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The Effect of Experimental Study Method on Teaching Basic Microbiology Concepts

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Abstract

In this study, the effects of experimental applications in the teaching of basic concepts in microbiology have been investigated. In the research, one-group pretest–posttest pre-experimental design was used. The study was conducted with 32 pre-service teachers. In the study, pre-service students' understanding of the basic concepts of microbiology, and the effects of microbiology applications on their learning were investigated by a concept test with a pre-test post-test application. Before each experimental application, the pre-service teachers were asked to define the basic concepts in the pre-test concept test. Then, the experimental application was carried out and two weeks later, they were asked to define the same concepts once more. Constructive content analysis method was used in the analysis of the data. Each concept was coded as giving the wrong answer and I don't know the answer 0, missing answer 1, correct answer 2 points. Thus, obtained pre-test and post-test scores were compared by using "Wilcoxon Marked Ranks Test", a nonparametric method. It was determined that laboratory applications were effective on pre-service teachers in obtaining accurate information about concepts they previously did not know and in correcting their misconceptions, if they had any.

Deneysel Çalışma Yönteminin Temel Mikrobiyoloji Kavramlarının Öğretimine Etkisi

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Öz

Bu çalışmada, temel mikrobiyoloji kavramlarının öğretilmesinde deneysel uygulamaların etkisi araştırılmıştır. Araştırmada tek gruplu ön test son test deneysel desen kullanılmıştır. Çalışma, 32 öğretmen adayı ile gerçekleştirilmiştir. Öğretmen adaylarının temel mikrobiyoloji kavramlarına ilişkin bilgileri ve mikrobiyoloji uygulamalarının bu kavramları öğrenmeye etkisi, ön test ve son test olarak uygulanan bir kavram testi ile incelenmiştir. Her deneysel uygulamadan önce, bir ön test ile öğrencilerin verilen temel kavramları tanımlamaları istenmiştir. Daha sonra deneysel uygulama yapılmış ve iki hafta sonra, öğrencilerin aynı kavramları bir kez daha tanımlamaları istenmiştir. Verilerin analizinde yapılandırıcı içerik analizi yöntemi kullanılmıştır. Her kavram için yanlış ve bilmiyorum cevapları 0, eksik cevap 1, doğru cevap 2 puan verilerek kodlanmıştır. Böylece elde edilen ön test - son test puanları, nonparametrik bir yöntem olan "Wilcoxon İşaretli Sıralar Testi" kullanılarak karşılaştırılmıştır. Laboratuvar uygulamalarının öğretmen adaylarının, daha önce bilmedikleri kavramlar hakkında doğru bilgi edinmelerinde ve yanlış anlamalarını düzeltmede etkili olduğu belirlenmiştir.

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Introduction

Many studies conducted in the field of positive sciences in the recent years have shown that students come to science classes with a series of concepts that hinder their learning and comprehension of certain subjects, and thus these studies have focused on students' comprehension of scientific concepts. These studies determined that students make sense of concepts in a way that is not compatible with the accepted scientific knowledge or the way experts of the field make sense of these concepts. Therefore, this difference in the students' perception is defined as "misconception" (Brown, 1992). Misconceptions denote concept structures, which are in conflict with scientific facts but developed or made by individuals (Dikmenli, Türkmen, Çardak & Kurt, 2005). Because they have the potential to hinder learning, they can also be seen as difficulties the teaching of the content of a certain topic (Brown, 1992).

Examining life in all its aspects, biology is quite rich in terms of concepts (Yakışan, Yel & Mutlu, 2009). In addition to having such rich conceptual content, biology is also a highly difficult class to both teach and learn because of its abstract and complex structure (Bahar, Johnstone & Hansell, 1999; Çimer, 2012). The fact that the concepts to be taught in biology courses are both high in numbers and of foreign origins make it difficult to teach them. Microbiology, a sub-branch of biology is one of the especially difficult fields to teach due to its content. It is harder for students to comprehend the working principles of studies on microorganisms compared to studies conducted on other groups of living beings. Thus, it is unavoidable to have misconceptions related to microbiology. In various studies on students' comprehension of biology concepts, it was determined that they have misconceptions: misconceptions were detected on such topics as diffusion, osmosis (Odom, 1995), photosynthesis (Anderson, Sheldon & Dubay, 1990; Amir & Tamir, 1994; Tekkaya & Balcı, 2003), respiration (Songer & Mintzes, 1994; Mann and Treagust, 1998; Yürük and Çakır, 2000), circulatory system (Yip, 1998), genetics (Cavello & Schafer, 1994; Stewart, Hafner & Dala, 1990; Kılıç, Atav, Sağlam, 2006; Kılıç & Sağlam, 2014), general biology (Tekkaya, Çapa & Yılmaz, 2000), and enzymes (Atav, Erdem, Yılmaz & Gücüm, 2004; Selvi & Yakışan, 2004). Classical methods such as lecturing and question-answer are not sufficient either in teaching concept-rich topics or getting rid of misconceptions. Studies also show that misconceptions are hard to get rid of by using traditional teaching methods and these methods are not sufficient in helping students develop correct concepts (Tekkaya & Balcı, 2003). Knowledge specifically in science branches like microbiology, where there is constant new development, is hard to acquire by traditional methods and wrong learnings can take place. One of the most significant reasons for this is that students cannot relate these concepts in their minds. In order for students to have the correct pile of knowledge, they should have a mental structure related to the concepts of microbiology and there should be a meaningful learning. Meaningful learning takes place when newly-learned concepts come together and connect with previous concepts in a conscious and orderly way (Güneş, Güneş & Çelikler, 2006). At this point, "structuralism," which explains how learning occurs and how individuals discover knowledge, comes to the fore (Colburn, 2000a). According to this approach, knowledge is actively structured in the person's mind by being related to previous knowledge and experiences (Anderson, 1992). It is first of all necessary to reveal students' previous knowledge in order to provide them meaningful learning (Pines & West, 1986; Tsai & Huang, 2002). Thus, revealing a person's formulation of the relationship between concepts that they have as well as putting forth their cognitive structures related to this would be the most effective way to determine whether a meaningful learning has taken place or not. Several techniques, which have been made for this reason, such as constructed grid, word relation test, branched tree, conceptual maps, and analogy (Bahar, 2003) are being used.

Along with traditional teaching methods, methods exclusive to the field such as observation and experiment have a central position in biology courses (Köhler, 2010, p. 146). In biology teaching, it is assumed that experiments are an important element of scientific research and information, and therefore should be a part of the courses. If students are carrying out an experiment either by themselves or in groups, it is called a real experimental course. This is generally named as "student experiment" (as well as a real experiment). There are also demonstration experiments in contrast to student experiments (Berck, 1999, p. 119). Experiments carried out in biology courses give students the opportunity to test scientific concepts and thus, learn better, and also help them to have an idea about scientific research methods and develop a positive attitude towards them (Berck, 1999, p. 120).

It is thought that an applied teaching of the basic concepts related to microbiology is effective for correct understanding of the concepts and the correct learning of the many topics that these concepts provide the basis for. Students come across these basic concepts in the microbiology, genetics, and reproduction subjects, and these concepts then constitute the basis for the comprehension of related topics. When basic concepts are learned incorrectly or incompletely, the learning related concepts is also negatively affected. The fact that placing newly acquired knowledge in the mind by relating it to previously existing ones enables meaningful and permanent learning has already been put forth in many studies (Willerman & MacHarg, 1991; Venville, Gribble & Donovan, 2005). The correctness of the knowledge students have determines their comprehension and has an effect on their later learning. Positive sciences contains abstract and difficult to understand consecutive topics. When a concept, which is part of consecutive topics, cannot be learned, it is known that then the teaching of other concepts, which are related to this, cannot be effectively taught (Gökdere & Orbay, 2005).

In this study, the aim was to determine the students' comprehension levels of basic microbiology concepts and to identify what kind of meanings they have attached to these concepts. To this end, applied teaching modules, which consist of microbiology concepts students have trouble with, were constructed and the aim was to get students to reach the right cognitive structure related to these concepts.

Theoretical Framework

Concepts are mental tools which enable an individual to think. They make it possible for us to understand the physical and social world and to communicate meaningfully. Understanding concepts is necessary to understand principles, to solve problems, and to understand the world (Senemoğlu, 2013, s. 513). Developing concepts is a type of learning. Concepts enable an individual to distinguish a group of beings, events, ideas, and processes from other groups, and they also help him form relations with other groups, beings, events, ideas, and processes (Çaycı, Demir, Başaran & Demir, 2007). Concepts are the units of thought, and they are the pillars of knowledge. Relations between concepts constitute scientific principles (Yağbasan & Gülçiçek, 2003). Misconception can be defined as the incompatibility between what an individual knows about a thing and the scientific view on it (Treagust, 1988). These ideas that students have are logical and consistent in their view although most of the time they are not acceptable in science (Gilbert, Osborne & Fensham, 1982). These concepts of the students, which are not considered as scientifically correct, are called various things such as misconception (Huddle & Pillay, 1996; Nakhleh & Krajcik, 1994), alternative concepts (Gonzalez, 1997; Schoon & Boone, 1998), subjective ideas (Caramazza, McCloskey & Green, 1981; Fensham, 1988, s. 82), general sensation concepts, spontaneous knowledge (Eryılmaz & Tatlı, 2000; Treagust, 1988), pre-comprehension (Novak, 1988), children's science, and intuitional ideas (Bell, Gilbert & Osborne, 1983). Misconceptions can happen during formal and informal teaching activities. Each individual has a different life, and thus each individual has a different misconception from others. It is known that many misconceptions cannot be eliminated by using traditional teaching methods (Fisher, 1985). In the present study, experimental method will be used in eliminating misconceptions, and each pre-service teacher will be active during the teaching modules so that they can face their own misconceptions and correct them. In literature, several reasons are given for the misconceptions such as; teachers not having enough knowledge on the topic, students having insufficient pre-knowledge and incorrect prejudgments, methods being teacher-centred and based on rote learning, topics in the teaching programs being unrelated and not related to daily life, and course books having incorrect information and not being updated in regular intervals (Tekkaya et al., 2000). Applied teaching is seen as a strong way that could provide an alternative solution to eliminate the aforementioned reasons of misconceptions.

Individuals who have misconceptions find it difficult to reach the next learning level in a healthy way. That is why there are many studies conducted to determine and correct the misconceptions in science teaching. In many of the studies in the field of biology education, it was determined that there are various misconceptions in students from different levels of education on such concepts as photosynthesis (Amir & Tamir, 1994; Anderson et al., 1990), respiration (Mann & Treagust, 1998; Songer & Mintzes, 1994); Yürük & Çakır, 2000), digestion (Çakıcı, 2005), circulatory system (Sungur, Tekkaya & Geban, 2001; Yip, 1998), genetics (Brown, 1990; Cavello & Schafer, 1994; Stewart et al., 1990). When related literature is examined, it is noteworthy that there is no such study on the concepts related to microbiology. However, there are studies on misconceptions concerning bacteria, microorganisms, virus, and fungi. Study results usually indicate that virus and bacteria are confused with one another (Dumais & Hasni, 2009; Larson et al., 2009), and that there are misconceptions about the vitality characteristics of virus and bacteria (Kurt & Ekici, 2013; Romine, Barrow & Folk, 2013; Romine, Siegel & Roberts, 2009) and in which microorganisms can be found as well as what their effects are (Jones & Rua, 2006; Uzunkaya, 2007). Eser Çetin, Özarslan, and Işık (2015) researched the biology teacher candidates' views on germs by using a drawing-writing technique and found that the teacher candidates did not have scientific perceptions on germs as they described them by using words such as monster and alien, and drew them as either facial figures or cartoon characters. The same study also puts emphasis on the inclusion of microscope observations, videos, posters etc., in lessons for the prevention of this type of anthropomorphic misconceptions. Studies about the concepts of microorganisms and bacteria have reported student perceptions such as seeing them as harmful and disease-causing rather than useful, having no other purpose, and thinking that bacteria are non-living germs (Eser, Çetin, Özarslan & Işık 2015; Karadon & Şahin, 2010; Kurt, 2013; Kurt & Ekici, 2013; Uzunkaya & Özgür, 2011). Hürcan Gürler & Önder (2014) have determined that 7th grade students are unable to distinguish between the concepts of bacteria and virus, and cannot associate them with daily life. While Kurt (2013) has determined in his study that biology teacher candidates have misconceptions that microbes are invisible. Aydın (2015), in a study they conducted with high school students determined that students associate the concept of microorganisms more with bacteria and viruses and that they have correct knowledge about the places microorganisms are present, and that the number of students with inaccurate ideas was very low, unlike the other studies. Bektaşlı (2018) determined that science teaching and biology teacher candidates had inadequate knowledge about the definition, structural features, and general features of archaebacteria, bacteria, and protista, and that they had many misconceptions. Within the scope of the project, misconceptions will be tried to be eliminated via the experimental method in laboratory environments, which will be designed by taking into consideration not only the misconceptions determined by the researchers but also the misconceptions presented in literature.

Method

Research Design

In the study, one-group pre-test–posttest pre-experimental design was used. In experimental design, whether or not the variable being tested had an effect was studied (Creswell, 2014, s. 219; Christensen, Johnson, & Turner, 2014, s. 258). This study was done in order to evaluate the pre-service teachers' comprehension levels of the basic concepts of microbiology and the effect of microbiology applications on learning of concepts. It is a qualitative study in which the data collected from the participants was in the form of written expression. It was carried out with a pre-test post-test inclusive concept test, the two evaluation results were digitized, and compared in this study.

Study Group

In order to determine the study group, one of the non-random sampling methods, "purposive sampling method" was used. In the purposive sampling method, it is essential to select the situations that are thought to have rich information to serve the purpose of the research (Yıldırım & Şimşek, 2006). In this study, in which the effect of experimental study method on teaching microbiology concepts was examined, was conducted with the participation of 32 biology pre-service teachers taking the "Microbiology Laboratory" course during the fall semester of 2016-2017 academic year. Microbiology laboratory is a course given in the first semester of 4th grade in the curriculum of the pre-service teachers in the sample.

Data Collection

Data were collected with four concept tests that were applied as pre-test and post-test. The concepts included in these tests were in the scope of topics covered by microbiology course and were determined by the researchers by considering the scope of topics covered in the course. The structure and scope validity of the identified concepts as basic microbiology concepts and their inclusion in the content of the applications were provided by the consensus of the researchers. In the tests, the participants were asked to write explanations against next to the given concepts. Experimental applications and concepts related to these experiments for each concept test are given below:

1. In the first concept test on the applications of topics titled "Microbiology Laboratory Order and Biosecurity" and "Sterilization," the concepts of *microorganism, bacteria, pathogen, endospore, sterilization, disinfection, pasteurization* and *contamination* were given, respectively.
2. In the second concept test on the applications of topics titled "Aseptic Techniques" and "Media Used in the Production of Microorganisms," the concepts were *aseptic, medium, bacterial culture, and bacteria planting.*
3. In the third concept test on the applications titled "Staining of Microorganisms" and "Culture Methods of Microorganisms," concepts were *isolation of microorganisms, inoculum, inoculation,* and *incubation.*

4. In the fourth concept test on the applications of the topics titled "Counting of Microorganisms", "Fungi, Viruses, Protozoon," and "Food Microbiology," the concepts of *virus, fungus, yeast,* and *mold* were used.

During the data collection process, students were asked to define the concepts given in the concept tests. Before moving onto laboratory applications concerning the concepts, pre-tests were applied to students. In both the pre-test and post-test, the students were given approximately 3 minutes for each concept. Likewise, two weeks after each application post-tests were also applied. Applications lasted 10 weeks including tests. The experiments were conducted twice every week, each application lasting 40 minutes. During the applications, the experiments were carried out by following the confirmatory method. In the confirmatory method, the process that the students are to follow (method, material) is given by the teacher and the students follow the instructions step by step and reach a conclusion (Colburn, 2000b). In this study, explanations about the application to be conducted were given to prospective teachers after theoretical information about the subject had been given. After the application process had been explained in detail, the materials and tools to be used have been introduced and presented for their use. It was ensured that the students themselves actively participated in the process and carried out the practices themselves. At the beginning of the semester, 4 working groups were determined and all applications were carried out by group work.

Data Analysis

Answers pre-service teachers gave in pre-tests and post-tests were transferred to computer environment and were evaluated with the help of MAXQDA, a qualitative data analysis program. In the analysis of the data, "constructive content analysis" (Mayring, 2002, s. 118) method was used. In constructive content analysis, a classification was done by checking whether the data fit the categories determined by the researcher. In this study, correct definitions expected for each of the 20 concepts were determined by the researchers before analysis, and pre-service teachers' answers were categorized as *incorrect, incomplete*, and *correct answer* or as *does not know the answer.* The coding of the data entered into the MAXQDA program according to these categories was done by one of the researchers, controlled by another, the opinions were discussed, and the data were arranged. Thus, the reliability of data analysis was increased. Each concept is coded by giving the wrong answer and I do not know the answer 0, missing answer 1, correct answer 2 points. Thus, the pre-service teachers were assessed over 40 points from the applications. The quantitative data obtained by scoring in this way were analyzed in the SPSS 23 program. In the comparison of pre-test and post-test scores of prospective teachers, firstly, Kolmogorov-Smirnov tests and normal distribution curves were examined to determine whether they were suitable for normal distribution. It was found that both pre-test and post-test scores calculated as a result of 4 applications and pre-test and post-test scores for each concept were not distributed normally. As a result, the non-parametric Wilcoxon Signed Ranks Test, which is a non-parametric method, was used to compare the total pre-test and post-test scores and the pre-test and post-test scores for each concept considering the lack of normal distribution and the small sample size. In this test, the same scores are kept out of the analysis and analyzed over the smallest sequence totals (Büyüköztürk, 2006, s .162). For this reason, the missing data of pre-service teachers in the applications have been entered into the SPSS program as the same data value with the previous or next score. Thus, the missing data was excluded from the analysis and the margin of error in the analyses was reduced.

Research Ethics

The research was carried out in accordance with the volunteerism of the participants. The participants were informed about the scope of the study and the right to leave the study at any time. The content of the study does not have any threats to the physical or mental health of the participants. Personality rights and private information of the participants were protected.

Findings

The total mean score of the answers given by the pre-service teachers to the concepts of microbiology was calculated as 15.75 for the pre-test and 30.60 for the post-test out of 40. The results of the Wilcoxon Signed Ranks Test for significance of this difference between pre-test and post-test scores are given in Table 1.

Table 1. Results of the Wilcoxon Signed Rank Test for the Difference between the Pre-test - Post-test Total Scores

Post-test - Pre-test	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	0	.00	.00	-4.94	.000
Positive Ranks	32	16.50	528.00		
Ties	0				

When Table 1 was examined, it was seen that there was a significant difference between the pre-test scores of the pre-service teachers regarding the microbiology concepts ($z = -4.94$, $p < .000$). It was seen that the difference observed when order points of difference scores were taken into consideration was favorable to posttest scores accordingly, it could be said that microbiology laboratory applications were effective in the learning of the concepts related to microbiology and microbiology laboratories of the pre-service teachers. Whether there was a meaningful difference between the answer given to each concept in the application in the pre-test and post-test was examined with the Wilcoxon Test which was calculated separately for each of the concepts Findings related to the tests were given in Table 2.

Table 2. Results of the Wilcoxon Signed Rank Tests for the Differences between the Pre-test -Post-test Scores of Microbiology Concepts

Concepts	Post-test – Pre-test	N	Mean Rank	Sum of Ranks	z	p
Microorganism	Negative Ranks	0	0	0	-2.83	.005
	Positive Ranks	8	4.50	36		
	Ties	24				
Bacteria	Negative Ranks	2	4.50	9	-1.73	**.083**
	Positive Ranks	7	5.14	36		
	Ties	23				
Pathogen	Negative Ranks	1	8	8	-2.30	.022
	Positive Ranks	10	5.80	58		
	Ties	21				
Endospore	Negative Ranks	1	8.50	8.50	-3.84	.000
	Positive Ranks	19	10.61	201.5		
	Ties	12				
Sterilization	Negative Ranks	0	0	0	-4.32	.000
	Positive Ranks	22	11.50	253		
	Ties	10				
Disinfection	Negative Ranks	0	0	0	3.42	.001
	Positive Ranks	14	7.50	105		
	Ties	18				
Pasteurization	Negative Ranks	1	4	4	-2.83	.005
	Positive Ranks	11	6.73	74		
	Ties	20				
Contamination	Negative Ranks	0	0	0	-5.07	.000
	Positive Ranks	28	14.50	406		
	Ties	4				
Aseptic	Negative Ranks	0	0	0	-3.76	.000
	Positive Ranks	16	8.50	136		
	Ties	16				
Medium	Negative Ranks	0	0	0	-2.64	.008
	Positive Ranks	8	4.50	36		
	Ties	24				
Bacterial culture	Negative Ranks	1	8	8	-2.04	.041
	Positive Ranks	9	5.22	47		
	Ties	22				
Bacteria planting	Negative Ranks	0	0	0	-3.31	.001

	Positive Ranks	13	7	91		
	Ties	19				
Isolation of microorganisms	Negative Ranks	0	0	0	-3.45	.001
	Positive Ranks	14	7.50	105		
	Ties	18				
Inoculum	Negative Ranks	0	0	0	-4.58	.000
	Positive Ranks	21	11	231		
	Ties	11				
Inoculation	Negative Ranks	0	0	0	-4.69	.000
	Positive Ranks	22	11.50	253		
	Ties	10				
Incubation	Negative Ranks	2	12.50	25	-3.85	.000
	Positive Ranks	21	11.95	251		
	Ties	9				
Virus	Negative Ranks	0	0	0		
	Positive Ranks	20	10.50	210	-4.18	.000
	Ties	12				
Fungus	Negative Ranks	0	0	0	-4.82	.000
	Positive Ranks	26	13.50	351		
	Ties	6				
Yeast	Negative Ranks	2	9	18	-3.51	.000
	Positive Ranks	18	10.67	192		
	Ties	12				
Mold	Negative Ranks	1	8	8	-3.63	.000
	Positive Ranks	17	9.59	163		
	Ties	14				

Table 2 shows, for each concept, the number of people that showed positive change (positive ranks), the number of people that showed negative change (negative ranks), and the number of people that did now show any change (ties).When these numbers in the table were examined, it was seen that 8 people in the concept of microorganism, 7 people in the concept of bacteria, 10 people in the concept of pathogen, 19 people in the concept of endospore, 22 people in the concept of sterilization, 14 people in the concept of disinfection, 11 people in the concept of pasteurization, 28 people in the concept of contamination, 16 people in the concept of aseptic, 8 people in the concept of medium, 9 people in the concept of bacterial culture, 13 people in the concept of bacteria planting, 14 people in the concept of microorganism isolation, 21 people in the concept of inoculum, 22 people in the concept of inoculation, 21 people in the concept of incubation, 20 people in the concept of virus, 26 people in the concept of fungus, 18 people in the concept of yeast, and 17 people in the concept of mold had positive changes in the post-test compared to the pre-test.

When Table 2 is examined once again, it shows that in the concepts of *bacteria* (2 persons), *pathogen* (1 person), *endospore* (1 person), *pasteurization* (1 person), *bacterial culture* (1 person), *incubation* (2 persons), *yeast* (2 persons) and *mold* (1 person), there is a negative change between the pretest and posttest in a small number of people. When these negative expressions were examined, it was seen that some pre-service teachers answered these concepts correctly in the pre-test and incompletely in the post-test.

When whether negative changes were statistically significant was examined, it was concluded that the changes experienced in all concepts other than the concept of bacteria were meaningful. The changes in response to the concepts of endospore, sterilization, contamination, aseptic, inoculum, inoculation, incubation, virus, fungus, yeast and mold are at $p < .001$ level; microorganism, disinfection, pasteurization, nutrient, bacterial cultivation, microorganism isolation, $p < .01$; Changes in response to the concepts of pathogen and bacterial culture were found to be significant at $p < .05$ level.

Frequencies of students' correct, incomplete and wrong (or I don't know) answers to the concepts are given in Table 3. When Table 3 is examined, it can be seen that ratio of correct answers is significantly higher in the post-test compared to the pre-test.

Table 3. Frequencies and Percentages of Answers Given to Concepts in the Pre-test and Post-test

Answer* / Concept	Pre-test C	Pre-test I	Pre-test W/K	Post-test C	Post-test I	Post-test W/K
Microorganism	20 %62.5	10 %31.3	2 %6.3	26 %81.3	6 %18.8	-
Bacteria	11 %34.4	19 %59.4	2 %6.3	15 %46.9	17 %53.1	-
Pathogen	22 %68.8	4 %12.5	6 %18.8	31 %96.9	-	1 %3.1
Endospore	4 %12.5	18 %56.3	10 %31.3	23 %71.9	2 %6.3	7 %21.9
Sterilization	5 %15.6	17 %53.1	10 %31.3	23 %71.9	9 %28.1	-
Disinfection	4 %12.5	12 %37.5	16 %50	15 %46.9	9 %28.1	8 %25
Pasteurization	5 %15.6	15 %46.9	12 %37.5	12 %37.5	16 %50	4 %12.5
Contamination	2 %6.3	2 %6.3	28 %87.5	29 %90.6	1 %3.1	2 %6.3
Aseptic	5 %15.6	1 %3.1	26 %81.3	18 %56.3	4 %12.5	10 %31.3
Medium	23 %71.9	2 %6.3	7 %21.9	31 %96.9	-	1 %3.1
Bacterial culture	6 %18.8	7 %21.9	19 %59.4	11 %34.4	8 %25	13 %40.6
Bacterial planting	14 %43.8	11 %34.4	7 %21.9	25 %78.1	6 %18.8	1 %3.1
Isolation of microorganisms	8 %25	5 %15.6	19 %59.4	21 %65.6	3 %9.4	8 %25
Inoculum	1 %3.1	-	31 %96.9	22 %68.8	-	10 %31.3
Inoculation	3 %9.4	-	29 %90.6	25 %78.1	-	7 %21.9
Incubation	5 %15.6	-	27 %84.4	23 %71.9	1 %3.1	8 %25
Virus	10 %31.3	17 %53.1	5 %15.6	30 %93.8	1 %3.1	1 %3.1
Fungus	1 %3.1	11 %34.4	20 %62.5	12 %37.5	19 %59.4	1 %3.1
Yeast	3 %9.4	13 %40.6	16 %50	9 %28.1	20 %62.5	3 %9.4
Mold	12 %37.5	12 %37.5	8 %25	26 %81.3	3 %9.4	3 %9.4

*C: frequency of correct answers, I: frequency of incomplete answers, W/K: frequency of wrong and "I don't know" answers

Changes related to each concept in Table 3 are summarized briefly below:

The ratio of correct answers concerning the concept of microorganism increased from 62.5% to 81.3%. The ratio of incomplete answers decreased from 31.3% to 18.8% and the ratio of incorrect/"I don't know" answers, which were 6.3% in pre-test, were completely gone.

The ratio of correct answers concerning the concept of bacteria increased from 34.4% to 46.9%. That of incomplete answers decreased from 59.4% to 53.1%, and the ratio of incorrect answers and the "I don't know"s, which were 6.3% in the pre-test, were gone.

The ratio of correct answers concerning the concept of pathogen increased from 68.8% to 96.9%. That of incomplete answers, which were 12.5% in the pre-test, were gone. The ratio of incorrect and “I don’t know” answers which were 18.8% decreased to 3.1%.

The ratio of correct answers concerning the concept of endospore increased from 12.5% to 71.9%. The ratio of incomplete answers which were 56.3% in the pre-test decreased to 6.3% and the ratio of incorrect and “I don’t know” answers, which were 31.3%, decreased to 21.99%.

The ratio of correct answers concerning the concept of sterilization increased from 15.6% to 71.9%. That of incomplete answers, which were 53.1% in the pre-test, decreased to 28.1%, and the ratio of incorrect and “I don’t know” answers, which were 31.3%, came down to zero.

The ratio of correct answers concerning the concept of disinfection increased from 12.5% to 46.9%. That of incomplete answers which were 37.5% in the pre-test decreased to 28.1%; however, the ratio of incorrect and “I don’t know” answers which were 50% in the pre-test decreased merely to 25%.

The ratio of correct answers concerning the concept of pasteurization increased from 15.6% to 37.5%. That of incomplete answers which were 46.9% in the pre-test increased to 50%, and the ratio of incorrect and “I don’t know” answers decreased from 37.5% to 12.5%.

The ratio of correct answers concerning the concept of contamination increased from 6.3% to 90.6%. The ratio of incomplete answers decreased from 6.3% to 3.1% and the ratio of incorrect and “I don’t know” answer answers, which were 87.5% in the pre-test, decreased to 6.3%.

The ratio of correct answers concerning the concept of aseptic increased from 15.6% to 56.3%. That of incomplete answers increased from 3.1% to 12.5%; the ratio of incorrect and “I don’t know” answers decreased from 81.3% to 31.3%.

The ratio of correct answers concerning the concept of medium increased from 71.9% to 96.9%. The ratio of incomplete answer came down to zero from 6.3%. The ratio of “I don’t know” and incorrect answers decreased to 3.1% from 21.9%.

The ratio of correct answers concerning the concept of bacterial culture increased from 18.8% to 34.4%. That of incomplete answers increased from 21.9% to 25%, and the ratio of incorrect and “I don’t know” answers decreased from 59.4% to 40.6%.

The ratio of correct answers concerning the concept of bacteria planting increased from 43.8% to 78.1%. The ratio of incomplete answers decreased from 34.4% to 18.8%, and the ratio of incorrect and “I don’t know” answers decreased from 21.9% to 3.1%.

The ratio of correct answers concerning the concept of microorganism isolation increased from 25% to 65.6%. That of incomplete answers decreased from 15.6% to 9.4%, and the ratio of incorrect and “I don’t know” answers decreased from 59.4% to 25%.

The ratio of correct answers concerning the concept of inoculums increased from 3.1% to 68.8%. No incomplete knowledge was detected in either the pre-test or the post-test concerning this concept. The ratio of incorrect and “I don’t know answers decreased from 96.9% to 31.3%.

The ratio of correct answers concerning the concept of inoculation increased from 9.4% to 78.1%. No incomplete knowledge was detected in either the pre-test or the post-test concerning this concept. The ratio of incorrect and “I don’t know” answers decreased from 90.6% to 21.9%.

The ratio of correct answers concerning the concept of incubation increased from 15.6% to 71.9%. No incomplete knowledge was detected in the pre-test, however 3.1% incomplete knowledge was detected in the post-test concerning this concept. The ratio of incorrect and “I don’t know” answers decreased from 84.4% to 25%.

The ratio of correct answers concerning the concept of virus increased from 31.3% to 93.8%. That of incomplete answers decreased from 53.1% to 3.1%, and the ratio of incorrect and “I don’t know” answers from 15.6% to 3.1%.

The ratio of correct answers concerning the concept of fungus increased from 3.1% to 37.5%. The ratio of incomplete answers increased from 34.4% to 59.4%, and the ratio of incorrect and "I don't know" answers which were 62.5% in the pre-test decreased to 3.1%.

The ratio of correct answers concerning the concept of yeast increased from 9.4% to 28.1%. That of incomplete answers increased from 40.6% to 62.5%, and the ratio of incorrect and "I don't know" answers decreased from 50% to 9.4%.

The ratio correct answers concerning the concept of mold increased from 37.5% to 81.3%. The ratio of incomplete answers decreased from 37.5% to 9.4%, and the ratio of incorrect and "I don't know" answers decreased from 25% to 9.4%.

Endospore, sterilization, pasteurization, contamination, aseptic, inoculum, inoculation and incubation concepts for which there is a significant increase in the number of correct answers are the ones for which the number of correct answers is significantly low in the pre-test. This indicates that students have come across these concepts for the first time and/or may have misconceptions based on their prior incomplete and/or incorrect knowledge for these concepts. The increase in the number of correct answers after the application indicates that pre-service teachers have shown a significant level of success and that their incorrect and incomplete knowledge, which may be misconceptions, has been eliminated to a great extent.

In order to illustrate in what way and how the frequency changes indicated in Table 3 are experienced, Table 4 gives an example of the answers of pre-service teachers for each concept, which show positive changes to the pre-test final test.

Table 4. Examples of Pre-service Teachers' Answers

Concepts	**Answers in pre-test***	**Answers in post-test***
Microorganism	*"Very small units found in the body"* (PT6**,W)	*"Very small organism that cannot be seen by naked eye"* (PT6, I)
Bacteria	*"Small organisms which cannot be seen by naked eye that are everywhere. Has many reproduction sites."(PT26, I)*	*"They are very small microorganisms. There are many different species of bacteria. They can be cultivated in the laboratory. They can be found everywhere and can easily reproduce." (PT26, C)*
Pathogen	*"The process of inspecting the living thing when an unwanted object is detected on it." (PT40, W)*	*"Disease causing organism." (PT40, C)*
Endospore	*"Do not know"(PT11, K)*	*"The process in which bacteria in the vegetative form protects itself when there are no suitable conditions and going back to the vegetative form when the conditions are suitable." (PT11, C)*
Sterilization	*"Protecting a structure in a sterile environment without compromising its structure and losing its function" (PT3, W)*	*"The process in which microorganisms are cleansed from all vegetative forms and spores." (PT3, C)*
Disinfection	*"It is the cleaning of an environment with chemical substances." (PT31, I)*	*"It is the process of purifying an environment from disease causing bacteria." (PT31, C)*
Pasteurization	*"Pasteurization of a chemical substance."(PT1, W)*	*The process of bringing something to high temperatures and suddenly coiling it down. Getting rid of microorganisms this way … Used in milk. The milk is sprayed into a medium of 140 ^{0}C and suddenly cooled down after 2-3 seconds. " (PT1, I)*
Contamination	*"Do not know"(PT16, K)*	*"The mixing of unwanted organisms or substances to the experiment due to the*

		environment not being sterile when conducting the experiment." (PT16, C)
Aseptic	*"Dilution of substances by the addition of water." (PT20, W)*	*"Purified from microorganisms, no contamination" (PT20, C)*
Medium	*"Cultures in which we create microorganisms and keep them under necessary conditions" (PT19, W)*	*"Environment created for the repercussions of microorganisms (excluding intracellular parasites)" (PT19, C)*
Bacterial culture	*"Culture medium prepared for production of bacteria under appropriate conditions" (PT1, W)*	*"The sample of bacteria produced in a medium" (PT1, C)*
Bacteria planting	*"Do not know"(PT28, K)*	*"Transfer of bacteria into sterilised medium under aseptic conditions." (PT28, C)*
Isolation of microorganisms	*"Do not know "(PT39, K)*	*"Separation of certain microorganisms from a population of microorganisms." (PT39, C)*
Inoculum	*"Do not know "(PT33, K)*	*"Microorganism to be cultivated." (PT33, C)*
Inoculation	*"Do not know "(PT36, K)*	*"Cultivating a microorganism." (PT36, C)*
Incubation	*"Substances that prevent some bacteria from reproducing."(PT5, W)*	*"The production of the planted microorganisms under suitable conditions." (PT5, C)*
Virus	*"Small living things that we cannot see with naked eye." (PT34, W)*	*"Nucleic acids which are covered by a protein coat." (PT34, C)*
Fungus	*"Are fungi. They can be in harmful or useful forms." (PT14, I)*	*"Non-photosynthetic eukaryotic microorganisms. They have cell walls like plants and centrosomes like animals." (PT14, C)*
Yeast	*"There are yeast bacteria. Some bacteria species (yeast bacteria) can cause yeast production by reproducing in that environment." (PT26, W)*	*"Single celled fungi are called yeasts." (PT26, I)*
Mold	*"Do not know"(PT38, K)*	*"They are fungi in the form of mycelium that breed by forming multicellular strands." (PT38, C)*

*C: correct answers, I: incomplete answers, W: wrong answers, K: "I don't know"
**PT: Pre-service teacher (for coding of participants)

Discussion and Conclusion

There are many studies which emphasize going beyond traditional methods and make various suggestions such as using visual material, making practical experiments, relating the topics to daily life, and using techniques that would interest students in order to ensure a meaningful learning and to overcome the learning difficulties concerning concepts related to biology (e.g. Coştu, Karataş & Ayas, 2003; Çimer, 2012; Güneş, Şener Dilek, Demir, Hoplan & Çelikoğlu, 2010; Tekkaya et al., 2000). Based on these suggestions, in the present study, how pre-service teachers' knowledge about 20 key concepts of microbiology change at the end of the applied teaching with experiments, was investigated. During this applied teaching, teacher candidates were made to personally carryout the experiments in groups of 2-3 people (preparation of the medium, sterilization of the medium on autoclave, preparation of glassware for sterilization and their sterilization, use of flame and inoculation loop, cultivation of microorganisms from pure culture, isolation of microorganisms from various sources, examination of colony morphology, examination of bacteria, fungi, yeast samples under microscope, gram staining etc.) and abstract concepts were made to be concrete and able to be experienced by them. It is thought that study results will make important contribution to literature since conceptual structures of pre-service teachers are highly relevant in order for them to construct many other concepts related to microbiology and biology. In addition, it is thought that information related to these concepts affect daily life behaviours. Jones, Gardner, Lee, Poland and Robert (2013) reported in their study, in which they determined the knowledge and behaviours of university students before and after microbiology courses, that there was a positive change in students' knowledge levels and behaviors. It has been observed that the students who have taken microbiology course had an increased - perception about the risks that may cause microbial contamination and started to take measures to prevent microbial contamination especially in the behaviours such as using a public telephone, touching a faucet in a public bathroom, handling money, borrowing soap from a friend while camping and, working in the dirt without gloves and taking out the trash. Therefore, it is considered that having the right information about the concepts related to microbiology is an important step for a change in the behaviours of people.

When findings are examined, it can be seen that the answers of pre-service teachers changed in general from "I don't know" to "correct" for *contamination, aseptic, inoculum, inoculation*, and *incubation,* which are concepts they have either heard for the first time or do have said they do not know the meaning of in the pre-test. In this case, it can be argued that the lab applications had an effect on their getting correct knowledge on concepts they have no knowledge of before. Moreover, it can be seen that the number of correct answers in the post-test increased for virus, fungus, yeast, mold, endospore, sterilization, disinfection, and pathogen for which they had given incorrect or incomplete answers in the pre-test. In other words, lab applications contributed to the correct comprehension of these concepts. It is also evident that for the microorganisms and bacteria, of which pre-service teachers somehow have some idea beforehand as these may be come across in daily life, the correct, incorrect or incomplete answers of pre-service teachers do not change much and continue more or less the same at the end of post-test as well. It was determined that there is some change in the positive direction for the incomplete and incorrect answers as far as the concept of microorganism is concern; however, it was also seen that the knowledge on the concept of bacteria does not change and the misconception continues for this concept. When literature is examined, it can be seen that there is a high level of misconception for such concepts as bacteria and fungus (e.g. Dumais & Hasni, 2009; Kinchin, De-Leij & Hay, 2005; Kurt & Ekici, 2013; Tekkaya et al., 2000). For instance, in a study conducted by Kurt and Ekici (2013), too, it was determined that pre-service teachers have misconceptions related to the concept of bacteria, and it was indicated that the primary reason for this is that bacteria is a difficult concept to learn since it is related to many fields. At the end of the study, it was emphasized that employing topic-appropriate teaching strategies, methods, and techniques would be beneficial in students learning the concepts properly. In the present study, while the applied teaching was very effective in the learning of such concepts as virus, fungus, yeast, and mold, as indicated by Kurt and Ekici (2013), it was insufficient in eliminating misconceptions about bacteria *which is related to various different fields.* One of the possible reasons for the misconceptions related to these concepts is the teachers. Özyürek (1983) argues that teachers underestimate and simply these concepts because they have already developed them and this affects the teaching process negatively. Moreover, it is noteworthy that pre-service teacher try to explain the given concepts by using daily speech expressions and find it difficult to express them in an academically correct way. Canpolat, Pınarbaşı, Bayrakçeken and Geban (2004) indicated that many studies put forth how using colloquial language in teaching science concepts may cause misconceptions in students and argued that teachers should use full and correct definitions of concepts as much as possible. At this point, teachers at primary and secondary schools have a huge responsibility for students to learn concepts properly, especially during their first encounter with the concepts they also see in daily life. It is necessary for teachers to have a basic foundation related to the concepts they teach, they should not cause misconceptions and they should be able to relate new concepts to daily life through practical applications (Güneş et al., 2010).

Misconceptions teachers have are considered to be one of the reasons of the misconceptions of students (Sander, 1993). In this respect, it is highly important to determine and eliminate the misconceptions of pre-service teachers, who will be tomorrow's teachers. Since misconceptions are permanent and continuous, it is difficult to eliminate them through traditional teaching methods, and also they are not sufficient in developing correct concepts in time (Tekkaya et al., 2000). Thus, results of this study are promising in order to eliminate misconceptions. As indicated in the findings, many incorrect answers were turned into correct answers after the laboratory applications. The fact that laboratory activities are not given sufficient precedence in our country makes it difficult for many concepts to be taught. Classical methods such as lecturing and question-answer are not enough to teach concepts. Indeed, findings of the study show that it is useful for pre-service teachers to use concepts during experiments and make applications experiencing their knowledge directly. It will be helpful for the correct teaching of concepts if teachers make experiments appropriate for applied teaching in other topics where misconceptions are prevalent. Moreover, if pre-service teacher are informed about the study results on misconceptions in biology education and about how they could eliminate misconceptions during their education, it would be an important step in preventing misconceptions, which are difficult to correct.

In this study, the effect of experimental study method on the biology teacher candidates' learning of microbiology concepts was investigated. With microbiology experiments it has been determined that the teacher candidates have amended their wrong or missing knowledge determined before the experiments significantly after knowledge the experiments. It can be suggested to conduct this study, which was conducted in a single-group pre-test post-test experimental design, in a control-group pre-test post-test experimental design. In this way, the group where the same concepts are given only theoretically can be compared with applied learning group. The use of parametric tests in the analysis of the data from the experimental group with pre-test post-test control-group experimental design will also increase discourse power. The determination of the student expressions for concepts with the open-ended concept test used in this study is important for understanding the level of scientific language used by the students. However, it is also possible to consider studies using two- or three-stage concept tests for ease of application and evaluation.

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Statement of Publication Ethics

During the writing process of this study scientific, ethical and citation rules were followed; no falsification was made on the collected data and this study was not sent to any other academic media for evaluation.

Conflict of Interest

We declare no conflict of interest in preparing this article.

Researchers' Contribution Rate

Authors	Literature review	Method	Data Collection	Data Analysis	Results	Conclusion
Esin Atav	☒	☒	☒	☒	☒	☒
Dilek Sultan Acarlı	☒	☒	☒	☒	☒	☒

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Appendix 1

Bartın University Journal of Faculty of Education
The Ethical Issues Declaration Form For Authors

Article Title	The Effect of Experimental Study Method on Teaching Basic Microbiology Concepts
Discipline	Biology Education
Type of Article	Research article
Year of Data Collection	2016-2017 (fall semester)

As the author of the article, I declare in this form that scientific and ethical rules are followed in this article and that the article does not require the permission of ethical committee for the reason that the content of the study does not have any threats to the physical or mental health of the participant. The research was carried out in accordance with the volunteerism of the participants. The participants were informed about the scope of the study and the right to leave the study at any time. Personality rights and private information of the participants were protected.

Date 08/05/2020

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