitudes towards action (Ajzen & Fishbein, 1977). Thus, determining attitudes is important to the teaching method to be followed while leading an individual to adopt behavioral aims as it is widely known that there is a positive relationship between cognitive success and emotional success (Bloom, 1979). Attitudes can be measured through direct or indirect measurement techniques (Kagitcibasi, 2010).

In the current study, student biology teachers' attitudes towards microbe were investigated through applying semantic differential attitude scale for the concept of microbe. However, when the related literature is concerned, to the best knowledge of the author, there is not any study that carries out such an evaluation. It is determined that the studies conducted on the attitudes towards microbe

generally focus on certain issues. In this vein, it was noticed that several issues were investigated such as definition of microbes through specific adjectives (Byrne, Grace & Hanley 2009; Deangelo, 2000), attitudes towards health and hygiene (Westaway & Viljoen 2000), attitudes towards disease and health (Eiser, 1989; Jones & Rua, 2008), attitudes towards AIDS (Irwin et al., 1991; Odunjinrin & Akinkuade, 1991; Walker, Stocklmayer & Grant, 2011; Li et al., 1993), attitudes towards tuberculosis (Haasnoot et al., 2010; Khan et al., 2006; Khan et al. ,2008; Semegni, 2012), microbiophobia (Williams & Gillen, 1991), attitudes towards food hygiene (Griffith et al., 2001; Rimal et al., 2001), and the effect of education on perceptions of microbes and diseases (Jones et al., 2012).

Significance of the Research

As can be seen in the studies conducted, at each and every level of education, students and teachers had many alternative concepts. At this point, through applying triangulation and using the free word-association test and the drawing-writing technique, student teachers' conceptual structures can be determined, and their misconceptions can be revealed. However, in the literature review conducted on this issue, it is found out that there are a few studies using both the free word-association test and the drawing-writing technique to reveal student biology teachers' conceptual structures related to "microbe". Therefore, it is believed that the results of the current study conducted through using free-word association test and drawing-writing technique will fill this gap in the literature providing data of quality. Moreover, there is not any study that investigates student biology teachers' semantic differences towards the concept of microbe, and thus, it is believed that the data collected in the current study will contribute to the literature. Therefore, the current study is considered important as the results are gained through the participation of biology teachers and using the free word-association test, the drawing-writing technique and the semantic differential attitude scale towards the concept of microbe. In addition to all these, as the study was conducted on student biology teachers that would teach the correct concepts to their students when they graduate, it is believed that the study will contribute to teacher education.

The Aim of the Research

Microbes are one of the important concepts that individuals face at any time in their lives, and whose effects either positive or negative can be felt. Considering the issue from student biology teachers' perspective, it is important for them to be competent in this subject as it will be their duty to teach the concept of microbes and related information to students effectively and correctly during their professional life. At this point, the aim of the current study is to investigate student biology teachers' cognitive structures related to "microbe" using the free word-association test and the drawing-writing technique and determine through which adjectives they express their attitudes towards the concept of microbes.

Methodology of Research

The free word-association test, the drawing-writing technique and the semantic differential attitude scale were used, and the mixed research design was applied as the research design of the current study. The researchers conducted in this design are defined as the researcher's combined use of the qualitative and quantitative methods, approaches and concepts in a study or in successive studies (Creswell, 2003; Tashakkori &Teddlie, 1998; Johnson & Onwuegbuzie, 2004). While Johnson and Turner (2003) expressed the importance of the mixed research as "the multiple data collection by researcher, using different strategies, methods and approaches", Creswell (2006) expressed it as "better understanding of the research problem may be obtained by using the quantitative and qualitative approaches together, in comparison with individual use of either approach. Thus, the mixed research design is the combination of the powers of the quantitative and qualitative methods (Creswell, 2005; Creswell et al., 2003). Also in this research the mixed research design is used in order to obtain detailed, various and rich data

about the biology student teachers' cognitive structures on the concept of "microbe". Data enrichment is provided through using the free word association test in qualitative dimension and using the draw-write technique in quantitative dimension.

Sample

The study was comprised of 44 biology student teachers' studying at the 4th and 5th grades of Biology Education Department in Necmettin Erbakan University. 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 (Coyne, 1997; Creswell, 2008; Given, 2008; Knight et al., 2013; Patton, 1990; Teddlie & Yu, 2007).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

These types of measurement tools were used as the data collection instrument in the current study. This data collected instruments prepared by author. These are: the free word-association test, the drawing-writing technique and the semantic differential attitude scale of the concept of microbe. The basic aim of using different measurement tools in the study is to collect rich data through data triangulation (Yildirim & Simsek, 2000). Since it is stated that using different data collection methods in the same study increases the consistency, intelligibility and actuality (Glesne & Peshkin, 1992; Patton, 2002; Poggenpoel & Myburgh, 2003; Roberts et al., 2006; Shenton, 2004).

A Free Word Association Test

A free word association test is a technique which aims to determine a student's or a group's conceptual framework. The principal aim of this technique is to present the words as stimuli to the participants one by one in each time (Atasoy, 2004). Free word association tests are one of the most frequently used and widespread techniques which aim to determine a student's cognitive structure and the relationships between the concepts in this structure; in other words, the information network, and to find out whether the relationships among the concepts in the long-term memory are enough or not. These tests have been used in many studies (Bahar et al., 1999; Bahar & Ozatlı, 2003; Ozatlı & Bahar, 2010). This technique is based on the process in which an answer is suggested to a word that is used as an independent stimulus without limiting the mind to any specific response (Bahar at al., 1999; Sato & James, 1999). The participants are required to provide concepts that come to their minds in this free word association test, in a specific time (40 seconds) (Gussarsky & Gorodetsky, 1990), the words that are provided as answers are subject to frequency distribution that is followed by an in-depth analysis. In this way, it is possible to determine the participants' descriptions and gather findings on the related meanings of the word used as a stimulus. These practices of using free word association tests help reveal the meanings related to various concepts used in studies (Daskolia et al., 2006). The word association test consists of two sections (Fig. 1);

In the first section; the biology student teachers were asked to provide the very first 10 words that come to their minds in 40 seconds when they read or hear the concept "Microbe". The key concept is provided one under the other in order to prevent sequential answering as they would just consider their answer and provide the words regarding that word rather than focusing on the key concept, which would threaten the validity and the reliability of the study. In this study, the concept of "Microbe" has been provided for the biology student teachers to complete the free word association test. In this test, the concept of microbe has been provided in the following format as the stimulus word;

Microbe-1:……

Microbe-2:……..

.

.

.

Microbe-10:……..

SENTENCE:……..

In the second section; the participants were asked to write sentences related to the key concept given in 20 seconds, and these sentences were carefully investigated while doing the data analysis since the answer provided in relation to the key concept can only be an answer of association that is not meaningfully related to the word. Moreover, the data analysis is directly affected by some cases such as whether the sentence is scientific and whether it includes different misconceptions considering the possibility that the sentence provided can be more complex and of high structure. At this stage, the participants were asked questions such as "Please write a sentence on the concept of microbe"

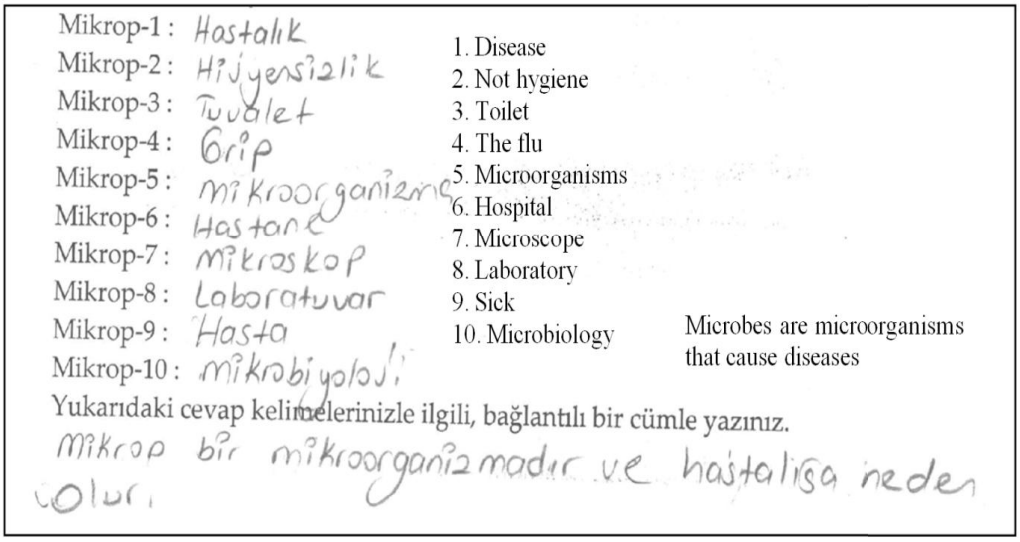


Figure 1: The examples of free word-association test (P16).

Drawing-writing Technique

Through this measurement instrument, it was aimed to investigate thoroughly the student teachers' views on the concept of microbe (Rennie & Jarvis, 1995). This technique is very useful as during the study it helps collect natural and high quality data on latency thoughts, understanding, and attitudes (Backett-Milburn & Mckie, 1999; Pridmore & Bendelow, 1995; White & Gunstone, 1992). In this regards, the participants were asked to provide their views freely and without any limitation in 5 minutes to the question "What is Microbe? What do you think about Microbe? Please explain through drawing". The following are some examples of drawing-writing technique (Figure 2. and Figure 2.).

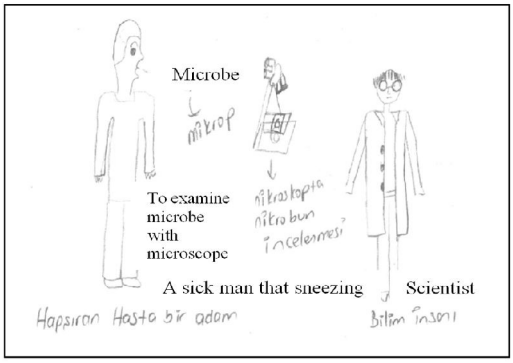


Figure 2: The examples of drawing-writing technique. The answer sheet for (P16).

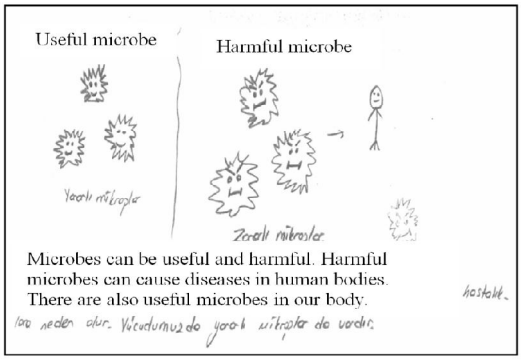


Figure 3: The examples of drawing-writing technique. The answer sheet for (P6).

Semantic Differential Attitudes Scale of the Concept of Microbe

The scale asks the participants to rate the concept of microbes according to their semantic differences and aims to reveal the participants' attitudes towards microbes. In this scale, the participants select one of the adjectives at opposing poles considering its suitability for the concept of microbes. This scale, developed by Osgood, Suci and Tannenbaum (Russell, 1975), proves effective in determining affective characteristics (Anderson, 1987).

In this scale, 5 or 7 scaled score interval is used. It is a unipolar scale. It is a unipolar rating scale that is defined through two opposite attributes at opposing poles. In the current study, the scale was designed and applied to the participants as a 5-Likert style scale with appropriate adjectives suitable for the concept of microbe. The studies investigating the related attitudes were taken into consideration while determining the adjectives (Byrne et al., 2009; Deangelo, 2002; Jones et al., 2012; Westaway &Viljoen, 2000) and general adjectives were selected so that they would not be related to the special dimensions of the issue. Two experts in biology education and measurement and evaluation were asked to provide views during the development of the scale. The adjectives were evaluated as from positive to negative, always (5 points), generally (4 points), sometimes (3 points), generally (2 points), and always (1 point). Following the calculation of each frequency, percentage and arithmetic values of each bipolar adjectives, total attitude scores were calculated by averaging the responses for all 9 pairs. If the participants' scores fell into the options of 5 and 4, they were thought to adopt positive attitude; if into 3, they were thought to adopt neutral attitudes, and if 2 and 1, they were thought to adopt negative attitudes. In this vein, the points of 3.5 and over mean positive attitudes; the scores between 3.5 and 2.5 mean neutral attitudes, while 2.5 and lower mean negative attitudes (Lohr & Bummer, 1992). In this context, the participants were given the semantic differential attitude scale related to the question "Which features do you find related to the concept of microbe?" The following are some example items from the semantic differential attitude scale of the concept of microbe.

disease .....☐.....☐.....☐.....☐.....☐.....health
necessary .....☐.....☐.....☐.....☐.....☐.....unnecessary

☐

Reliability and Validity of the Data Collection Instruments

Validity in qualitative studies means that a researcher observes the case that is investigated as it is and presents it objectively as much as possible (Yildirim & Simsek, 2006) It is also the approximation of what we believe to measure and what we plan to measure (Marvasti, 2004; Roberts, Priest & Traynor, 2006). However, the biggest issue in ensuring validity in qualitative studies is how researchers can prove

their objectivity. Subjectivity may emerge while researchers collect, save, or interpret data. It is possible to conduct a valid qualitative study of high quality only through minimizing this subjectivity as much as possible (Yildirim, 2010). In this research, the internal validity of the themes and subthemes categories was ensured by the author and two experts in biology and biology education. Moreover, in this study, two important processes were realized to ensure the validity of the results of the study.*(a) Data coding and analysis (how conceptual categories were obtained) were discussed in detail* (Hruschka et al., 2004) (*b) student teachers' views that were believed to best represent each and every category obtained through the study were selected as examples, and these examples were provided in the findings section* (Yildirim & Simsek, 2006).

Moreover, considering the reliability of the study, the codes and the categories provided by two researchers were compared in order to confirm whether the codes provided under each conceptual category represented the aforementioned conceptual categories. The list of codes and themes were finalized after two experts in the field of biology and biology education coded the data individually. The consistency of the coding carried out by the participants independently was determined through the marks such as "Agreement" or "Disagreement". When the researchers used the same codes for the student biology teachers' statements, these codes were considered agreements. However, when they used different codes, these codes were considered disagreements. When either of the researchers was not sure about the coding, s/he asked for the other's opinion, and then coded the data. The reliability of the data analysis was calculated using the formula [Agreement / (Agreement + Disagreement) x 100] (Miles & Huberman, 1994). The average reliability between the coders was calculated as 93% for free word-association test and 95% for drawing-writing technique. For the general of the semantic differential attitudes scale the Cronbach Alpha Reliability Coefficients have been found as 0.90.

Data Analysis

For the data analysis, the student biology teachers' answer sheets were firstly numbered from 1 to 44. The data collected were analyzed through the free word-association test and the drawing-writing technique based on content analysis (Finson, Beaver & Cramond, 1995). The basic aim of content analysis is to reach concepts and relationships that can account for the data. To achieve this aim, similar data are collected and organized within certain concepts and analyzed in that readers will easily understand these (Yildirim & Simsek, 2006).

The data collected through the free word association test were analyzed using the techniques of number of words, number of answers and semantic relationship (Atasoy, 2004). The words that had the same meanings were classified under the category of the frequently stated words. The words that were not considered related, that were not related to the other words, and that were repeated only one were not taken into consideration during the data analysis. The words were categorized using the criterion of semantic relation, and the frequency calculations of these words under each category were made. In many studies, using this kind of data analysis is stated to provide reliable results (Daskolia et al., 2006; Kostova & Radoynovska, 2008; Kostova & Radoynovska, 2010).

In the drawing-writing technique; however, the drawings and statements provided related to the concept of microbe were analyzed in two different sections. The data collected were subject to content analysis. In order to achieve this, the statements provided by each participant related to the concept of microbe were organized under certain categories and sub-categories within the section of the statements. The participants' drawings related to the concept of microbe were analyzed in the same way. Many drawings that are considered unrelated to the point, drawings that are not related to other drawings, and drawings that were repeated only once were not taken into consideration. Moreover, in both free-word association test and drawing-writing technique, the interesting statements in the text provided by the participants were numbered and quoted within the sign " " (P19). In the drawing-writing technique, the examples of the drawings provided by the student biology teachers were numbered and provided in the text such as (P11) and (P24).

When the student biology teachers' views provided to the semantic differential attitude scale of the concept of microbe were evaluated, scoring was made through 1 to 5. In the bipolar scale, the positive

adjectives were rated and evaluated as 5 points while the negative ones were rated as 1 point. According to this rating, differences were found between the student biology teachers' positive, neutral and negative attitudes towards microbe.

The internal validity of the categories and subcategories revealed throughout the study was assured through the author and the two experts in biology and biology education. Moreover, SPSS-20 was used to evaluate the semantic differential attitude scale of the concept of microbe, and Nvivo was used to create Model 1.

Results of Research

In this section were ordered in which the data collection instruments were used. Therefore, firstly the data collected through the free-word association test were presented, then the data collected through the drawing-writing technique, and finally the data collected through the semantic differential attitude scale of the concept of microbe.

The Results Determined Through Free Word-Association Test

As a result of the analysis of the data collected through the free word-association test, 10 (ten) categories were specified through the words provided by the student teachers'. In this regard, the categories and the words in each category were listed. When these words were meaningless and repeated only one, they were not joined with the other words. Therefore, 12.53% (45 words) of these mentioned words were not included in the categories. As a result, these words not listed in the subcategories were not provided in Table 1. Related to the word, microbe, 46 words left were distributed among 10 (ten) categories. The words specified in each category and the categories were provided in Table 1. 399 words were specified in total.

Table 1. Associations with the concept "microbe" (categories and answers included in each category and cumulative frequency of response words).

Categories	Associations included in categories and their frequencies	Total frequency of associations in this category
1. Microbial variety and activity	"bacteria" (30) "viruses" (24) "infectious" (23) "spread" (4)	81
2. Immunity	"immunity" (36) "vaccination" (17) "serum" (5) "blood" (4) "antibody" (4) "antibiotics" (3) "white blood cell" (2) "antigen" (2) "defense" (2)	75
3. Microbial disease and types of disease	"disease" (39) "cold" (7) "AIDS" (2) "the flu" (2)	50

Categories	Associations included in categories and their frequencies	Total frequency of associations in this category
4. Definition of microbes	"unicellular" (12) "living being" (7) "harmful" (6) "microorganisms" (5) "infectious" (5) "everywhere" (3) "parasite" (2) "invisible" (2)	42
5.Precautions that can be taken against microbes and ways of treatment	"medicine" (5) "soap" (4) "treatment" (3) "hospital" (3) "hygiene" (3) "health" (2) "protection" (2)	22
6. The vitality characteristics of microbes and metabolism	"circulation" (7) "death" (4) "water" (3) "DNA" (2) "respiration" (2) "fast reproduction" (3)	21
7. Microbial environment	"dirt" (7) "pollution" (3) "waste water" (2) "waste material" (2)	14
8. Fields of analyzing and studying microbes	"microbiology" (4) "microscope" (3)	7
9. Symptoms of diseases caused by microbe infection	"having a fever" (6)	6
10. Evolutionary microbiology	"mutation" (3)	3
	General Total	321

As a result of the analysis of the data collected through the free word-association test and the words provided by student teachers, 10 categories were determined, namely, "*microbial variety and activity*" (81), "*immunity*" (75), "*microbial disease and types of disease*" (50), "*definition of microbes*" (42), "*precautions that can be taken against microbes and ways of treatment*" (22), "*the vitality characteristics of microbes and metabolism*" (21), "*microbial environment*" (14), "*fields of analyzing and studying microbes*" (7), "*symptoms of diseases caused by microbe infection*" (6), and "*evolutionary microbiology*" (3).

When Table 1 is examined, according to the findings revealed, in the first category, the related answers provided by student biology teachers in response to the concept of microbes mostly fall into the category of "microbial variety and activity" and appeared as the dominant category (f=81). While most of the student teachers focused on the words of *"bacteria", "viruses", "infectious"*, few students linked with the word of *"spread".* This result indicates that the student teachers relate the concept of microbes mostly with microbial variety and activity in their cognitive structures. Moreover, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: *fungi*, *protozoa*, and *rickettsia*.

In the second category, student teachers provided associations with "immunity (f=75). The answer words provided by student teachers in this category were determined mostly as *"immunity", "vaccination",* and *"serum".* The words provided less frequently by student teachers were *"blood", "antibody", "antibiotics", "white blood cell", "antigen"*, and *"defense"*. Furthermore, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: *phagocytosis, lymph, leucocyte, macrophage,* and *mast cells*.

In the third category, the words provided by the student biology teachers were categorized under "microbial disease and types of disease" (f=50). While the student teachers provided more frequently the words of *"disease"* and *"cold"* in this category, *"AIDS"* and *"the flu"* were less frequently stated. Furthermore, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: dysentery, *HIV, inflammation, diarrhea and typhoid*.

The fourth category emerged as "definition of microbes" (f=42). In this category, the student teachers' provided the words of *"unicellular", "living being", "harmful"* and *"microorganisms",* and *"infectious"* more frequently than the ones *"everywhere", "parasite",* and *"invisible"*. It was determined that the student teachers' cognitive structures about definition of microbes were not at a satisfactory level. Moreover, the words provided in this category by the participants but not included in this category as they were stated only once are as follows: *animal, human, primitive living being, small living beings, organism*, and *microscopic*.

In the fifth category, the answer words provided by the student teachers were categorized under ""precautions that can be taken against microbes and ways of treatment" (f=22). In this category, the participants used the words *"medicine"* and *"soap"* more frequently than *"treatment"*, *"hospital"*, *"hygiene"*, *"health"*, and *"protection"*. Moreover, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: *water with vinegar, cleanness*, *disinfection*, and *sterile*.

The sixth category was specified as "the vitality characteristics of microbes and metabolism" (f=21). The words provided by the student teachers related to this category were determined as *"circulation", "death", "water", DNA", "respiration"*, and *"fast reproduction".* Moreover, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: *perspiration and metabolism*.

The seventh category was determined as "microbial environment" (f=14). The words frequently provided by the student teachers related to this category were determined as "*dirt*". Other statements were "*pollution*", "*waste water*", and "*waste material*". Moreover, the words that were provided in this category by the student teachers but not included in this category as they were stated only once are as follows: *stool, carpet, air, food*, and *atmosphere*.

The eighth category was determined as "fields of analyzing and studying microbes". The participants provided the concepts "*microbiology*" and "*microscope*". In addition, the words such as "*biotechnology*" and "*research*" were not included as they were not stated more than once.

The ninth category emerged as "symptoms of diseases caused by microbe infection". The participants focused on the word "*having a fever*". Moreover, as the words "*shaking*", "*vomiting*", and "*sneezing*" were not repeated more than once, they were not included in this category.

The last category emerged as "evolutionary microbiology". In this category, the participants provided only "*mutation*" as the answer word.

On the other hand, some examples of the student biology teachers' statements related to the concept of microbe, and analyses are provided below:

"Microbes are organisms like bacteria and viruses that infect others through dirty environments and that cause infection and disease when they reach living things" (P28). The participant's statement above indicates that it had a misconception. Not all microbes cause diseases. Some might serve as a factor of disease, but some may not. It was noticed that the participant linked the concept of microbes with microbial variety by providing microbes such as bacteria and viruses, with microbial disease and definition of microbe by stating the factor that causes infection and disease and with microbial environment by suggesting the dirty environments. This participant's answer words were

determined as the concepts of "*infection, inflammation, immunity, antibody, dirt, microscope, living being, bacteria, virus, and disease*".The participant did not use the concepts of "*immunity*, *antibody, microscope*, and *living being*".

The statements such as *"Microbes spread faster in crowded environments where there are many people and live more in these environments" (P34)* and *"Many diseases that threaten our health are transmitted by microbes from one to another" (P35)* indicated that the participant linked the concept of microbes with *infectious*, *ways of infection*, *spread*, and *mobility*.

The statement "*Our immune system fights against microbes. White blood cells are the cells that help our immune system" (P33)* reflects the participants' associations with immunity. When the participant's answer words were analyzed, it was determined that the participant did not provide answer words such as "*bacteria, disease, immunity, white blood cell, macrophage, vaccination, serum, antibody, having a fever, vomiting* and *diarrhea* and failed to use the words related to symptoms of disease and ways of treatment such as "*vaccination, serum* and *having a fever*" in full sentences.

Considering the statement provided as *"Microbes cause diseases ... analyzing microscopic living beings such as bacteria and viruses that cause diseases" (P27)*, it can be stated that this participant had a lack of knowledge since not all microbes cause diseases (such as yogurt yeast, rennet, wine yeast, vaccination, and antibiotics). Some microbes are also useful. Moreover, scientific studies do not only investigate bacteria and viruses that cause diseases. All harmful and useful microbes are within the scope of scientific studies.

*"I clean the objects that include microbes" (P31).*The answer words provided by the participant were the concepts of "t*yphoid, dysentery, disease, cleanness, bacteria, virus, antigen, antibody, immunity*, and *DNA*". Although these answer words were more frequently related to types of diseases and immunity, the statement provided were found to be related to the theme of precautions that can be against microbes and ways of treatment.

"People sneeze when they are ill, and spread microbes into the environment"(P2). The statement provided by this participant indicates a relationship with the symptoms of diseases. There is a remarkable misconception in this statement since people do not sneeze only when they are ill or do not always sneeze. They may react in different ways when they get ill.

"Unhealthy and dirty environments, dirty clothes, and not washing hands frequently lead microbes available everywhere to cause diseases transmitting through these environments" (P12). The participant provided statements related to microbial environment and precautions that can be taken against viruses. There is a remarkable misconception in the statement provided by the participant. Microbes available everywhere does not always lead to diseases. They cause diseases if immune system is not strong.

In the overall analysis, it appeared that some of the student teachers did not write any meaningful sentence related to words, while some did not write any sentence. This might be attributed to the fact that they either did not want to write on purpose or did not write as they did not know. A great majority of student biology teachers viewed microbes from the perspectives of microbial variety and mobility. This situation is what student biology teachers are generally expected to correlate, but not a desired result. However, they tended to have fewer associations with the categories of *microbial environment for microbes, the vitality characteristics of microbes and metabolism, precautions that can be against microbes and ways of treatment, analyzing and studying microbes, symptoms of diseases caused by microbe infection and evolutionary microbiology*. Moreover, the participants' definitions of microbes appeared to be less related to microbial diseases and types. It was also determined that the level of associations related to the definition of microbes were not satisfactory. Although student biology teachers' conceptions related to the categories of "*definitions of microbes, microbial variety and activity, and immunity*" were not at a desired level, it was determined that their cognitive structures were valid, but based on superficial statements. This situation indicates that student biology teachers' cognitive structures are based on rigid and deficient knowledge obtained through memorization.

When the themes obtained were compared with the ones in the related literature, it was determined that student biology teachers' conceptual structures about the concept of microbes shared similarities with those of the students at primary, secondary and high school students' conceptual structures about the concept of microbes.

Since as stressed in the categories of "*microbial variety and activity*" and "*microbial diseases and types*", microbes were stated to be the main factor that causes diseases those humans suffer from. While the activities of microbes were often considered as negative and harmful to humans, they were particularly evaluated as the cause of human diseases or harmful. Moreover, in the other studies in the literature conducted by Bryne et al. (2009) and Vasquez (1985), it was stated that the leading structures were the conceptual structures particularly related to the harm caused by microbes to humans.

Simonneaux (2000), stressing the theme of "*immunity*", argued that the interviews conducted through the study were centered on the concepts of antigen and antibody. The concepts of antigen and antibody are also the concepts that particularly stressed by the participants in the theme of immunity.

There are results in the literature similar to the ones obtained through the theme of *"definition of microbes*" in the current study. Byrne and Grace (2010) determined that the participants defined microbes using adjectives such as good-bad, frightening, having teeth, and harmful. While there are detailed studies in which participants compare microbes in size (Simonneaux, 2000), in the current study, student teachers were not found to have this kind of comparisons. As indicated by Deacon and Olatunji (2007), people generally stress that microbes are terrifying, pathogenic, and have a contagious structure. Therefore, in this theme, negative emphasizes were provided regarding microbes.

The emphasis placed by the student teachers in the theme of *"precautions that can be taken against microbes and ways of treatment*" was on the use of medicine against microbes. Rachman (2004) and Tsao and McKay (2004) argue that people always have the fear of infection through microbes and their pathogenic characteristics. As stressed in this dimension, in order to prevent many microbial and contagious diseases (such as diarrhea and the flue), it is necessary to comply with hygiene rules (Bir & Podmore, 1990; von Schirnding et al., 1993; Yach et al., 1989). Communication and spread of diseases can only be prevented through following these rules. The results of the study in this theme indicated that hygiene played a greater role in the precautions that could be taken against microbes.

Concerning the emphasis placed in the theme of "*the vitality characteristics of microbes and metabolism*" and as indicated in the literature, it was determined that the participants expressed their views considering the harm caused to humans and the environment. Among the views stated are the fast multiplication and spread of microbes and the harm caused to humans and the environment. The vitality characteristics and metabolisms of microbes naturally lead humans to adopt attitudes such as hate, fear, and disgust (Byrne, Grace & Hanley, 2009; Nagy, 1953).

There are similarities between the emphasis placed in the theme of "*microbial environment*" and the results of the studies conducted in the literature since in the related literature it was determined that the participants viewed microorganisms as ugly-bad, that they lived in environments such as garbage cans (Jones & Rua, 2006; Maxted, 1984; Simonneaux, 2000) and that they were simple living things whose tasks are to decompose organic materials in the nature (Hilge & Kattmann, 2003) In the current study, (P13) also used the same statements for the environments in which microbes lived.

In the theme of "*fields of analyzing and studying microbes*", it was stated that microbiology was the discipline that analyze microbes and microscopes were necessary. These statements bare similarities with the ones in the related literature since the studies conducted included the participants' statements indicating that microbes were too small, could not be seen with the naked eye, and that a microscope was needed to enlarge microbes to analyze (Byrne, 2011).

As determined in the theme of *"symptoms of diseases caused by microbe infection*", it was stressed that people had a fever as a result of the diseases passing through microbes. In the related literature, it was argued that the participants lacked knowledge about infections caused by microbes, spread, and symptoms of diseases (Au & Romo, 1996; Inagaki &Hatano, 1993; Jones & Rua, 2008; Kalish, 1996a; Prout, 1985). The current study also indicated that the student teachers did not have sufficient knowledge about the symptoms of diseases caused by microbial infections.

Regarding the emphasis placed in the theme of "*evolutionary microbiology*" in the current study, there is not any study in the related literature that share similarities or differences.

The Results Determined Through Drawing-Writing Technique

It is determined that the data collected through the drawing-writing technique to investigate student biology teachers' cognitive structures related to the concept of microbe fall into 10 (ten) categories in total. These can be listed as follows: *"definition of microbes" (90), "microbial environment" (37), "microbial variety and activity" (35), "microbial disease and types of disease" (29),"immunity" (16), "routes of transmission of microbes" (13), "precautions that can be taken against microbes and ways of treatment" (12), "symptoms of diseases caused by microbe infection" (12), "the vitality characteristics of microbes and metabolism" (6) and "the importance of microbes" (3)*. When the statements provided by the student teachers were analyzed, it was determined that they mostly used the terms, *"pathogenic" (22), "harmful" (16), "too small to be seen with the naked eye" (10) and "useful" (9)*. However, it is seen that in this context, the findings of drawing are divided into 8 categories, and the findings of writing are into 10 categories (Table 2).

Insert Table 2 Here.

Table 2. The findings of the categories and subcategories obtained through drawing-writing technique related to the concept of microbe.

Main Category	Sub-category	Drawing (f)	Writing (f)
1. Definition of microbes	pathogenic	2	22
	harmful	-	16
	too small to be seen with the naked eye	2	10
	useful	-	9
	shapeless microbe	6	-
	caricatures with hands, face, and legs similar to humans	6	-
	microorganism	-	5
	simple structure of organisms	-	2
	small organisms	-	2
	tiny living things	-	2
	bad looking	2	-
	heterotroph	-	2
	parasite	-	2
	Total	18	72
2. Microbial environment	dirt	2	5
	toilet/toilet seat cover	3	3
	animal	2	2
	human	2	2
	coin	2	2
	garbage cans	2	2
	salivary	-	2
	plant	2	2
	trough of fresh-water fountain	2	-
	Total	17	20
3.Microbial variety and activity	bacteria	2	11
	virus	4	7
	invertebrate animals	3	-
	paramecium	2	2
	amoeba	2	-
	spreading/transmission/mobility	2	-
	Total	15	20
4. Microbial disease and types of disease	sick people/ diseases	8	2
	cause of a disease	-	7
	AIDS	2	2
	lethal	2	2
	disrupting the functioning of an organism	-	2
	transmission of diseases	-	2
	Total	12	17

Main Category	Sub-category	Drawing (f)	Writing (f)
5. Immunity	immunity	-	6
	antibiotic	2	2
	antibody	-	2
	vaccine	-	2
	serum	2	-
	Total	4	12
6. Routes of transmission of microbes	through respiration/breathing	4	3
	through air	2	-
	through hand contact/contact	2	-
	through spitting	2	-
	Total	10	3
7. Precautions that can be taken against microbes and ways of treatment	hospital	2	4
	bed	2	-
	medicine	2	-
	using hands while sneezing/coughing	2	-
	Total	8	4
8.Symptoms of diseases caused by microbe infection	sneezing	5	3
	coughing	2	2
	Total	7	5
9. The vitality characteristics of microbes and metabolism	DNA	-	2
	cell wall	-	2
	living things / the simplest form of life	-	2
	Total	0	6
10. The importance of microbes	in ecological cycle/ natural ecosystem not being deteriorated	-	3
	Total	0	
	General Total	91	162

However, according to Table 2, the findings of the student teachers' drawings related to the concept of microbe fall into 8 categories. These can be listed as follows: "*definition of microbes*" (18), "*microbial environment*" (17), "*microbial variety and activity*" (15), "*microbial disease and types of disease*" (12), "*routes of transmission of microbes*" (10), "*precautions that can be taken against microbes and ways of treatment*" (8), *"symptoms of diseases caused by microbe infection" (7) and "immunity" (4).* The examples of the figures provided by the student teachers related to the concept of microbe are provided in between Figure 3 and 10. Considering the participants' drawings, it was found that although the participants also used abstract drawings (Nagy, 1953); they benefited more from drawings that explain conceptual structures. The examples of the figures provided by the student teachers related to the concept of microbe are provided in between Figure 4 and Figure 11.

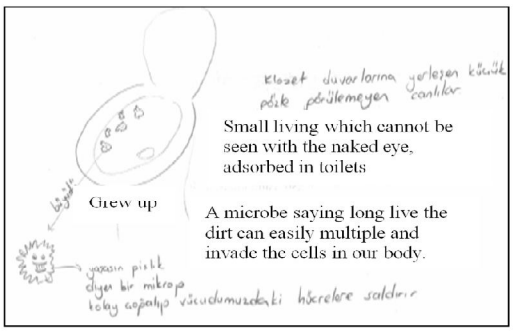


Figure 4: Microbial environment (P32).

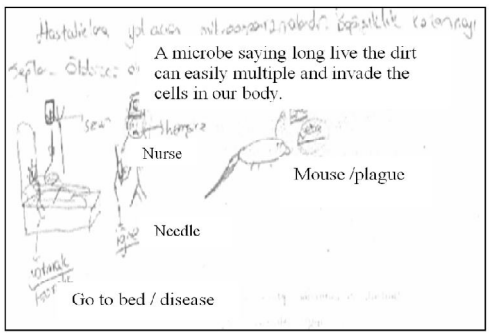


Figure 5: Immunity (P31).

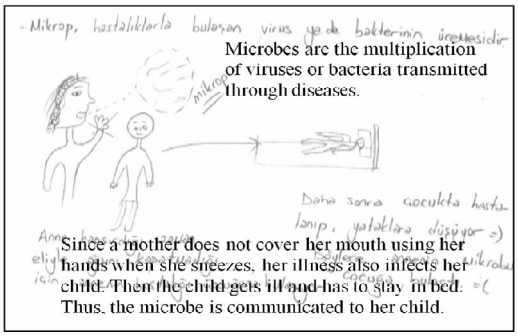


Figure 6: Precautions that can be taken against microbes and ways of treatment (P28).

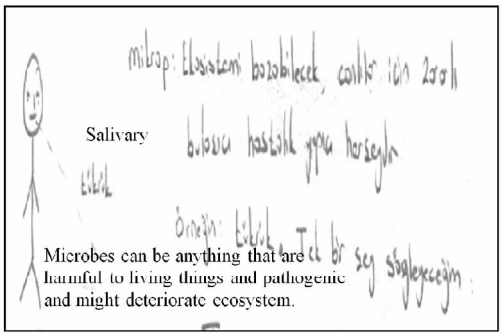


Figure 7: Routes of transmission of microbes (P16).

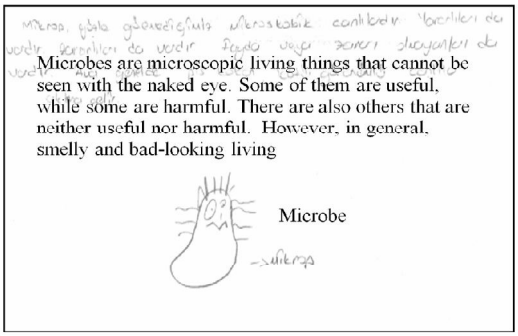


Figure 8: Definition of microbes (P9).

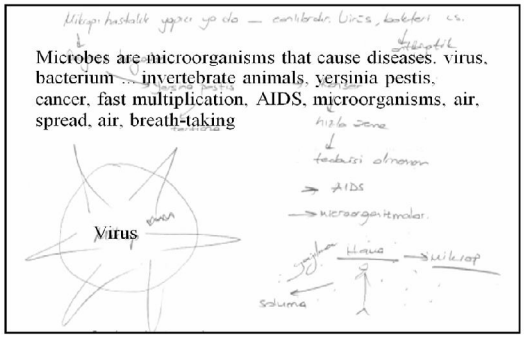


Figure 9: Microbial disease and types of disease (P18).

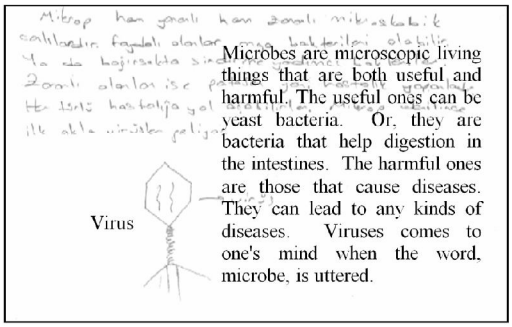


Figure 10: Microbial variety and activity (P2).

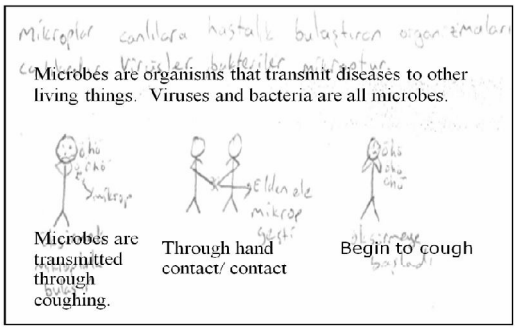


Figure 11: Symptoms of diseases caused by microbe infection (P33).

According to Table 2, the findings of the student teachers' writing related to the concept of microbe fall into 10 categories. These can be listed as follows: *definition of microbes* (72), *microbial environment* (20), *microbial variety and activity* (20), *microbial disease and types of disease* (17), *immunity (12),* the vitality characteristics of microbes and metabolism (6), *symptoms of diseases caused by microbe infection (5), precautions that can be taken against microbes and ways of treatment* (4), *routes of transmission of microbes* (3) and *the importance of microbes* (3).

The following include some of the exemplary statements provided by the student teachers and the corresponding categories regarding the concept of microbes;

The examples determined in the theme of "*definition of microbes*";

"Microbes are organisms with simple structures that are too small to be seen with the naked eye and can be both useful and harmful. There are some useful types of bacteria such as the ones that produce vitamin K. There are also other harmful types such as HIV "(P1).

"They are microorganisms that are either useful or harmful. They can cause diseases; however, they can live in a cell without causing any harm. There are other types such as those that produce their own food as well as others like parasites"(P4).

"It is the name given by public to refer to small organisms. They are in general viewed as pathogenic; however, there are some other microbes that do not lead to diseases, even some are useful" (P14).

"They are harmful and dirty organisms"(P17).

"... generally smelly and bad-looking living things come to my mind"(P9).

The examples determined in the theme of "*microbial environment* ";

"... they are organisms that are available anywhere that we contact with. Such as a coin"(P20).

"Microbes are everywhere. Toilets, garbage, table, money, spitting etc." (P21).

" those that live easily in human epithelial cells ..." (P27).

"small living things that are in toilets and cannot be seen with the naked eye... a microbe saying "long live the dirt"(P32).

The examples determined in the theme of "*microbial variety and activity* ";

"... virus, bacterium ... invertebrate animals, yersinia pestis ... cancer, fast multiplication ... AIDS, microorganisms, air, spread ..." (P19).

"... viruses, bacteria that infect a living organism and cause a disease ..." (P22).

The examples determined in the theme of "*microbial disease and types of disease*";

"... microbes, healthy person, ill person" (P25).

"... when I hear the word microbe, diseases come to my mind"(P34).

The examples determined in the theme of "*immunity*";

"... they infect a body through an open wound and have effects that trigger immune system"(P27).

"... when our body is infected with microbes, antibodies begin to fight with them, and our immune system is activated"(P29).

"Microbes help acquire immunity"(P31).

"until antibodies know microbes when they enter our body... if the microbe is one of the microbes that our immune system has detected before, our immune system fights off this microbe and we recover quickly"(P36).

"... I consider them necessary for immune system" (P35).

The examples determined in the theme of "*routes of transmission of microbes*";

"They can be easily communicated from animals to humans"(P17).

"Since a mother does not cover her mouth using her hands when she sneezes, her illness also infects her child. Then, the child gets ill and has to stay in bed ☺ In this way, the microbe in mother's body is communicated to her child ☹" (P28).

"As a result of the waste products left in natural water sources, microbes invade humans through such ways as contact and then cause diseases"(P30).

The examples determined in the theme of "*precautions that can be taken against microbes and ways of treatment*";

"... microbe, disease, hospital, medicine"(P22).

"serum, stay in bed, disease, vaccination ..." (P31).

The examples determined in the theme of "*symptoms of diseases caused by microbe infection definition of microbes*";

"atishoo" (P7).

"Beginning to cough ..." (P33).

The examples determined in the theme of "*the vitality characteristics of microbes and metabolism*";

"Microbes are living things"(P40).

"Microbes are the foundation of vitality. They are the simplest forms of life" (P39).

The examples determined in the theme of "*the importance of microbes*";

"… living things without which ecosystem would deteriorate ..." (P16).

"... microbes are the necessary component of life ... they play a great role in ecological cycle" (P23).

"…as a result of the deterioration of natural ecosystem, waste products thrown unconsciously into natural water resources" (P30).

The Results Determined Through the Semantic Differential Attitude Scale of the Concept of Microbe

This study determined student teachers' conceptual structures about the concept of microbes as well their semantic attitudes towards this concept since affective dimension is very important in

learning and success (Mayring & Rhöneck, 2003; Mayring, 2009; Pekrun et al., 2010). Positive attitudes affect learning and success positively; on the other hand, negative attitudes affect these negatively. The descriptive values of the data collected on student biology teachers' attitudes towards the concept of microbe through the semantic differential attitude scale are provided in Table 3.

Table 3. The findings of the descriptive values of the data collected through the semantic differential attitude scale of the concept of microbe.

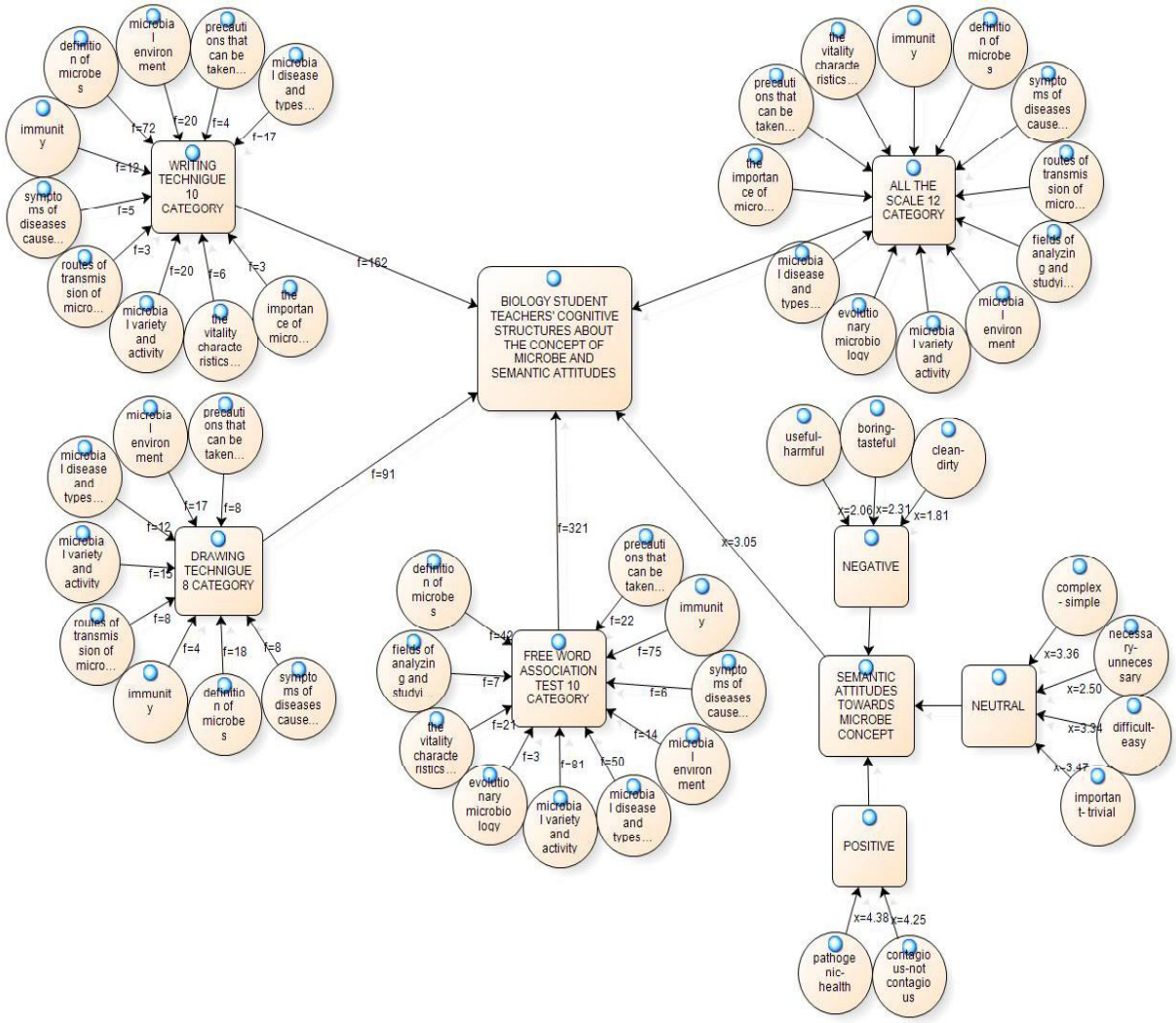
Semantic statements	N	Mean	SD	Always		Usually		Partially		Usually		Always	
				n	%	n	%	n	%	n	%	n	%
difficult- easy	44	3.34	1.32	12	27.3	6	13.6	17	38.6	3	6.8	6	13.6
boring -tasteful	44	2.31	1.32	3	6.8	6	13.6	11	25	6	13.6	18	40.9
complex - simple	44	3.36	1.24	11	25	7	15.9	17	38.6	5	11.4	4	9.1
pathogenic -health	44	4.38	.92	29	65.9	4	9.1	10	22.7	1	2.3	-	-
contagious- not contagious	44	4.25	.91	25	56.8	5	11.4	14	31.8	-	-	-	-
necessary- unnecessary	44	2.50	1.04	1	2.3	5	11.4	19	43.2	9	20.5	10	22.7
useful- harmful	44	2.06	1.02	-	-	2	4.5	18	40.9	5	11.4	19	43.2
clean- dirty	44	1.81	1.04	-	-	3	6.8	11	25	5	11.4	25	56.8
important- trivial	44	3.47	1.06	9	20.5	11	25	18	40.9	4	9.1	2	4.5

As indicated in Table 3, while it was determined considering the values of arithmetic average that student teachers considered the concept of microbes as partially difficult and partially easy ($\overline{X}$ =3.34; 38.6 %) in other words, neutral, they adopted various attitudes determined as partially boring ($\overline{X}$ =2.31; 40.9 %), partially neither complex nor simple ($\overline{X}$ =3.36; 38.6 %), always disease ($\overline{X}$ =4.38; 65.9 %), always contagious ($\overline{X}$ =4.25; 56.8 %), partially unnecessary ($\overline{X}$ =2.50; 43.2 %), partially harmful ($\overline{X}$ =2.06; 40.9 %), partially dirty ($\overline{X}$ =1.81; 56.8 %) and partially important ($\overline{X}$ =3.47; 40.9 %). These results indicate that the student teachers adopted different attitudes based on different adjectives. Each adjective was discussed and evaluated in its own context. In this vein, it was noticed that student teachers frequently considered the concept of microbes as pathogenic, (65.9%), contagious (56.8%) and dirty (56.8%). The participants of the study conducted by Rene and Gilbert (1994) associated microbes with diseases, which is in alignment with the current study. On the other hand, the total score of semantic attitudes towards the concept of microbes was calculated according to the arithmetic average of 9 bipolar semantic adjectives. Accordingly, the total attitude scores of the student teachers was calculated as $\overline{X}$ = 3.05. This score indicates that the student teachers adopted attitudes towards the concept of microbes as neutral-partial. The student teachers' neutral attitudes can be seen as an indication that their cognitive structures about the concept of microbes were not at the desired level.

The studies conducted in the related literature determined that the participants in general adopted negative attitudes towards the concept of microbes, and accordingly described microbes using such adjectives as bad, harmful to humans, causing harm to health, smelly, damaging the environment, causing people to suffer from disease, spreading fast, uncontrolled, disgusting, frightening, and contagious (Byrne et al., 2009; Deacon & Olatunji, 2007; Nagy, 1953; Rachman, 2004; Simonneaux, 2000). Therefore, the results of the current study share similarities with the results of the studies conducted in various levels of education in the related literature. These statements are an indication that the participants adopted negative feelings towards microbes such as fear and hate. However, it is stressed that the training and courses taken about microbes help individuals be more conscious of microbes, and that it is possible to overcome incorrect knowledge caused by such factors as culture, religion, personality and family, which prove to be effective in adopting attitudes (Davey et al., 1993; Jones et al., 2012; Uzunkaya & Ozgur, 2011).

The Model of the Student Teachers' Cognitive Structures about Microbes

Through using the free word-association test and the drawing-writing technique and evaluating student teachers' views on microbe, their cognitive structures were mapped. As indicated in this model, according to the analyses, while 10 categories were determined in the student biology teachers' cognitive structures related to microbe though the free word-associated test, 8 categories in the drawings and 10 categories in the writings were determined through the drawing-writing technique. As a result of the analysis of the data collected through the free-word association test and the drawing-writing technique, 12 categories were determined in total in the student biology teachers' cognitive structures related to microbe. On the other hand, when the categories obtained through the free word-association test and drawing-writing technique completed by the student biology teachers' were analyzed, 3 categories (*definition of microbes, microbial variety and activity and immunity)* appear to be as the most commonly and frequently emerging categories and their cognitive structures are framed within these categories (Model 1).



Model 1: The model created through the data collected via the free word-association test, the drawing-writing technique, and the semantic differential attitude scale, "student biology teachers' cognitive structures related to microbe and attitudes".

The Student Teachers' Misconceptions about the Concept of Microbes

One of the most important findings of the study is to determine that the student biology teachers had many misconceptions in each theme of the concept of microbes. Constructivist epistemology endorses the view that eliciting what childrens already know and understand about scientific concepts is important, because prior knowledge affects future learning. Previous ideas should not be ignored if good learning outcomes are to be achieved (Scott, 1987; Selley, 1999) because they can form the basis of conceptual restructuring (Ausubel, 1968) so that meaningful learning can then take place. Therefore, it is essential to determine the participants' misconceptions about the concept of microbes. In this vein, the following include the participants' important misconceptions determined through the free word-association test and the drawing-writing technique:

The misconceptions determined in the theme of "*microbial variety and activity*";

Related to microbial variety; the statement can be exemplified as "*.... they are organisms such as bacteria and viruses that are transmitted through dirty environments"*(P28) and *"They are primitive living beings, bacteria, virus, the flu, and HIV"* (P36). *The* statements provided by the student biology teachers in the drawing-writing technique were limited to the examples of bacteria and viruses as in the answers words provided in the free word-association tests. They provided statements such as microbes are bacteria in pre-school school or bacteria are microbes (Bilaloglu, 2006). In these statements, it was determined that fungi were not provided in the theme of microbial activity and that fungi were not considered as microbes. It was also determined that primary school students did not consider mold and yeast as living organisms (Bulunuz et al., 2008). In alignment with the findings of this study, Simonneaux (2000) and Jones and Rua (2006) state that the participants could not differentiate appropriately between bacteria and viruses in terms of structure, function, and variety and thus had misconceptions.

The misconceptions determined in the theme of *"immunity";*

Considering the related literature, in the study conducted by Jones and Rua (2008), it was argued that primary and secondary school students had inaccurate information about immunity. Likewise, in another study conducted by Byrne and Grace (2010), it was determined that 11-year old students did not have sufficient knowledge about immunity and had misconceptions. Jones and Rua (2008) stated that teachers and students had a great deal of lacking information and a number of misconceptions about such issues as vaccination, immunity system, treatment of diseases, and use of medicine.While the student biology teachers' misconceptions are found to be similar to those of primary, secondary, and teachers.

The misconceptions determined in the theme of *"microbial disease and types of disease";*

Microbes as being pathogenic; *"Microbes cause diseases"* (P27). The participant's statement indicates that the participant considers microbes as pathogenic. However, not all microbes cause illnesses. Some might serve as a factor of illness, but some may not. In the studies conducted by Karadon and Sahin (2010) and Uzunkaya and Ozgur (2011), a great majority of the primary school students considered microorganisms as harmful and pathogenic. Likewise, secondary school students (Bandiera, 2007) and pre-school students (Bilaloglu, 2006) also considered microbes harmful and pathogenic. In general, the participants of the studies associate microbes with diseases (Rene & Gilbert, 1994).

The misconceptions determined in the theme of *"definition of microbes"*;

Considering the answer words provided by the participants in the free word-association test, the word "*invisible*" was provided in the category of "*definition of microbes*". In the study conducted by Kalish (1996b), it was determined that pre-school students considered microbes as some sort of invisible mechanism. Although microbes can be seen through instruments such as microscopes and appear as concrete objects and there are various studies conducted on groups of different ages, the participants state that microbes are invisible living things although they live everywhere.

The misconceptions determined in the theme of *"precautions that can be taken against microbes and ways of treatment";*

Regarding the precautions that are taken against microbes, several statements such as *"I clean the objects that include microbes"* (P31), *"... I can be vaccinated ..."* (P39) and *"I do not get into environments that include microbes"* (P43) are put forward. As microbes live everywhere, it is not possible to clean the

environments where microbes live. Moreover, as microbes live everywhere, it is not possible not to get into the environments where microbes live. Several studies indicated that primary school students felt bad when they heard of microbes or organisms (Karadon and Sahin, 2010), and attached meanings to the concepts of diseases (Eiser, 1989) and health (Bir & Podmore, 1990) through the words, doctors, and hygiene.

The misconceptions determined in the theme of *"the vitality characteristics of microbes and metabolism";*

Regarding how microbes feed themselves, the statement "*When we talk about microbes, those that cannot produce their own food, in other words, heterotrophic ...*" (P27) was put forward. Microbes can be both heterotrophic and autotroph. There are also microbes that can produce their own food. Moreover, there are not only parasite microbes. It is noticed that the participant/participants had inaccurate information about the way microbes feed themselves.

"... except viruses, they multiply in the bodies of living beings" (P19) It was determined that the participants did not provide some characteristics such as propagating their genes and reactions considering the vitality and metabolism of microbes. It is noticed that the participant had inaccurate knowledge since only viruses can multiple in a living organism. They cannot multiple in a nonliving environment. Multiplication is a feature related to vitality.

The misconceptions determined in the theme of *"microbial environment";*

Regarding the environments where microbes live; "*They are microorganisms that multiply in environments lacking hygiene"* (P19). Microbes can multiple both in environments lacking hygiene and all environments. It was stated that pre-school children associated the concept of microbes with the concepts of hygiene and health (Ergazaki et al., 2010). Williams and Gillen (1991) argued that students' fear of microbes was based on the lack of hygiene. It is also argued that students' views of the environments where microbes live are generally the same and linked to the lack of hygiene according to the wide range of intelligences (Uzunkaya & Ozgur, 2011).

The misconceptions determined in the theme of *"symptoms of diseases caused by microbe infection";*

Regarding the symptoms of diseases caused by microbes; *"People sneeze when they are ill, and spread microbes into the environment"* (P2). The symptoms of diseases caused by microbes lead to different reactions by living things such as rubescence, joint disorders and metabolism disorders. People can sneeze as due to a symptom of a disease; however, this does not mean that they will be ill. If the immune system reacts and fights off the microbe, diseases can be prevented.

On the other hand, considering the statements provided by the student teachers, it was found that although they did not have any misconceptions about the themes of "*fields of analyzing and studying microbes*" and "*evolutionary microbiology*", their cognitive structures regarding these themes were not sufficient.

The misconceptions identified in the data collected through the drawing-writing technique were, in general, similar to those determined in the data collected through the free word-association tests. In this context, the important misconception identified in the participants' statements in the drawing-writing technique was determined as follows:

The misconceptions determined in the theme of *"definition of microbes";*

Some misconceptions were determined such as the following "*...They are in some sort of parasites that are pathogenic ...*" (P10)

"*Causing infections and diseases when they invade living things"* (P28)

"Of the tiny living things that cannot be seen with the naked eye, the ones that cause diseases are called microbes" (P8). Not all microbes are pathogenic and all are parasites.

The misconceptions determined in the theme of *"microbial environment";*

"... These microbes live in garbage cans and on street alleys" (P13)

"... spittle" (P16)

"*The trough of fresh-water fountain is microbe-infested"* (P19). These statements indicate that the student teachers viewed only specific environments that disturb humans as the places where microbes live. However, microbes can live anywhere, and it is not right to think that only dirty environments are where microbes live.

The misconceptions determined in the theme of *"microbial variety and activity"*;

Some other misconceptions are *"Microbes are the multiplication of viruses or bacteria transmitted through diseases"* (P28)

"... viruses and bacteria are all microbes" (P33). The student teachers viewed microbes as bacteria and viruses. However, microbes do not include only bacteria and viruses.

The misconceptions determined in the theme of *"microbial disease and types of disease";*

"... diseases come to my mind ..." (P41)

"*... ill people ...*" (P1) are other misconceptions determined. The student teachers' views of the variety of microbial diseases were very limited. In this vein, they associated it only with the words, ill and diseases.

The misconceptions determined in the theme of *"routes of transmission of microbes"*;

"... transmitted to the environment in various ways" (P19)

"*Microbes are transmitted from hands to hands...Microbes spread through coughing...*" (P33) are other misconceptions determined. Given that student teachers based the ways of microbe transmission on the lack of hygiene, it was determined that their knowledge structure was not sufficient.

The misconceptions determined in the theme of *"symptoms of diseases caused by microbe infection";*

"atishoo" (P7)

"*Beginning to cough ...*" (P33), these misconceptions were found to be limited, ordinary, and based on memorization.

The misconceptions determined in the theme of *"the vitality characteristics of microbes and metabolism";*

"Microbes are living things" (P40)

"Microbes are the foundation of vitality. They are the simplest forms of life" (P39), these statements were found to be meaningful, but limited.

The student teachers did not have any misconceptions in the themes of *"immunity"*, *"precautions that can be taken against microbes and ways of treatment"*, and *"the importance of microbes"*; however, their conceptual associations were not found to be sufficient.

In general, the student biology teachers provided abstract shapes (caricatures) that are formless, cells of bacteria, similar to animals and humans. Bryne (2011) found similar findings in the primary, secondary, and high school students' drawings on microorganisms. The pre-school students (Ergazaki et al., 2010) and secondary school students stated that microbes had organs like animals and humans (*hands, mouths, noses*) (Uzunkaya & Ozgur, 2011). Categories were found to be depicting viruses, bacteria, animal cells and others (*diseases, caricature, insects, protozoa, and unclassified*) in the students', teachers', and doctors' drawings (Jones & Rua, 2006). While the student biology teachers' conceptual structures are found to be similar to those of primary, secondary, and high school students, they also bear some similarity to the teachers' and doctors' conceptual structures. Considering the current study, it can be stated that the student biology teachers' conceptual structures are not sufficient. Accordingly, scientific facts should be taught regarding this issue since there are many differences between the concepts used in daily life and scientific concepts (Bandiera, 2007). It is important for student biology teachers to obtain the necessary scientific facts about this issue for their success in their profession considering that they will be teachers of biology.

While the associations determined in the study reflect students' platitudes (image), this situation is discussed in other studies conducted using different concepts and terms (Dikmenli, 2010b). It can be put forward that student biology teachers' cognitive structures about microbes are superficial. The current study revealed that of the 12 categories determined through both the free word-association test and the drawing-writing technique, 3 appeared as the dominant categories, namely, *definition of microbes, microbial variety and activity, and immunity.* The student biology teachers' levels of knowledge were found to be sufficient in these categories; however, it was also determined that they had some misconceptions about the concept of microbes. These results bear some similarity to some of the results of the study conducted by Nagy (1953), Rene and Gilbert (1994), Kalish (1996a, b), Reis et al. (2002), Bilaloglu (2006), Jones and Rua (2006), Byrne and Sharp (2006), Bandiera, (2007), Jones and Rua (2008), Byrne and Grace (2010), Ergazaki et al. (2010), Uzunkaya and Ozgur (2011), and Byrne (2011) on microbes and these results prove to support one another. On the other hand, some of the student biology teachers viewed the concept of microbes as human-centered, some viewed as abstract shapes (*caricature*), some as an invisible component, some as an indispensable component of ecological balance, and some as a defense (*immune*). These results are similar to those indicated by Nagy (1953) and Byrne (2009).

However, as is known, the concept of microbes is the most commonly used concept in many disci-

plines related to each other. It was also noticed that the student biology teachers had some misconceptions in the majority of the categories determined as related to the concept of microbes. Misconceptions are due to the fact that the connections between concepts cannot be structured completely in individuals' minds while they are learning concepts. Unless educators explain the basic characteristics of a concept and the differences between this concept and similar concepts precisely, students at various levels will have misconceptions. Before defining a concept, educators should first explain it reflecting its basic characteristics and help understand its relationship with other concepts (Wandersee et al., 1994). Thus, educators can prevent students from having misconceptions. Moreover, students' cognitive structures, cognitive process skills and academic success should be increased through computer simulations on microbiology (Huppert et al., 2002).

Moreover, according to the results of the current study, it was determined that student biology teachers do not have the expected level of biological literacy since the statements provided to the writing technique revealed that student biology teachers could not go beyond just providing a few platitudes and only focused on the definitions of microbes. It is thought-provoking that these students, who will be biology teachers when they graduate, are not equipped with necessary knowledge. Student biology teachers should develop subjective comments regarding the importance of knowledge of biology, think creatively, ask different questions and process and evaluate knowledge thoroughly. Kinchin (2005) stated that university students avoided providing specific terms that limited the conceptual development in microbiology courses. Thus, teaching concepts and conceptual learning should be attached great importance. As stated by Uno and Bybee (1994), *biological literacy should be based on the fundamental facts such as principles in Biology, important concepts in Biology, how human affect biosphere, scientific research methodology, and the historical review of biological concepts. Subjective comments should be geared towards the biological information in scientific research; creative thinking should be encouraged; different questions should be asked, and knowledge should be both evaluated and processed*". According to the results of the current study, it was determined that although the student biology teachers could make relationships in some of the main categories, though not sufficient; however failed to do so in some of the categories, and had some important misconceptions. Therefore, the conceptual biological literacy that student biology teachers were expected to have could not be determined (Uno & Bybee, 1994). As stated by Kurt et al. (2009), it was determined that the vast majority of the student biology teachers did not have biological literacy. It can be also stated that the student biology teachers' dates did not have biological literacy.

Conclusions

The aim of the current study is to investigate student biology teachers' cognitive structures related to "microbe" using the free word-association test and the drawing-writing technique and determine through which adjectives they express their attitudes towards the concept of microbes. Cognitive structures of student teachers about microbes are important given that these structures will help them to structure the nature of biology and biology related concepts. In the current study, through the data collected using different measurement instruments, the student biology teachers' positive and negative associations related to microbes and their cognitive structures were revealed.

In this vein, as a result of the analysis of the data collected through the free word-association test, 10 categories were determined through the answer words provided by the student teachers, namely, *"microbial variety and activity", "immunity", "microbial disease and types of disease"*, "*definition of microbes*", "*precautions that can be taken against microbes and ways of treatment*", "*the vitality characteristics of microbes and metabolism*", "*microbial environment*", "*fields of analyzing and studying microbes*", "*symptoms of diseases caused by microbe infection*", and "*evolutionary microbiology*. As a result of the analysis of the data collected through the drawing-writing technique, 10 categories were determined through the answer words provided by the student teachers, namely, *definition of microbes, microbial environment, microbial variety and activity, microbial disease and types of disease, immunity, routes of transmission of microbes, precautions that can be taken against microbes and ways of treatment, symptoms of diseases caused by microbe infection, the vitality characteristics of microbes and metabolism and the importance of microbes.* While in the drawing-writing

technique, two different categories, *"the importance of microbes"* and *"ways of microbe transmission"* were determined, in the free word-association test, two different categories, *"fields of analyzing and studying microbes"* and *"evolutionary microbiology"*, and were determined. Moreover, in the drawing-writing technique, 10 categories were determined through analyzing the written statements, while through the drawings only 8 categories were determined. The categories that were not found in the drawings of the participants were *"the vitality characteristics of microbe"* and *"the importance of microbes."*

As a result of the analysis conducted through different measurement instruments while determining common theme categories, it was found that different theme categories also revealed. This result confirms that the study has achieved its aim and indicates that through using different measurement instruments, it is possible to obtain detailed data that both support and differ from one another.

Consequently, one of the most important factors that affect learning is the existing knowledge and conceptual structures. Individuals cannot attach meanings to ideas that do not correspond to scientific facts in these conceptual structures. If the concepts learned are not meaningfully acquired and structured, learning gets more difficult, leading to misconceptions and inaccurate information. Therefore, it is necessary to determine students' conceptual structures, inaccurate and incomplete information, and concepts before starting to teach. Teaching and learning should be planned through suitable strategies, methods, and techniques. Thus, students can code meaningfully new concepts and information in their minds, and create accurate correlation between these concepts and information, which leads to more meaningful and permanent learning.

According to the results, guidelines have been derived in order to enable a better and more fruitful way of teaching about the concept of microbe. e.g.

*Contents from different fields of biology have to be integrated in order to give the students a broader basis for conceptual change about the concept of microbe.

*The results of the present study showed that there was considerable ambiguity related to the concept of microbes. The generalized conceptual structures presented may provide a useful reference point of student biology teachers' ideas, primary, secondary, and high school teachers need to make sure that children understand the scope and limits of concept of microbe, so that this important aspect of the science curriculum is effectively taught and adequately learned.

* A range of learning materials such as charts, leaflets, posters, slide presentations and laboratory materials can be developed to support the teaching of microorganisms' related issues in the primary, secondary, and high school science curriculum.

* In the science courses, microorganisms should be mentioned not only the damage and disease but also the function and structural features. Industrial applications of microorganisms (biotechnology, genetics engineering etc.) are an important issue in context of science-technology-society-environment.

* Furthermore, using a combination of several models and assessment techniques depending on the microbiological concepts might be helpful for teachers to overcome the persistent misconceptions. Teachers should also be explicitly aware of their students' prior knowledge and misconceptions, and should examine why misconceptions occur.

* It was found that they have a lot of alternative concepts. That the alternative concepts are plenty may be due to naive experiences of student teachers and / or due to insufficient and inappropriate teaching of the sections in the biology course programs emphasizing the topic of microbe in the different educational levels of pre-university Turkish education system.

* Also both at university and pre-university levels of education, experts who prepare curriculum should prepare contents that focus on applications for students to learn concepts well. It should be kept in mind that that the biology student teachers who will be teachers in the future take quality education means they will give quality education to their students.

* In teaching concepts, the teachers need to teach students associative thinking so that they can see the micro and macro relationships between concepts. In this context, science courses curriculum may be prepared and teachers may be educated, in accordance with this.

* In teaching the invisible abstract concepts, drawings may be included intensively in every education level for the development of visual images of students. Thus, students' cognitive structures can be formed as more powerful.

* Appropriate course contents may be incorporated into the teacher education programs to gain biological literacy and associative thinking skills with daily life. Thus, students may be more interested in courses; their learning may be facilitated because they could find answers to the biological, social and individual questions they are curious about.

Recommendations for Further Research

The methodology that was employed for this research was productive and yielded valid data. It might be asked, however, whether the approach gave enough scope for student biology teachers to express their own ideas about the concept of microbe. Yes, in some studies (Jones & Rua, 2008; Simonneaux, 2000) data were collected on the concept of microbes using various measurement tools. Data collection instruments such as Likert-type scales, drawing, pictures, and photographs were used in these studies. The current study conducted through using the free word-association test, the drawing-writing technique, and the scale of semantic differential attitudes can be re-conducted with students and teachers using the interview technique in addition to different measurement techniques, which is believed to contribute to the literature. On the other hands, it might require pre-test and post-test evaluations by teacher-researchers. What is needed is a method whereby biology teachers and teacher-researchers can determine in a class setting what their children, students and student teachers know before and after instruction. Evaluation of a variety of pertinent instruments would make for worthwhile research. Because, there is clearly need for more detailed studies, it is also clear that student biology teachers' ideas about the concept of microbe offer rich insight into their conceptions of biological phenomena.

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Received: *June 21, 2013* Accepted: *August 30, 2013*

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