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THE EFFECTS OF APPLIED BIOTECHNOLOGY EDUCATION FOR TEACHERS AND PRE-SERVICE TEACHERS ON THEIR BIOTECHNOLOGICAL PERCEPTIONS

M.S.
2015

FATİH UNIVERSITY

The Graduate School of Sciences and Engineering

Master of Science in
Genetics and Bioengineering

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By

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A thesis submitted to

the Graduate School of Sciences and Engineering

of

Fatih University

in partial fulfillment of the requirements for the degree of

Master of Science

In

Genetics and Bioengineering

May 2015
Istanbul, Turkey

APPROVAL PAGE

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M.S. Thesis – Genetics and Bioengineering
May 2015

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ABSTRACT

Modern biotechnology has made great progress in recent years and is progressing rapidly every day. Depending on their level of development, many countries invest in the Biotechnological research and increase training activities in this area. In our country, despite the growing biotechnological developments in recent years, investment in research and education is insufficient (Erbas, 2008). In education programs, not enough attention is given to theoretical and practical applications of biotechnology (Peksen, 2009).

As a result of teachers' not having sufficient knowledge and equipment about biotechnology and teachers, students also cannot have sufficient infrastructure in this regard. In today's world, with the increasing prevalence of biotechnology and its adaptation into the daily life, students seem to have limited knowledge on issues related to biotechnology (Bal, 2007; Özel, 2009). In this study, Classroom Teachers, Science and Technology teachers and biology teachers and candidate teachers in these areas were provided in groups with practical training on basic biotechnology for 9 days in the laboratory. At the beginning and end of this training; the biotechnology questionnaire prepared for the participants was applied in the form of a pre-test and post-test, and the results were analysed with SPSS data analysis program.

Following the evaluation of the questionnaires, a significant increase in positive attitudes and knowledge of the participants on biotechnology has been observed.

Keywords: Biotechnology, Biotechnology Education

UYGULAMALI BİYOTEKNOLOJİ EĞİTİMİNİN ÖĞRETMEN VE ÖĞRETMEN ADAYLARININ BİYOTEKNOLOJİK ALGILARI ÜZERİNE ETKİLERİ

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Yüksek Lisans Tezi – Genetik ve Biyomühendislik
Mayıs 2015

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ÖZ

Modern biyoteknoloji son yıllarda büyük bir gelişme kaydetmiştir ve her geçen hızla ilerlemektedir. Pek çok ülke gelişmişlik düzeyine bağlı olarak Biyoteknolojik çalışmalara yatırım yapmakta ve bu alandaki eğitim çalışmalarını arttırmaktadır. Ülkemizde, son yıllarda artan biyoteknolojik gelişmelere rağmen araştırma ve eğitimlere yapılan yatırımlar yetersiz kalmaktadır (Erbas, 2008). Öğretim programları içerisinde, biyoteknolojiye yönelik teorik ve pratik uygulamalara yeteri kadar yer verilmemektedir (Peksen, 2009). Öğretmenlerin biyoteknoloji konusunda yeterli bilgi ve donanıma sahip olmamasının bir sonucu olarak, öğrenciler de bu konuda yeterli alt yapıya sahip olamamaktadırlar. Biyoteknoloji konularının giderek yaygınlaştığı ve günlük yaşamın içerisine adapte olduğu günümüzde, öğrencilerin biyoteknoloji ile ilgili konularda kısıtlı bilgi düzeyine sahip olduğu görülmektedir (Bal, 2007; Özel, 2009).

Bu çalışmada, Sınıf Öğretmenleri, Fen ve Teknoloji Öğretmenleri ve Biyoloji öğretmenleri ile bu alanlardaki öğretmen adaylarına gruplar halinde 9 gün boyunca laboratuarda temel biyoteknoloji konuları ile ilgili uygulamalı eğitimler düzenlenmiştir. Bu eğitimlerin başlangıcında ve sonunda katılımcılara hazırladığımız biyoteknoloji anketi ön-test ve son-test olarak uygulanmış ve sonuçlar SPSS veri analiz programıyla değerlendirilmiştir.

Anketlerin değerlendirilmesi sonucunda, katılımcıların biyoteknolojiye olan olumlu yaklaşımları ve bilgi düzeylerinde anlamlı bir artış olduğu görülmüştür.

Anahtar Kelimeler: Biyoteknoloji, Biyoteknoloji Eğitimi

In memory of my mother

ACKNOWLEDGEMENT

My endless thanks and respect go to my well beloved teacher Assoc. Prof. Mustafa Fatih ABASIYANIK, for whose patience and attention I remained grateful during my graduate studies, who tried to guide me with his constructive criticism the right way.

I offer my sincerest thanks to my valuable teacher Assoc. Prof. Süleyman İNCEKARA, an expert in the field, who supported and guided me with his experience through my studies.

And I offer my sincerest thanks to my dear father Hüseyin ÖZBEK, who always believed in me and strongly supported me during my studies, and to my dear husband Yavuz ÇİMEN, who was always there during the times that I had to take from our children throughout my studies.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION

ANOVA	Analysis of variance
df	Degree of freedom
DNA	Deoxyribonucleic acid
F	F value
f	Frequency
GAPDH	Glyceraldehyde 3 -phosphate dehydrogenase
GDO	Genetically modified organism
N	Data Number
PCR	Polymerase chain reaction
RFLP	Restriction fragment length polymorphism
SDS-PAGE	Sodium dodecyl sulfate polyacrylamide gel electrophoresis
sig	Significance level
SPSS	Statistical package for social science
ss	Standard deviation
X	Arithmetic average

CHAPTER 1

PROBLEM STATEMENT

1.1 INTRODUCTION TO THE RESEARCH PROBLEM

The development of biotechnology highlights the impact of science and technology on the community. This impact of science is, of course, not new, but it has been brought into sharp focus by many recent developments in this burgeoning science” (Schibeci, 2000).

There is not sufficient research and discussion in this area, and therefore little is known about the developments in biotechnology, especially in Turkey. Nevertheless, the fact that the people do not know much about or are not interested in this area causes them to be subject to further risks in this biotechnology (Erbas, 2008).

Another important reason for the slow progress in biotechnology in our country is also the deficiencies in education. Theoretical and practical applications of biotechnology are not given enough space in the curriculum (Peksen, 2009; Senler, 2006; Darcin and Turkmen, 2006).

Science and Technology, Biology and Class teachers' serious lack of knowledge about biotechnology in our country is shown by researches (Senler, 2006).

As a result of the fact that teachers do not have sufficient knowledge and equipment in biotechnology and students in this regard cannot have adequate background in this area. Although biotechnology issues are becoming increasingly common and are adapted into everyday life nowadays; it is observed that students have a limited knowledge level about the issues related to biotechnology (Bal, 2007; Özel, 2009).

By giving more space to work in the laboratory in curriculum, experimental experiences of candidate teachers should be increased and thus they should be ensured to use experimental methods in their professional life (Altun, 2011; Uzunkol, 2012; Çelik, 2010).

The above quotations from different literature indicate the overall problems that have been stemmed from the emergences of biotechnology, its use in education, and reflections to Turkey. The world has been changing rapidly and getting smaller along with this change. This is great importance for every country to synchronize with the world by means of scientific researches and advances in the information era, in which we live. Innovations are required in the system of education, together with global communication and increasing knowledge. With advancing technology, the system of education is going beyond memorization and depending on patterns. Therefore, the significance of learning by seeing, feeling and experiencing is increasing by leaps and bounds (Molebash, 1998).

Along with the rapid developments taking place in the field biotechnology in recent years, it has become a significant scientific field. Consequently, the education of biotechnology has also gained importance. Education is the key element which forms the level of development and welfare of a society. Therefore, the development, renovation and up-to-datedness of the teachers, who play a key role in education, are indispensable for the next generations. Correspondingly, the level of knowledge, attitudes and assessments towards biotechnological developments of the teachers who will provide training in biotechnology come into prominence (Kayabas, 2008).

1.2 DOMINANT EDUCATIONAL PROBLEMS ABOUT BIOTECHNOLOGY

The biotechnological developments in 21^{st} century have led to an important scientific revolution in such a level as to change the lives of people. It has created an endless source to fight against diseases and environmental disasters, and to supply the needs of fast growing world population (Lui, 1999). Serious studies and investments have been made in the biotechnology field in developed countries and these countries have gained dominance in biotechnology both economically and socially. However, the countries which are developing including Turkey haven't been able to spare enough budgets for research and they have fallen behind the developed countries in biotechnology applications (Kiymaz, 2000). For this reason, although the importance and applications of biotechnology have been growing rapidly throughout the world, the reflections in our country are rather slow.

Depending on the fact that the reflections of developments in biotechnology are rather slow in Turkey, critical deficiencies in education have also surfaced. Biotechnology education, according to the education programme of Ministry of National Education, appears in Science and Technology class in the curriculum of secondary education, 8^{th} grades as "Cell Division and Genetics" and in the 11^{th} grade curriculum as "Genetics, Genetics Engineering and Biotechnology" (MNE, 2006). While the sufficiency of biotechnology education is under discussion, it gains importance to know whether the level of knowledge of Science and Technology, Biology and Class teachers, and teacher candidates’ competency who will provide training for biotechnology. Considering the developments on the topic is rather new, and the graduate programmes for training teachers don't give enough places to biotechnology subjects. So, it is apparent that the knowledge and skills of teachers isn’t sufficient. Additionally, the highest ranking teachers providing education at the moment in Turkish education system started their jobs after 80's in which the level of biotechnology education was quite low compared to the present. Considering the teachers’ lack of educational opportunities and practical applications to keep them up to date, it is clear that their level of knowledge and skills on biotechnology is insufficient. As a matter of fact, in some scientific studies intended for candidate teachers of Science, it was revealed that the knowledge levels of teachers were not enough and recommendations were suggested to increase their competencies in biotechnology (Senler, 2006; Yüce, 2009; Darçin, 2006; Darçın: 2011).

It is important for teachers to know about biotechnology’s social, cultural and ethical aspects, as well as the developments in biotechnology. However, it is crucial for people to have knowledge about science and technology in order to make better social and personal choices, and to distinguish between the useful and harmful elements for themselves. Some studies have shown that people’s attitudes towards biotechnology are directly dependent on their knowledge about biotechnology. In other words, better knowledge of biotechnology results in more positive attitudes towards biotechnology. In this case; the knowledge levels of the Science and Technology teachers and teacher candidates, who will provide biotechnology education, have great importance. It is estimated that the knowledge and awareness level of the students that these teachers could influence with their sufficiency in this field will increase (Usak, 2008).

Biotechnology plays an increasing and influential role in people's daily life; therefore, there should be a public consciousness of biotechnology. Since this consciousness can be created with the help of a comprehensive biotechnology education, teacher training on biotechnology especially gains importance. Depending on the teachers and candidate teachers' lack of knowledge about biotechnology shows that there is a serious gap in this field. A theoretical and practical biotechnology education is essential for teachers and candidate teachers. However, there is not a systematic education provided in this direction. The lack of this education leads to problems with ethical use of biotechnology and an insufficiency in using critical thinking abilities, and therefore, creates a reason for lacking with biotechnology field at a level of students, teachers, and society (Kidman, 2006).

Students' interest in biotechnology is strictly based on the competency of the teachers in this subject. In general, teachers are limited to the curriculum and they don't update their biotechnological knowledge. As a result of this, students become aware of biotechnological developments through daily news in a more experimental, interrogative, and application-based way. Due to the fact that the teachers are limited to curriculum, multi-directional and curious learning eagerness of the students are blunted. In this case, it is clear that the students who are willing to learn biotechnology will not be able to take this chance due to the negative attitude and incompetence of the teachers about this subject (Kidman, 2006).

Biotechnology is an interdisciplinary field including engineering, medicine, science and technology, agriculture, and their applications. Therefore, it is an applied science that can be learned with laboratory studies and the role of laboratory applications in biotechnology education is of great importance. Starting out from here, what should be discussed is whether the content of "Genetics and Biotechnology" class in the curriculum of candidate science and technology teachers is sufficient or not, and, whether the applied laboratory education is on par with today's standards or not. The lack of laboratory-centered education in Turkey’s primary and secondary education systems, insufficient laboratory experience and shallow practical knowledge of the teachers who are teaching biotechnology among the most significant problems in biotechnology education.

Biotechnology which expands its information content with numerous innovative researches, is a constantly renovated field which comes into prominence. The rate of research, application and education in biotechnology is one of the key elements that are indicative of the development level of a country. On account of the fact that biotechnology has grown rapidly for the last few years, it takes time for societies to adapt to this development. But, the sooner a society integrates to this rapid development, the faster progresses it will make. The way to this integration led by the teachers and the teacher education in this subject are among the problems with the highest priority. Teachers as the key elements of education systems, play a critical role in shaping the next generations. A competent teacher model in the biotechnology field means accessible and useful information for students and thus, students and society will become more awarer of biotechnology (Celikten, 2003).

1.3 CONCLUSIONS

In the light of all the problems mentioned, it seems that there is a serious deficiency in teaching biotechnology in our country. It is primarily possible to eliminate the lack of education with the training of teachers, who are the chief factors of education. It is essential for teachers to receive both theoretical and practical 'in-service' and 'pre-service' training in the topics of biotechnology and this training and education needs to be updated periodically. In this study, the effects of biotechnology training on teachers will be observed through pre-test and post-test measurement techniques, preparing a practical biotechnology training program for teachers and candidate teachers, in order to address the problems described above. Thus, the importance and necessity of biotechnology training at this point will be tried to be recognized.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Depending on its rapid development in recent years, the interest in biotechnology is increasing every day. It is very important to understand and explain biotechnology, which covers many scientific fields and is a branch of science within life. Education is the most important factor for a society to be composed of individuals aware of biotechnology and equipped in it.

First used in 1919 by Karl Ereky; the definition, meaning and scope of the term "biotechnology" at that time, have undergone considerable change with the implementation of modern and developing technologies in this area. Biotechnology, which has evolved a rapidly and provided many benefits in the last 10-15 years, is defined in the OECD (Organisation for Economic Co-operation and Development) report published in 1982 as "technology that is applied to the processes in which basic science and engineering principles and raw materials are transformed into products with the help of biological tools" This new field is successfully implemented in many areas such as biology, biochemistry, environment, energy, pharmaceutics, cosmetics, medicine, veterinary medicine, agriculture, forestry, stockbreeding, food, mining and industry and realizes the dreams of mankind step by step (Kaynar, 2010).

This study will be about how biotechnology is defined in various sources, and will state the pros and cons of using biotechnology concerning the application areas. The focus will be on biotechnology education; the studies regarding biotechnology education in the world and our country, the knowledge levels and attitudes of teachers and students on biotechnology, and the deficiencies and gaps to be filled in education will be discussed.

Practical training in the fields of biotechnology will be given to teachers and teacher candidates, and an evaluation will be made through pre-test and post-test applications by measuring the effects of this training on teachers and teacher candidates. In this evaluation; the shortcomings in biotechnology training in our country, the insufficiencies in the curriculum and necessities of in-service and pre-service biotechnology education for teachers will be discussed.

2.2 LITERATURE CITED

An overview of the literature will be given in this section.

2.2.1 Biotechnology Definition and Scope

The definition of biotechnology has changed over the years with revolutionary inventions in this area. Biotechnology, in the service of humanity about 8000 years, has started to gain a modern definition, alongside the traditional one, with the discovery of DNA in the 1950's. Traditional biotechnology is defined as using live cells or their products to get new products (http://www.nal.usda.gov/research-and-technology/ biotechnology; http://www.ncbiotech.org/biotech-basics/what-is-biotechnology; http://www.bio. org/node/517; Hoffman, 2006; FAO, 2010). Modern biotechnology, on the other hand, is a technology that modifies the genetic material of living cells in order to get new products or make them gain new functions using specific methods and that depends on biology developing new technologies and products through bio-molecular and cellular processes (Career Pathways: Focus on Biotechnology, 2006; An introduction to biotechnology, AMGEN; Agricultural Biotechnology, 2010; Eu, 2010; FAO, 2010; WHO, 2005).

Modern biotechnology, which realizes technological and innovative developments today and covers genetic engineering, is a science that includes all the necessary research to cure diseases, to reduce the environmental damage we cause, to produce solutions to hunger, to consume less energy, and to have a secure, clean and more efficient industrial production (http://www.bio.org/node/517). Modern biotechnology, which completely covers the fields of agriculture, industry, environment and health, utilizes biological processes to solve problems or to obtain useful products. Colour codes are used in classification of biotechnology, with its numerous sub-areas. Ease of classification is provided by defining each sub-area with a specific color.

Table 2.1 Colour codes of biotechnology.

RED	Health, medical and diagnostic biotechnology
GOLD	Bioinformatics and nanobiotechnology
YELLOW	Food biotechnology and nutirition science
GREEN	Agricultural and environmental biotechnology
BLUE	Aquaculture, coastal and marine biotechnology
PURPLE	Business biotechnology
BROWN	Arid zone and desert biotechnology
BLACK	Bioterorism, biowarfare, biocrimes and anti-crop biotechnology
GREY	Classical fermentation and bioprocess technology
WHITE	Gene-based bioindustries

A part of the colour codes shown in Table 2.1 is described as follows:

Green Biotechnolog; It covers the application area of modern plant engineering. Herbicides and resistance developers for insects, fungi and viruses are manufactured here through biotechnological methods Gene technology is one of the most important areas of green biotechnology. Gene technology allows transferring specific genes from one plant species to another, and thus, constitutes the basis for developing resistance.

Blue Biotechnology; It generally refers to the ocean and water biotechnology, and the protection of various ocean creatures and ensuring the continuation of species can be given as examples.

Grey Biotechnology; It is concerned with the field of environmental technology. Here, biotechnology processes are utilized in soil treatment, waste water treatment, waste gas and exhaust air cleaning, and recycling garbage and other wastes.

Red Biotechnology; Red biotechnology, which covers the medical field, is considered as the most important application area of biotechnology. This field plays an increasingly important role in the development of new drugs like those of cancer. It is of great importance to use DNA chips, biosensors etc. for diagnosis in terms of biotechnology.

White Biotechnology; It is also known as industrial biotechnology and is the design and use of organisms in a way to produce various useful chemicals or to destroy harmful and polluting chemicals through various enzymes.

2.2.2 History of Biotechnology

The need for labor starting to decrease with the industrial revolution has been completely terminated with developments in biotechnology. The industrial age which began with discovery of important energy sources such as underground storage of coal, fuel oil and natural gas is coming to an end. With the Industrial Revolution, people have urbanized by leaving their villages and lands and begun working in factories. Continents have been furnished with rails, miles of roads have been made along with the poles forming the telegraph and telephone wires. Gas-powered cars have been produced, buildings made of steel, aluminum and glass have been built forming concrete foundations.

Scientists and engineers have begun are to launch a new and important works, serious studies in physics and chemistry have been conducted. Looking into the world of atoms and electrons, quantum mechanics and relativity theory were created. Physicists and engineers sent people to the moon and brought them back, chemists have made efforts to produce synthetic materials. Plastics were invented, and petrochemicals, fertilizers and protective agents against agricultural pests were discovered. Invention of X-ray equipment and MRI by engineers, medical vaccinations, production of antibiotics and drugs were among the historical developments. The industrial age, conducted with abundant and cheap energy obtained by extraction from nature is replaced with the biotechnology age (Rifkin, 1998; Kiper, 2013).

Biotechnology, which started to develop with the combination of genes by isolating, identifying and assembling in different combinations, that is, the recombinant DNA technique, has progressed rapidly with the production of genetically designed tissues, organs and organisms. The creation of the human genome, new genetic successes, DNA chips and genetically engineered embryos are the milestones in biotechnology. Computers provide the environment for organization and communication to manage the genetic information forming that forms the biotechnology economy. The computer and genetic technology exist in a new and powerful technological reality together (Rifkin, 1998).

In 1985, Ralph Brinster et al., placed human growth hormone genes into mouse embryos. Mice showed twofold faster development, and were two times larger than an ordinary mouse. These mice, described as "Super Mouse" were able to pass on their HGH genes to the next generation (Hammer et al. 1985). Scientists, who isolated the luciferase genes in the firefly in 1987, placed them into the genes of a tobacco plant. As a result, tobacco leaves shined (Wet et al. 1987) Gene transformation has allowed for the attainment of desired properties with the new recombinant organisms formed as a result of inter-species gene transfer.

An important biotechnological step was taken in the mining industry in 1980. In a study conducted to attain copper, which is very difficult to extract with conventional metalworking techniques, a particular type of bacteria was sprayed to the low percentage copper ore, an enzyme, that left almost pure copper and ate the salt in the ore, was produced (O'Toole, 1980). In 1994, scientists used microbial agents to break down the minerals surrounding the gold to increase the rate of recovery. Removing mineral residues and the low percentage of ores from metals is performed in a more economical manner by means of microorganisms (Frederick, 1994). Experiments on renewable resources have been made to replace coal, fuel oil and natural gas. Scientists planned to produce ethanol from sugar and grains to produce fuel (Rifkin, 1998). The feature of E.coli bacteria to consume agricultural residues, wood shavings and solid waste and to transform them into ethanol was improved (Frederick, 1994). In 1993, Sommerville made an important work in the chemical industry as a result of his studies. A gene that produced a plastic was placed into mustard seedlings, thereby plastic was produced by the plant (Rifkin, 1998).

The first commercial food product developed by placing genes was grown in 1966. More than three-quarters of Alabama cotton crop was genetically engineered to kill pests. In 1977, US farmers planted 8 million acres of genetically engineered soybeans and more than 3.5 million acres of genetically engineered corns (Hotz et al. 1997).

The first genetically engineered insect was a species of predatory mites released in Florida in 1996. Researchers at the University of Florida planed that recombinant mites eat other mites which devastated strawberries (Rifkin, 1998). In the late 1980s, vanilla was obtained from plant cell culture at laboratory by a biotechnology company in California. Vanilla came to be produced in a commercial scale by isolating the gene encoding the metabolic pathway of vanilla flowers that grew in a bacteria bath and yielded products (Rifkin, 1998).

Many changes taking place in agriculture were followed by the revolutionary changes in livestock sector. Animals were transformed into chemical plants to produce drugs. Transgenic animals were formed as organ donors for transplantation into human. In 1988, scientists developed a new genetically engineered type of pigs, which was brought to market seven weeks earlier and 30% more efficient than normal pigs (Ford, 1988).

In 1996, to produce the drugs classified as anti-cancer, Genzyme Transgenics Company announced the birth of a transgenic goat called Grace, which bore the generative gene to produce a monoclonal antibody. In 1997, a group of researchers in Virginia announced the birth of a transgenic calf called Rosie (Johannes, 1997). This calf was carrying the human protein alpha-lactalbumin, nutritious for premature babies, in its milk (Graves, 1997).

In 1997, Wilmut and colleagues announced the first cloned mammal. He replaced the DNA in a normal sheep egg with the one that he took from the glands in the breast of a sheep, and placed this egg into another sheep's uterus and developed it there. With the birth of Dolly, it has understood that it is possible to produce identical copies of a mammal that cannot be distinguished from the original. Subsequently, Campbell et al announced the birth of a cloned sheep called Polly that carried human genes in its biological code. Researchers placed a human gene into the related cells in a sheep fetus grown in the laboratory, and cloned a sheep from the growing cells (Koata, 1997).

2.2.3 Applications of Biotechnology

There are numerous studies related to the application areas of biotechnology. Biotechnology contains such technological application areas as; bioprocessing technology, monoclonal antibodies, cell culture, recombinant DNA technology, cloning, protein engineering, biosensors, nano-biotechnology and microarray.

These applications are;

Medical Applications; Development of early diagnosis and treatment methods for diseases, recombinant DNA, synthetic peptides, recombinant vaccine production, development of new drugs, cloning and storage of artificial cells, tissues and organs for treatment purposes, storage of stem cells to prevent and reduce genetic diseases and development of gene therapy applications for cancer.

Agriculture and Livestock Applications; Development of plant species resistant to biological agents (bacteria, viruses, fungi, etc.) that adversely affect the yields of agricultural products, making plants more convenient without the use of environmentally damaging chemical drugs in these studies, obtaining better quality products by enriching the useful materials in plants, development of new varieties of strategically important plants such as wheat, cotton, corn, tomatoes etc. in particular through hybridization method and realization of artificial seed production, protecting animals against diseases using recombinant drugs and vaccines, obtaining better quality meat, milk and wool, increasing the growth rate, and the development of parasite-and-disease-resistant animals.

Food Applications; Conventional fermentation processes (bread, yogurt, cheese, beer making, etc.), enzyme technologies and the production of genetically modified foods.

Industrial Applications; Production of protein and antibody through recombinant techniques, development of vaccines, hormone production, DNA analysis in criminal studies, development of plant species suitable for adverse conditions in agriculture, development of new drug molecules and studies to develop diagnostic kits for rapid diagnostic methods using specific genes, nucleotides and peptides.

Environmental Applications; Bioremediation, producing clean energy such as, biogas and commercial bioethanol from biomass, bio-hydrogen and electricity production as a clean and renewable source, the elimination of toxic elements in wastewater and hazardous waste by microorganisms, bio-mining and producing nanoparticles to clean contaminated soil and water (Agricultural Biotechnology, 2010; Pinstrup & Cohen 2000; CCST, 2002; UNCTAD, 2002; Baianu, 2004; TUBITAK, 2004; Young, 2004; WHO, 2005; Van Eenennaam, 2006; IUCN, 2007; Tang & Zhao, 2009; FAO, 2010).

There are very important social, economic and environmental benefits of biotechnology, as a modern and advanced technology. However, it should also be highlighted that it may lead to such problems as affecting human and environmental health adversely, destroying socio-economic structure, breaking biodiversity and varieties of classic products, and damaging traditional, ethical and religious values (Ozgen et al., 2007).

Biotechnology has got many advantages such as medical product development, production of edible vaccines, protection against diseases, maintaining high efficiency and sustainability, improve the quality by better food production, conservation of water and soil, a decrease in the use of pesticides (Pinstrup & Cohen, 2000; Carpenter, 2001; CCST, 2002; Rappert, 2008).

Besides all their advantages, biotechnology applications contain risks within themselves. The issues such as the lack of control in GMO's, failure to clearly guarantee the safety of biotechnological products, decline in biodiversity, threatening the ecological balance, intervening in living organisms, concerns about animal health and ethical ones like religious debates are of the significant risks that biotechnology carries (Trewavas, 1999; Pinstrup & Cohen 2000; Carpenter, 2001, CCST, 2002; UNCTAD, 2002; Wieczorek, 2003; Young, 2004; Winter, 2006; IUCN, 2007; Rappert, 2008; Eu, 2010).

2.2.4 Biotechnology Education

Along with the rise of biotechnology as a science determining the future, the importance of biotechnology education has also increased. It is very important that all individuals in society should have knowledge and comment about biotechnology, and make decisions on risky fields of biotechnology (Schibeci, 2003).

Research on biotechnology education is divided into three as community oriented, student-oriented and teacher oriented. The knowledge level of students and teachers in the field of biotechnology and their attitudes and perceptions on this issue have been evaluated by researches, together with those measuring the perceptions and attitudes of society towards biotechnology.

Studies conducted for teachers and student teachers, who will provide biotechnology education to students and will also affect the society at this point, are of great important. When we look at the studies of this nature around the world;

It is emphasized that training a teacher who is equipped in biotechnology and competent in content and application areas is very important in terms of training quality students who can define biotechnology well and are aware of its advantages and disadvantages (Gelamdin et al., 2013) It has been seen that there are compliance problems between teachers and students and the biotechnology subjects that attract students are not given to them by teachers as they are not in the curriculum (Steele, 2004; Kidman, 2009, 2010). Due to the deficiency in teacher training curriculum; Hong Kong Science Educators stated that the curriculum should be enriched with the fundamental subjects in biotechnology, and teachers should also be well-equipped in ethical and debated issues and develop their knowledge about biotechnology (Lui et al., 1999). It has been highlighted in another study that there are problems related to the method of learning biotechnology with teachers, and that they have problems teaching this interdisciplinary area to students, and recommendations to improve the pedagogical content knowledge about biotechnology have been made (Moreland et al., 2006).

It was seen that primary school science teacher candidates did not lean towards the genetic studies on people and animals while supporting the genetic modification on plants and micro-organisms, and it was recommended that necessary regulations should be made in the teacher training curriculum and the lack of knowledge be resolved. (Chabalengula et al., 2011) Although biotechnology has begun to be considered as the main content by technology by educators, it is not applied at a sufficient level in technological educational programs (Kwon et al., 2009). Although teachers showed positive attitudes towards biotechnology regarding agricultural education, which is one of the most important applications of biotechnology, it was stated that they had inadequate levels of knowledge and sources and that the curriculum did not cover sufficient information on biotechnology (Boone et al., 2006).

Serious shortcomings of the education in our country have emerged depending on the fact that the reflections of biotechnological developments in Turkey are slow. Biotechnology education, according to the curriculum of Ministry of Education, is included in the Science and Technology course of Secondary 8th Grade curriculum as "Cell Division and Genetics" and in the 11th Grade curriculum as "Genetics, Genetic Engineering and Biotechnology" (MNE, 2006).

In a scientific study carried out for science teacher candidates, teachers appeared to have an insufficient level of knowledge and recommendations were presented to improve that (Senler, 2006). In another study, teachers candidates were shown to have a middle-level knowledge through the "Genetics and Biotechnology" course featured in the curriculum in 2006-2007 academic year, however, it was also stated that it varied depending on the university they were attending and their geographic locations prior to the university education, and recommendations to eliminate these differences were made (Yuce 2009). In another specific study; it was indicated that teachers did not have adequate knowledge about gene transfer and genetically modified plants, but their overall knowledge about biotechnology seemed to be sufficient. Additionally, it was seen that teacher candidates exhibited a positive attitude towards biotechnological methods other than animal and plant modification (Darcin, 2011). In another study, it was stated that teacher candidates did not have sufficient level of knowledge about biotechnological concepts and practices, and recommendations to add extra topics to the content of biotechnology in science education programs in Turkey and to create pre-service and in-service biotechnology programs were made (Darcin & Turkmen, 2006).

2.3 GAPS AND VOIDS

There are a limited number of studies on biotechnology education in the world and in our country. The level of knowledge and attitudes toward biotechnology were measured through surveys in researches intended for teachers, teacher candidates and students. In addition to this; the problems in the training of teachers and students were mentioned with particular emphasis on the deficiencies in the curriculum.

Assessments were made by giving practical biotechnology training for teachers in America and the UK (http://www.ncbe.reading.ac.uk; Borgerding, 2013). Researches related to biotechnology education were conducted in European Union countries (http://www.eibe.info), Australia (www.biotechnology.gov.au) and New Zealand (www.biotechlearn.org.nz), and websites that include theoretical and visual educational resources were brought into use for teachers. In our country, the researches conducted are aimed at survey evaluations for the knowledge and attitudes towards biotechnology. There is not an institution that organizes training and offers an adequate level of resources and materials for teachers and teacher candidates.

Ours is the first and only case study in Turkey that aims to fill this gap by providing comprehensive pre-service and in-service applied biotechnology training for teachers. An important step will be taken with the results obtained from the practicality of this training.

2.4 CONCLUSION

The distribution of genetically modified living beings and the foods derived from them are rapidly increasing in the world. The short and long term effects of these products especially on human health are poorly understood. Creating new products bearing new features through gene modification, which is one of the main applications of biotechnology, is an area that needs to be explored and positioned correctly in terms of application and ethics.

It is of great importance for the future to train individuals with sufficient knowledge about biotechnology, which affects the life of every individual of the society and covers all areas of life increasingly each day. A society composed of individuals knowing the advantages and disadvantages of biotechnology, making research, with the potential to decide what is risky for him/herself, and most importantly having an objective perspective is today an important indicator of development. At this point, the necessity and importance of biotechnology education become apparent.

It is necessary that all sections of society should be given training on biotechnology. The knowledge levels of teachers on this issue, who educate the community and are the most important of these segments, are of great importance. Making innovative arrangements for biotechnology training of teachers is a very important step to be taken in terms of keeping up with the era and reaching the level of developed countries.

CHAPTER 3

RESEARCH DESIGN

3.1 INTRODUCTION

In this chapter, the questions and the method used to fulfill the purpose of the study are given. Furthermore, the extension and the scope of the study are stated and the study design is explained here. Then the applications of the study and the method formed to obtain the results are given.

3.2 RESEARCH QUESTIONS AND PURPOSE

Recently, depending on the developments in science and technology, the modern concept of 'biotechnology' has come to be used and has shown a great progress. With this fast progress, the importance of the studies performed in the field of biotechnology has increased and the roads to make investments on this field have been opened. Economically developed countries have adopted themselves to the fast-growing field of biotechnology and made great progresses in basic fields such as industry, medicine, and agriculture. In order for the bio-technology, which covers many working fields and includes interdisciplinary information, to develop a certain type of training specific for itself has become a basic element. In this context, the following questions have been used to understand how important the biotechnology education is for our country.

On what level is the bio-technology education in our country?

As referred to in Chapter 1, the importance of bio-technology has increased in recent years and the level of the knowledge and competence of the educators have gained importance as well. In our country, the progress in the education of biotechnology has been slow; and moreover, the necessary transition towards this field has not been fulfilled yet. The education of biotechnology should begin at early ages, and students should gain sufficient biotechnology knowledge. These are very important issues to ensure the development of our country on the road to pace-to-pace development in modern sciences.

Is the biotechnology education sufficient in the curricula of the educational policies that raise teacher and students?

As referred in Chapter 2, the insufficient existence of the biotechnology education at schools is debatable; moreover, the knowledge level of the teachers to teach biotechnology is another important point. Class teachers, science teachers and biology teachers should have the up-to-date knowledge and competence on all relevant topics about biotechnology. However, the programs at universities that train teachers are not sufficient, and when the fact that the most experienced teacher has 20 years' experience is considered, it becomes obvious that the teachers need to gain and improve their knowledge with their own efforts. And this shows that teachers should be trained before giving biotechnology education; and after they start active duty, they should be kept up-to-date with in-service trainings. The training of teachers on biotechnology and the curricula transitions that will enable them to have the competence in that field are of great importance.

Why is biotechnology training for teachers necessary?

The answer to this question is referred in detail in 5th and 6th Chapters. Students are affected from the situation in which teachers have no, little or medium level knowledge on biotechnology. The knowledge and attitudes of the teachers on biotechnology are a defining factor in determining the interests and perceptions of the students.

Has the applied biotechnology training made a difference on participants' attitudes towards biotechnology and their biotechnological skills?

The answer for this problem was given in findings. The collected information with pre and post tests discussed in related section and differ of the analyses results were shown.

How can university-society relationship be spread to the rest of the country in terms of biotechnology education?

Assessments were made in the conclusion and discussion section.

What is the purpose of the study?

Obtaining scientific conclusions on whether our country is self-sufficient in the field of biotechnology education or not; and emphasizing the need for this education and contribute to the process of making the authorities become aware of the missing points in education -if any.

3.3 RESEARCH BOUNDARIES AND SCOPE

Under the ‘research boundaries and scope’ title, the following questions are addressed:

What is the scope of the study?

This study is on biotechnology education which has a great effect on the development of biotechnology by constantly being updated and developed and having a greater importance day after day. During the study, there have been biotechnology pre-service and in-service trainings by using laboratory applications.

Which fields are teachers and teacher candidates chosen ?

Class teachers, Science and Technology Teachers, Biology Teachers and teacher candidates in these fields.

Why are these teachers and teacher candidates chosen?

The subjects of biotechnology in the curricula are given to the students by Class teachers, Science and Technology Teachers, Biology Teachers.

3.4 PRACTICAL RESEARCH DESIGN

Practical research design is the basic application that is necessary for a systematic, well-planned and ideal research. In this chapter, practical research design has been performed systematically and all the steps are explained in detail in the following section.

Problem statement: The knowledge levels of the teachers who teach or will teach biotechnology which is being constantly developed and improved are insufficient. These problems have been dealt with in the beginning section based on the literature scan.

Literature Search and Review: Studies on biotechnology in the world are very few in number. All the resources that have been published in this field have been examined online and the magazines were scanned. Books published on biotechnology and education were examined as well.

Selection of appropriate research methods and techniques: For this study, as a quantitative method, *the experimental method* was used. This method examines whether the effects of the applications performed on two or more groups differed or not. The class teachers, science and technology teachers and biology teachers were given trainings on biotechnology in laboratory in groups and the effects of these trainings were assessed with pre-test and end-test methods.

The widely-known “Likert Scale” was prepared for the measurement of knowledge and attitudes. In Likert Scale, the subjects are given various judgments and statements and asked to state their agreement levels on each item. This scale is mostly used to measure the attitudes and inclinations of individuals, and can have points of 5, 7, 9 or 11. In our study, the most commonly used scale, the 5 point Likert Scale, was used. As seen in Table 3.1, our study had 4 groups of teachers and teacher candidates selected from different fields.

Table 3.1 Target groups and the number of participants.

Group	Target Group	Number of Participants
1	Class Teachers and Science and Technology Teachers	8
2.	Biology Teachers	20
3.	Class Teacher Candidates and Science and Technology Teacher Candidates	17
4.	Biology Teacher Candidates	16

Laboratory practices were organized for each of the teachers and teacher candidates groups on the topics given in Table 3.2 for 9 days in the laboratory.

Table 3.2 Laboratory practice program topics.

1. Day	DNA Testing	DNA isolation	PCR	Electrophoresis	
2. Day	Gene Cloning	DNA isolation	PCR		
3. Day	Gene Cloning	Medium preparation	Eksonucleas treatment	PCR	
4. Day	Gene Cloning	DNA purification and ligation	Transformation	Incubation	Construction of result
5. Day	GDO Analysis	DNA isolation from sample	PCR	Electrophoresis	Construction of result
6. Day	Protein Purification	Medium preparation	Transformation		
7. Day	Protein Purification	Medium preparation	Incubation	Medium preparation	Inoculation
8.Day	Protein Purification	SDS-page	Construction of results	Degradation of cell membrane	
9. Day	Protein Purification	Protein resolution	Construction of results		

Ours is a study adopted by TÜBİTAK under the name "Biotechnology Academy" within the "Support Program for Science and Community Projects". In the project conducted between 06/17/2013 - 10/03/2014, a 9-day hands-on training was given in 4 groups. The project activities and program have been announced in the following manner over the internet, and applications have been submitted.

Table 3.3 The project activities list.

Name of Application	**Application / Experiment**
DNA Testing	DNA-Based Forensic Detection of Criminals
GMO Analysis	Analysis of GMO (Genetically Modified Organisms) Food
Gene Cloning	How to create GMO (genetic cloning) and DNA sequencing methods
Protein Purification	Having Bacteria Produce Green Fluorescent Protein and Purification of this Protein
Protein Characterization	Analysis of the proteins produced by SDS-PAGE

- In the final stage of the "DNA Testing" experiment, DNA samples belonging to different individuals will be carried out by electrophoresis and the identification of the DNA sample in question will be determined.
- In the final stage of "The Gene Cloning" experiment, as a result of the incubation of the bacteria whose ampicillin-resistant gene is cloned in ampicillin broth, whether the bacteria are cultured or not will be evaluated and if bacteria colonies are observed as a result of this experiment, it will be concluded that the gene cloning is successful. An actual vector design will be created in this application, and the trainers will observe the stages here in all their nakedness, and apply them themselves.
- In the final stage of "GMO Analysis" experiment; the experiment of carrying out PCR outcomes at the electrophoresis will be made, whether the tested food contains GMO or not will be determined.
- In the experiment of "Protein Purification", the pre-designed vector will be transferred to the bacteria and GFP protein will be produced. This protein which emits green light under UV light will be able to observe passing through the separation column.

- In the experiment of “Protein SDS-PAGE”, bacteria proteins will be screened on the gel using the SDS-PAGE technique, and as a result of this observation, whether the bacteria produce the intended proteins or not will be determined.

Table 3.4 The cycle of the education programs.

Activity	**Dates**
Science and Technology and Classroom Teachers	August 12 – August 20
Biology Teachers	August 26 – September 3
Dept. of Sci. and Tech and Class. Teaching, Und. Sts.	September 9 – September 17
Dept. of Biology Teaching, Undergraduate Students	January 20 – January 28

Applications submitted via the Internet are evaluated in order of priority. Of the applications made by prospective teachers, senior students were accepted by application order, when the quota was not filled, the former grade students were accepted in order.

Training, food and service costs of the participants were met by TUBITAK. The students were provided with an accommodation comfortable and close to the university, and, transportation was carried out with the morning and evening shuttles. Breakfast, lunch and dinner were given, and afternoon tea was serviced. In order for the student not to have any problems throughout the project and to focus on the training completely, a special effort was made, and all the questions and problems of the students were dealt with in person by our team.

In many empirical studies, the effect of the independent variables on the dependent ones is calculated based on the differences among the similar measurements made on the dependent variable before and after the process. The measurement before the process is called "pre-test", and the measurement after the process is called "post-test", and these tests are supposed to measure the same value in the same manner. Based on this method, the questionnaire given in the Attachment-1 is applied at the beginning and at end of the laboratory trainings for each group. The effect of the training on the teachers was measured by using a questionnaire which were applied for twice as pre-test and post-test.

Data Analysis: In order to facilitate the assessment of the questionnaire results, the SPSS (Statistical Package of Social Sciences) program which is helpful in analyzing statistical data and which is preferred by many disciplines was used. With this program, the data obtained with the pre-test and post-test applications are compared and statistical conclusions are provided.

Data interpretation and Explanation: After the data analysis is over, the obtained statistical data will be explained and the conclusions will be assessed. The need for biotechnology training for teachers will be discussed and a conclusion will be drawn based upon the present data.

3.5 CONCLUSION

In this chapter where the methodology is explained, the study frame is drawn and the design is shown. By taking the problems defined in the literature on biotechnology education into consideration, the study has been conducted with laboratory assistance. And as a conclusion, the data collection and analysis techniques are mentioned. The research techniques developed in the light of the research questions are stated below in brief:

- Examining the library and resources
- Developing a questionnaire
- Laboratory trainings
- Pre-test and Post-test applications
- Analysis of the data with SPSS.

CHAPTER 4

RESULTS

4.1 RESULTS FOR DEMOGRAPHIC KNOWLEDGE OF TEACHERS

4.1.1 Results for Personal Knowledge of Teachers

In this section are given the results for personal knowledge of teachers.

4.1.1.1 Variable of Gender

Table 4.1 Descriptive values for gender variable of the participants.

Groups	Male	Female	Total
Pre-test	16	44	60
	26.6%	73.4%	100.0%
Post-test	13	41	54
	24.0%	76.0%	100.0%

A total of 117 people have participated in the pre-test and post-test. 3 people who completed the survey did not answer this question. As shown in Table 4.1, 16 (26.6%) of those participating in the pre-test were male 44 (73.4%) were female, and 13 (24.0%) of those participating in the post-test were male and 41 (76.0%) were female.

Figure 4.1 Gender distributions of participants.

4.1.2 Grade Variable

Table 4.2 Descriptive values for the grade variable of the participants.

Groups	1st Grade	2nd Grade	3rd Grade	4th Grade	Total
Pre-test	1	8	10	14	33
	3.0%	24.3%	30.3%	42.4%	100.0%
Post-test	1	8	13	11	33
	3.0%	24.3%	39.4%	33.3%	100.0%
Total	2	16	23	25	66

This study was conducted with teacher candidates and teachers. Teacher candidates are trained in the various classes of the university. A total of 117 people participated in the pre-test and post-test. Because of teachers did not mark, 51 people who completed the survey did not answer this question. As shown in the Table 4.2, 1 (3.0%) of the respondents to pre-test was 1st grade, 8 (24.3%) were 2nd grade, 10 (30.3%) were 3rd grade and 14 (42.4%) were 4th grade students, and, 1 (3.0%) of the respondents to post-test was 1st grade, 8 (24.3%) were 2nd grade, 13 (39.4%) were 3rd grade and 11 (33.3%) were 4th grade students.

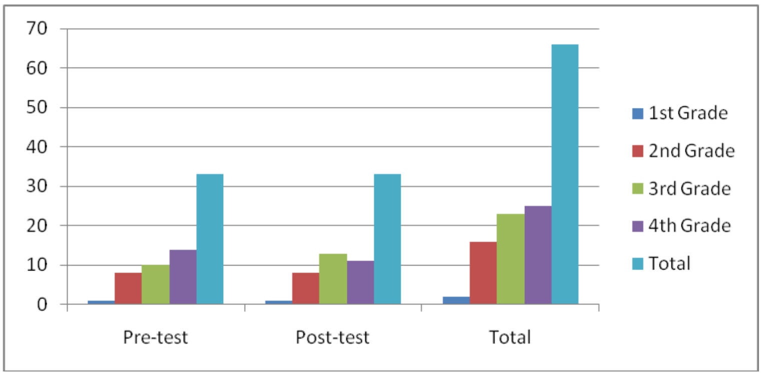

Figure 4.2 Grade distributions of participants.

Table 4.3 Descriptive values for biotechnology education variable of the participants.

Groups	Yes	No	Total
Pre-test	11	48	59
	18.6%	81.4%	100.0%
Post-test	15	39	54
	27.8%	72.2%	100.0%
Total	26	87	113

A total of 117 people participated in the pre-test and post-test. 4 people who completed the survey did not answer this question. As shown in the Table 4.3, 11 (18.6%) respondents to the pre-test were yes, 48 (81.4%) were no, 15 (27.8%) of the respondents to the post-test were yes and 39 (72.2%) were no.

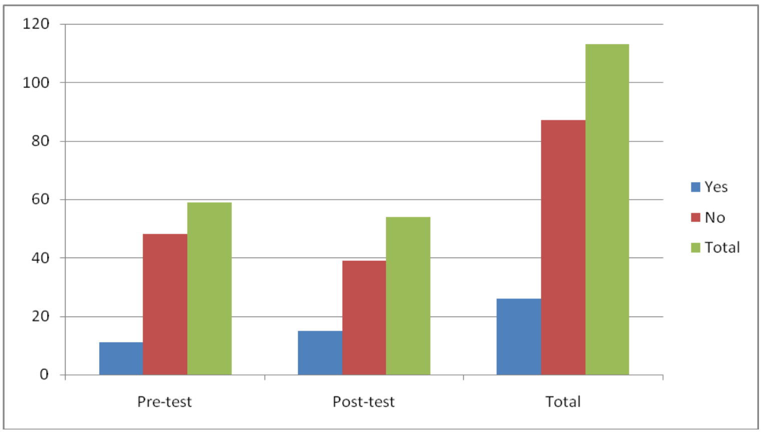

Figure 4.3 Distribution of biotechnology that have received training.

4.2 ANALYSIS OF THE ANSWERS OF THE SAMPLED GROUP TO THE PRE-TEST/POST-TEST STATEMENTS

4.2.1 The Pre-test and Post-test Findings Related to the Facts

Table 4.4 Pre-test/Post-test comparative frequency analysis of the statements in facts section.

	I've never heard of		I heard, but I cannot explain		I have enough information to explain		I know exactly		Total	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Biotechnology	0	0	6	0	42	14	12	42	60	56
	0.0%	0.0%	10.0%	0.0%	70.0%	25.0%	20.0%	75.0%	100.0%	100.0%
Microorganism	0	0	2	0	26	11	32	45	60	56
	0.0%	0.0%	3.4%	0.0%	43.3%	19.6%	53.3%	80.4%	100.0%	100.0%
Fermentation	0	0	3	1	32	14	25	40	60	55
	0.0%	0.0%	5.0%	1.8%	53.3%	25.4%	41.7%	72.8%	100.0%	100.0%
Penicillin	0	0	9	2	32	23	19	29	60	54
	0.0%	0.0%	15.0%	3.7%	53.3%	42.6%	31.6%	53.7%	100.0%	100.0%
Green revolution	30	11	22	18	6	18	2	9	60	56
	50.0%	19.7%	36.6%	32.1%	10.0%	32.1%	3.4%	16.1%	100.0%	100.0%
Genetic Engineering	0	0	9	0	38	24	13	32	60	56
	0.0%	0.0%	15.0%	0.0%	63.3%	42.8%	21.7%	57.2%	100.0%	100.0%
Gene cloning	0	0	10	1	35	16	15	39	60	56
	0.0%	0.0%	16.7%	1.7%	58.3%	28.6%	25.0%	69.7%	100.0%	100.0%
Genetically modified	0	0	4	0	36	10	19	46	59	56

organism (GMO)	0.0%	0.0%	6.8%	0.0%	61.0%	17.9%	32.2%	82.1%	100.0%	100.0%
Recombinant DNA	9	1	13	3	19	13	19	39	60	56
	15.0%	1.7%	21.8%	5.3%	31.6%	23.7%	31.6%	69.7%	100.0%	100.0%
Chromatography Techniques	24	1	21	3	9	18	5	33	59	55
	40.7%	1.9%	35.6%	5.7%	15.2%	32.4%	8.5%	60.0%	100.0%	100.0%
RFLP technique	48	6	10	11	2	21	0	17	60	55
	80.0%	11.0%	16.7%	20.0%	3.4%	38.5%	0.0%	30.5%	100.0%	100.0%
PZR technique	37	0	9	1	10	14	4	41	60	56
	61.7%	0.0%	15.0%	1.7%	16.7%	25.0%	6.6%	73.3%	100.0%	100.0%

42 (70.0%) people in the sample group stated in the pre-test stage that they had knowledge about "biotechnology", and that 12 (20.0%) participants stated that they knew the concept very well, on the other hand; in the post-test, 14 (25.0%) people stated that they knew this concept, and 42 (75.0%) stated that they knew it very well.

In the sample group, 26 (43.3%) people reported in the pre-test that they knew the concept of "microorganism", 32 (53.3%) stated that they knew it very well; in the post-test, 11 (19.6%) people stated that they knew this concept, and 45 (80.4%) of them stated that they knew it very well.

In the sample group, 32 (53.3%) people reported in the pre-test stage that they knew the concept of "fermentation", 25 (41.7%) stated that they knew it very well; in the post-test, 14 (25.4%) people stated that they knew this concept, while 40 (72.8%) stated that they knew it very well.

In the sample group, 32 (53.3%) people reported in the pre-test stage that they knew the concept of "penicillin", while 19 (31.6%) stated that they knew it very well; in the post-test, 23 (42.6%) people stated that they knew this concept, while 29 (53.7%) of them stated that they knew it very well.

In the sample group, 30 (50.0%) people reported in the pre-test stage that they didn't hear about the concept of "Green Revolution", 22 (36.6%) stated that they did not have sufficient knowledge about it and 6 (10.0%) stated that knew it; in the post-test, 11 (19.7%) people stated that they did not hear about this concept, 18 (32.1%) stated that they did not have sufficient knowledge about it while 18 (32.1%) stated that they knew it.

In the sample group, 38 (63.3%) people reported in the pre-test that they knew the concept of "Genetic Engineering", 13 (21.7%) stated that they knew it very well; in the post-test, 24 (42.8%) people stated that they knew this concept, and 32 (57.2%) stated that they knew it very well.

In the sample group, 35 (58.3%) people reported in the pre-test that they knew the concept of "Gene Cloning", 15 (25.0%) stated that they knew it very well; in the post-test, 16 (28.6%) people stated that they knew this concept, and 39 (69.7%) stated that they knew it very well.

In the sample group, 36 (61.0%) people reported in the pre-test stage that they knew the concept of "Genetically modified organism (GMO)", 19 (32.2%) stated that they knew it very well; in the post-test, 10 (17.9%) people stated that they knew this concept, while 46 (82.1%) of them stated that they knew it very well.

In the sample group, 9 (15.0%) people reported in the pre-test that they did not hear about the concept of "Recombinant DNA", 13 (21.8%) stated that they did not have sufficient knowledge about it, while 19 (31.6%) stated that they knew about the concept and 19 (31.6%) stated that they knew it very well; in the post-test, 1 (1.7%) stated that he did not hear about the concept, while 3 (5.3%) stated that they did not have sufficient knowledge about it, 13 (23.7%) stated that they knew it, 39 (69.7%) stated that they knew it very well.

In the sample group, 24 (40.7%) people reported in the pre-test that they did not hear about the concept of "Chromatography Techniques", 21 (35.6%) stated that they did not have sufficient knowledge about it, while 9 (15.2%) stated that they knew about the concept and 5 stated that they knew it very well; in the post-test, 1 (1.9%) stated that he did not hear about the concept, while 3 (5.7%) stated that they did not have sufficient knowledge about it, 18 (32.4%) stated that they knew it, 39 (30.5%) stated that they knew it very well.

In the sample group, 48 (80.0%) people reported in the pre-test that they did not hear about the concept of "RFLP Technique", 10 (16.7%) stated that they did not have sufficient knowledge about it, while 2 (3.4%) stated that they knew about the concept but no one stated that they knew it very well; in the post-test, 6 (11.0%) stated that they did not hear about the concept, while 11 (20.0%) stated that they did not have sufficient knowledge about it, 21 (38.5%) stated that they knew it, 17 (30.5%) stated that they knew it very well.

In the sample group, 37 (61.7%) people reported in the pre-test that they did not hear about the concept of "PZR Technique", 9 (15.0%) stated that they did not have sufficient knowledge about it, while 10 (16.7%) stated that they knew about the concept and 4 (6.6%) stated that they knew it very well; in the post-test, 1 (1.7%) stated that they did not have sufficient knowledge about it, 14 (25.0%) stated that they knew it, 41 (73.3%) stated that they knew it very well.

4.2.2 The Pre-test and Post-test Results Related to the Opinions

Table 4.5 Pre-test/Final-test comparative frequency analysis of the statements in opinions section.

	I strongly disagree		**I disagree**		**Neutral**		**I agree**		**I strongly agree**		**Total**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Agricultural products with high nutritional power and improved quality of food should be grown by changing the genetic structure of seeds through biotechnological methods.	2	1	15	8	14	20	18	22	11	5	60	56
	3.3%	1.8%	25.0%	14.3%	23.3%	35.7%	30.0%	39.3%	18.3%	8.9%	100.0%	100.0%
I can consume the agricultural products (wheat, tomatoes etc.) grown with this method.	6	4	17	11	13	21	17	15	6	5	59	56
	10.2%	7.1%	28.8%	19.6%	22.0%	37.5%	28.8%	26.8%	10.2%	8.9%	100.0%	100.0%
Genetically modified (GMO) products may be harmful to human health.	1	0	3	1	3	13	37	32	15	10	59	56
	1.7%	0.0%	5.1%	1.8%	5.1%	23.2%	62.7%	57.1%	25.4%	17.9%	100.0%	100.0%
Drugs must be developed with the help of microorganisms by biotechnological methods.	0	0	1	0	3	4	27	23	29	29	60	56
	0.0%	0.0%	1.7%	0.0%	5.0%	7.1%	45.0%	41.1%	48.3%	51.8%	100.0%	100.0%
I can use a drug produced with this method.	0	0	2	2	10	9	29	24	19	21	60	56
	0.0%	0.0%	3.3%	3.6%	16.7%	16.1%	48.3%	42.9%	31.7%	37.5%	100.0%	100.0%
Biotechnology should be used if it will cure fatal diseases (cancer etc.).	0	0	0	0	4	1	20	16	36	39	60	56
	0.0%	0.0%	0.0%	0.0%	6.7%	1.8%	33.3%	28.6%	60.0%	69.6%	100.0%	100.0%
Higher quality and more efficient animal breeds must be created by changing the genetic structure of animal breeds.	8	6	16	11	17	20	14	10	4	9	59	56
	13.6%	10.7%	27.1%	19.6%	28.8%	35.7%	23.7%	17.9%	6.8%	16.1%	100.0%	100.0%
I can eat the meat of a genetically	13	9	26	15	12	21	5	5	3	6	59	56

modified animal.	22.0%	16.1%	44.1%	26.8%	20.3%	37.5%	8.5%	8.9%	5.1%	10.7%	100.0%	100.0%
Waste released to the environment must be cleaned by biotechnological methods.	0	0	0	1	4	3	23	18	33	34	60	56
	0.0%	0.0%	0.0%	1.8%	6.7%	5.4%	38.3%	32.1%	55.0%	60.7%	100.0%	100.0%
Biotechnological methods should be used to purify contaminated water.	0	0	0	1	3	4	25	14	32	37	60	56
	0.0%	0.0%	0.0%	1.8%	5.0%	7.1%	41.7%	25.0%	53.3%	66.1%	100.0%	100.0%
Instead of the various materials used in industry, microorganisms and enzymes should be used.	0	0	0	0	13	5	22	18	25	33	60	56
	0.0%	0.0%	0.0%	0.0%	21.7%	8.9%	36.7%	32.1%	41.7%	58.9%	100.0%	100.0%
Materials and weapons must be produced in the military field using biotechnology.	7	9	8	7	24	17	10	10	10	13	59	56
	11.9%	16.1%	13.6%	12.5%	40.7%	30.4%	16.9%	17.9%	16.9%	23.2%	100.0%	100.0%
More resources should be allocated to biotechnological research all over the world and studies should be supported.	1	0	0	0	5	4	27	20	27	32	60	56
	1.7%	0.0%	0.0%	0.0%	8.3%	7.1%	45.0%	35.7%	45.0%	57.1%	100.0%	100.0%
Biotechnological research should be strictly controlled all over the world.	1	0	0	0	4	1	15	10	40	45	60	56
	1.7%	0.0%	0.0%	0.0%	6.7%	1.8%	25.0%	17.9%	66.7%	80.4%	100.0%	100.0%
The benefits of biotechnology are more than the risks.	3	1	3	3	32	25	18	17	4	10	60	56
	5.0%	1.8%	5.0%	5.4%	53.3%	44.6%	30.0%	30.4%	6.7%	17.9%	100.0%	100.0%
I rely on identifying parents and criminals with forensic DNA testing.	1	0	0	0	4	0	25	25	30	31	60	56
	1.7%	0.0%	0.0%	0.0%	6.7%	0.0%	41.7%	44.6%	50.0%	55.4%	100.0%	100.0%

In the sample group, it was stated in the pre-test stage that 15 (25.0%) people did not agree on the opinion of "Agricultural products with high nutritional power and improved quality of food should be grown by changing the genetic structure of seeds through biotechnological methods.", 14 (23.3%) were neutral, 18 (30.0%) agreed on it and 11 (18.3%) strongly agree on it; while it was stated in the post test stage that 8 (14.3%) did not agree on this opinion, 20 (35.7%) were neutral, 22 (39.3%) agreed on it and 5 (8.9%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 17 (28.8%) people did not agree on the opinion of "I can consume the agricultural products (wheat, tomatoes etc.) grown with this method.", 13 (22.0%) were neutral, 17 (28.8%) agreed on it; while it was stated in the post test stage that 11 (19.6%) did not agree on this opinion, 21 (37.5%) were neutral and 15 (26.8%) agreed on it.

In the sample group, it was stated in the pre-test stage that 3 (5.1%) people were neutral about the opinion of "Genetically modified (GMO) products may be harmful to human health.", 37 (62.7%) agreed on it and 15 (25.4%) strongly agree on it; while it was stated in the post test stage that 13 (23.2%) were neutral about it, 32 (57.1%) agreed on it and 10 (17.9%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 27 (45.0%) people agreed on the opinion of "Drugs must be developed with the help of microorganisms by biotechnological methods.", and 29 (48.3%) strongly agreed on it; while it was stated in the post test stage that 23 (41.1%) agreed on it and 29 (51.8%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 29 (48.3%) people agreed on the opinion of "I can use a drug produced with this method.", and 19 (31.7%) strongly agreed on it; while it was stated in the post test stage that 24 (42.9%) agreed on it and 21 (37.5%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 20 (33.3%) people agreed on the opinion of "Biotechnology should be used if it will cure fatal diseases (cancer etc.).", and 36 (60.0%) strongly agreed on it; while it was stated in the post test stage that 16 (28.6%) agreed on it and 39 (69.6%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 16 (27.1%) people did not agree on the opinion of "Higher quality and more efficient animal breeds must be created by changing the genetic structure of animal breeds. ", 17 (28.8%) were neutral, and 14 (23.7%) agreed on it; while it was stated in the post test stage that 11 (19.6%) did not agree on this opinion, 20 (35.7%) were neutral and 10 (17.9%) agreed on it.

In the sample group, it was stated in the pre-test stage that 13 (22.0%) people strongly disagreed on the opinion of "I can eat the meat of a genetically modified animal.", 26 (44.1%) disagreed on it and 12 (20.3%) were neutral about it; while it was stated in the post test stage that 9 (16.1%) strongly disagreed on it and 15 (26.8%) did not agree on this opinion and 21 (37.5%) were neutral about it.

In the sample group, it was stated in the pre-test stage that 23 (38.3%) people agreed on the opinion of "Waste released to the environment must be cleaned by biotechnological methods.", and 33 (55.0%) strongly agreed on it; while it was stated in the post test stage that 18 (32.1%) agreed on it and 34 (60.7%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 25 (41.7%) people agreed on the opinion of "Biotechnological methods should be used to purify contaminated water.", and 32 (53.3%) strongly agreed on it; while it was stated in the post test stage that 14 (25.0%) agreed on it and 37 (66.1%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 13 (21.7%) people were neutral about the opinion of "Instead of the various materials used in industry, microorganisms and enzymes should be used.", 22 (36.7%) agreed on it and 25 (41.7%) strongly agree on it; while it was stated in the post test stage that 5 (8.9%) were neutral about it, 18 (32.1%) agreed on it and 33 (58.9%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 24 (40.7%) people were neutral about the opinion of "Materials and weapons must be produced in the military field using biotechnology.", 10 (16.9%) agreed on it and 10 (16.9%) strongly agree on it; while it was stated in the post test stage that 17 (30.4%) were neutral about it, 10 (17.9%) agreed on it and 13 (23.2%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 27 (45.0%) people agreed on the opinion of "More resources should be allocated to biotechnological research all over the world and studies should be supported.", and 27 (45.0%) strongly agreed on it; while it was stated in the post test stage that 20 (35.7%) agreed on it and 32 (57.1%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 15 (25.0%) people agreed on the opinion of "Biotechnological research should be strictly controlled all over the world.", and 40 (66.7%) strongly agreed on it; while it was stated in the post test stage that 10 (17.9%) agreed on it and 45 (80.4%) strongly agreed on it.

In the sample group, it was stated in the pre-test stage that 32 (53.3%) people were neutral about the opinion of "The benefits of biotechnology are more than the risks.", 18 (30.0%) agreed on it; while it was stated in the post test stage that 25 (44.6%) were neutral about it, 17 (30.4%) agreed on it.

In the sample group, it was stated in the pre-test stage that 25 (41.7%) people agreed on the opinion of "I rely on identifying parents and criminals with forensic DNA testing.", and 30 (50.0%) strongly agreed on it; while it was stated in the post test stage that 25 (44.6%) agreed on it and 31 (55.4%) strongly agreed on it.

4.2.3 Pre-test/Post-test Comparison of the Statements of the Sample Group in the Survey

Table 4.6 Pre-test/post-test comparison of the facts statements of the sample group.

Category	Status	N	$\bar{x}$	ss	$Sh_{\bar{x}}$	t Test		
						t	df	Sig.
Biotechnology	Pre-test	60	3.100	.5431	.0701	-7.071	114	.000
	Post-test	56	3.750	.4369	.0584			
Microorganism	Pre-test	60	3.500	.5675	.0733	-3.306	114	.001
	Post-test	56	3.804	.4009	.0536			
Fermentation	Pre-test	60	3.367	.5813	.0750	-3.380	113	.001
	Post-test	55	3.709	.4971	.0670			
Penicillin	Pre-test	60	3.167	.6681	.0862	-2.841	112	.005
	Post-test	54	3.500	.5746	.0782			
Green revolution	Pre-test	60	1.667	.7955	.1027	-4.693	114	.000
	Post-test	56	2.446	.9894	.1322			
Genetic Engineering	Pre-test	60	3.067	.6069	.0784	-4.872	114	.000
	Post-test	56	3.571	.4994	.0667			
Gene cloning	Pre-test	60	3.083	.6455	.0833	-5.491	114	.000
	Post-test	56	3.679	.5084	.0679			
Genetically modified organism (GMO)	Pre-test	59	3.254	.5752	.0749	-6.174	113	.000
	Post-test	56	3.821	.3865	.0516			
Recombinant DNA	Pre-test	60	2.800	1.0544	.1361	-4.863	114	.000
	Post-test	56	3.607	.6790	.0907			
Chromatography techniques	Pre-test	59	1.915	.9521	.1240	-10.169	112	.000
	Post-test	55	3.509	.6905	.0931			
RFLP technique	Pre-test	60	1.233	.4997	.0645	-11.612	113	.000
	Post-test	55	2.891	.9751	.1315			
PZR technique	Pre-test	60	1.683	.9828	.1269	-13.908	114	.000
	Post-test	56	3.714	.4941	.0660			

In this study, t-tests were performed in order to determine whether there was a significant difference between the post-test, which was conducted after the training activities, and the pre-test, which was conducted before the training activities. Significant differences were found in all the items in this section. While the mean score increased by around 0.6 for the majority of the items, a score increase of 1.5 points has occurred in Chromatography Technique, RFLP technique and PZR technique; which can be considered a big one. Examining all the results, education activities has created a significant change in learning activities such as hearing about, knowing and explaining the facts.

Table 4.7 t-Test results for the statement of "Instead of the various materials used in industry, microorganisms and enzymes should be used." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	60	4.200	.7768	.1003	-2.233	114	.028
Post-test	56	4.500	.6606	.0883			

As seen in the Table 4.7, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "instead of the various materials used in industry, microorganisms and enzymes should be used." show a significant difference depending on the pre-test and post-test; significant differences were found between the arithmetic means of the groups (t = -2.233; p<.05). So, after receiving the training, the sample group has uttered the statement of "instead of the various materials used in industry, microorganisms and enzymes should be used" more frequently.

Table 4.8 t-Test results for the statement of "Biotechnological research should be strictly controlled all over the world." depending on the pre-test/post-test variable.

Status	N	$\bar{x}$	ss	$Sh_{\bar{x}}$	t Test		
					t	df	Sig.
Pre-test	60	4.550	.7686	.0992	-1.991	114	.049
Post-test	56	4.786	.4558	.0609			

As seen in the Table 4.9, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "Biotechnological research should be strictly controlled all over the world." show a significant difference depending on the pre-test and post-test; significant differences were found between the arithmetic means of the groups ($t = -1.991$; $p<,05$). So, after receiving the training, the sample group has uttered the statement of "Biotechnological research should be strictly controlled all over the world." more frequently.

Table 4.9 t-Test results for the statement of "Using the RFLP method, I can perform criminal detection by applying forensic DNA testing." depending on the pre-test/post-test variable.

Status	N	$\bar{x}$	ss	$Sh_{\bar{x}}$	t Test		
					t	df	Sig.
Pre-test	60	3.9333	.40617	.05244	2.479	111	.015
Post-test	53	3.4340	1.50012	.20606			

As seen in the Table 4.9, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "Using the RFLP method, I can perform criminal detection by applying forensic DNA testing." show a significant difference depending on the pre-test and post-test; significant differences were found between the arithmetic means of the groups ($t = 2.479$; $p<.05$). So, after receiving the training, the sample group has uttered the statement of "Using the RFLP method, I can perform criminal detection by applying forensic DNA testing." more frequently.

Table 4.10 t-Test results for the statement of "With GADPH PCR technique, I can perform the process of the replication of GAPC gene region." depending on the pre-test/post-test variable.

Status	N	$\bar{x}$	ss	$Sh_{\bar{x}}$	t Test		
					t	df	Sig.
Pre-test	60	3.9000	.43957	.05675	2.198	114	.030
Post-test	56	3.4821	1.40118	.18724			

As seen in the Table 4.10, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "With GADPH PCR technique, I can perform the process of the replication of GAPC gene region." show a significant difference depending on the pre-test and post-test; significant differences were found between the arithmetic means of the groups ($t = 2.198$; $p<.05$). So, after receiving the training, the sample group has uttered the statement of "With GADPH PCR technique, I can perform the process of the replication of GAPC gene region." more frequently.

Table 4.11 t-Test results for the statement of "I can perform the nested PZR technique." depending on the pre-test/post-test variable.

Status	N	$\bar{x}$	ss	$Sh_{\bar{x}}$	t Test		
					t	df	Sig.
Pre-test	60	3.9000	.30253	.03906	2.348	114	.021
Post-test	56	3.4464	1.46374	.19560			

As seen in the Table 4.11, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "I can perform the nested PZR technique." show a significant difference depending on the pre-test and post-test; significant differences were found between the arithmetic means of the groups (t = 2.348; p<.05). So, after receiving the training, the sample group has uttered the statement of "I can perform the nested PZR technique." more frequently.

Table 4.12 t-Test results for the statement of "To sequence the bacteria multiplied in a particular environment, I can perform the process of plasmid, that is, re-purification of the vector." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	60	3.7500	.67961	.08774	2.100	114	.038
Post-test	56	3.3214	1.41559	.18917			

As seen in the Table 4.12, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "To sequence the bacteria multiplied in a particular environment, I can perform the process of plasmid, that is, re-purification of the vector." show a significant difference depending on the pre-test and post-test; the difference between the arithmetic means of the groups was found to be significant (t = 2.100; p<.05). So, after receiving the training, the sample group has uttered the statement of "To sequence the bacteria multiplied in a particular environment, I can perform the process of plasmid, that is, re-purification of the vector." more frequently.

Table 4.13 t-Test results for the statement of "I know the meaning of the concept of “miniprep” used during this process." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	60	3.9167	.27872	.03598	6.106	114	.000
Post-test	56	2.8571	1.31327	.17549			

As seen in the Table 4.13, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "I know the meaning of the concept of “miniprep” used during this process." show a significant difference depending on the pre-test and post-test; the difference between the arithmetic means of the groups was found to be significant (t = 2.100; p<.05). So, after receiving the training, the sample group has uttered the statement of "I know the meaning of the concept of “miniprep” used during this process." more frequently.

Table 4.14 t-Test results for the statement of "I can view it in the agarose by cutting with the plasmid enzyme." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	59	3.8136	.47251	.06151	2.634	113	.010
Post-test	56	3.2857	1.46119	.19526			

As seen in the Table 4.14, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "I can view it in the agarose by cutting with the plasmid enzyme." show a significant difference depending on the pre-test and post-test; the difference between the arithmetic means of the groups was found to be significant (t = 2.634; p<.05). So, after receiving the training, the sample group has uttered the statement of "I can view it in the agarose by cutting with the plasmid enzyme." more frequently.

Table 4.15 t-Test results for the statement of "I can interpret the results." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	60	3.7833	.69115	.08923	3.709	114	.000
Post-test	56	2.9107	1.67632	.22401			

As seen in the Table 4.15, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "I can interpret the results." show a significant difference depending on the pre-test and post-test; the difference between the arithmetic means of the groups was found to be significant ($t = 3.709$; $p<.05$). So, after receiving the training, the sample group has uttered the statement of "I can interpret the results." more frequently.

Table 4.16 t-Test results for the statement of "I have theoretical information on DNA sequencing performed at this stage." depending on the pre-test/post-test variable.

Status	**N**	$\bar{x}$	**ss**	$Sh_{\bar{x}}$	**t Test**		
					t	**df**	**Sig.**
Pre-test	60	3.8500	.57711	.07450	3.756	114	.000
Post-test	56	3.0536	1.53053	.20453			

As seen in the Table 4.16, as a result of the t-test for the independent groups, which were formed in order to determine whether the points given by the teachers in the study group to the statement of "I have theoretical information on DNA sequencing performed at this stage." show a significant difference depending on the pre-test and post-test; the difference between the arithmetic means of the groups was found to be significant ($t = 3.756$; $p<.05$) So, after receiving the training, the sample group has uttered the statement of "I have theoretical information on DNA sequencing performed at this stage." more frequently.

4.2.4 Comparison of Pre-test and Post-test Scores by the Subject Variable

Table 4.17 One-way analysis of variance (ANOVA) results of pre-test scores of facts statements by the variable of subject.

f, x, ss Values					ANOVA Results					
Score	**Groups**	**N**	**X**	**ss**	**Variation Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
B9	Science	9	1.778	.8333	**Intergroup**	17.872	3	5.957	6.990	.000
	Biology	18	3.167	.8575	**Intragroup**	47.728	56	.852		
	Science Candidate	17	2.471	1.1246	**Total**	65.600	59			
	Biology Candidate	16	3.312	.7932						
	Total	60	2.800	1.0544						
B10	Science	9	1.222	.4410	**Intergroup**	21.583	3	7.194	12.767	.000
	Biology	17	2.176	.8828	**Intragroup**	30.993	55	.564		
	Science Candidate	17	1.294	.7717	**Total**	52.576	58			
	Biology Candidate	16	2.688	.7042						
	Total	59	1.915	.9521						
B12	Science	9	1.111	.3333	**Intergroup**	13.422	3	4.474	5.751	.002
	Biology	18	1.500	.7859	**Intragroup**	43.562	56	.778		
	Science Candidate	17	1.471	.7998	**Total**	56.983	59			
	Biology Candidate	16	2.538	1.2093						
	Total	60	1.683	.9828						

As a result of the analysis of variance, a significant difference was found between the groups by a 95% of reliability level in the items 9, 10 and 12 in the facts sections. In order to determine in which groups these differences existed, the Tukey analysis was made. As a result of the analysis, a similar difference was found in facts of B9 and B10. While there was no significant difference between the groups of science teachers and science candidate teachers and biology teachers and biology candidate teachers, a significant difference was found between these groups. While science teachers and science candidate teachers stated that they did not hear about or could not explain these facts, biology teachers and biology candidate teachers stated that they could explain these facts.

As for the fact B12, a significant difference was found between biology candidate teachers and other groups only. While biology teachers generally answered this item as

"I have enough knowledge to explain this fact.", those in the other groups generally answered as "I have never heard about it."

Examining the post-test scores, a significant difference was not observed in the fact B12. The significant difference in the other two items seemed to continue.

Table 4.18 One-way analysis of variance (ANOVA) results of post-test scores of facts statements by the variable of subject.

f, x, ss Values					ANOVA Results					
Score	**Groups**	**N**	**X**	**ss**	**Variation Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
B9	Science	8	3.625	.5175	**Intergroup**	6.380	3	2.127	5.827	.002
	Biology	15	3.800	.4140	**Intragroup**	18.977	52	.365		
	Science Candidate	17	3.118	.9275	**Total**	25.357	55			
	Biology Candidate	16	3.938	.2500						
	Total	56	3.607	.6790						
B10	Science	8	3.500	.5345	**Intergroup**	6.438	3	2.146	5.669	.002
	Biology	14	3.571	.5136	**Intragroup**	19.307	51	.379		
	Science Candidate	17	3.059	.8993	**Total**	25.745	54			
	Biology Candidate	16	3.938	.2500						
	Total	55	3.509	.6905						

Examining the Tukey analysis made to determine in which groups these differences existed, a significant difference was found between science candidate teachers and biology candidate teachers only. Looking at the mean scores, it was determined that biology teachers stated that they could explain these facts completely, while science teacher candidates stated that they had enough knowledge to explain these facts.

Overall, it can be said that mean scores of all the branch teachers and candidates have increased considerably compared to those in the pre-test and that the training given is quite helpful.

4.2.5 Comparison of Opinions Section

As a result of the one-way analysis of variance, a significant difference was not found between the groups by a 95% of reliability level in any of the statements in the opinions section. Then, it was investigated whether there was a significant difference in the post-test after the training or not. As a result of the one-way analysis of variance, a significant different was found in the statement of "I rely on identifying parents and criminals with forensic DNA testing.".

Table 4.19 One-way analysis of variance (ANOVA) results of post-test scores of opinions statements by the variable of branch.

f, x, ss Values					**ANOVA Results**					
Score	**Groups**	**N**	**X**	**ss**	**Variation Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
C16	Science	8	4.125	.3536	**Intergroup**	3.009	3	1.003	4.816	.005
	Biology	15	4.800	.4140	**Intragroup**	10.830	52	.208		
	Science Candidate	17	4.412	.5073	**Total**	13.839	55			
	Biology Candidate	16	4.688	.4787						
	Total	56	4.554	.5016						

Examining the Tukey analysis made to determine in which groups these differences existed, a significant difference was found between biology teachers and science teachers. Examining the average scores, while biology teachers answered "I strongly agree" to the statement of "I rely on identifying parents and criminals with forensic DNA testing." in general, science teachers answered "agree" to it in general.

4.2.6 Comparison of the Skills Section

Table 4.20 One-way analysis of variance (ANOVA) results of pre-test scores of skills statements by the variable of branch.

f, x, ss Values					**ANOVA Results**					
Score	**Groups**	**N**	**X**	**Ss**	**Variation Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
D4g	Science	9	4.0000	.0000	**Intergroup**	10.058	3	3.353	4.005	.012
	Biology	18	3.2222	1.1143	**Intragroup**	46.876	56	.837		
	Science Candidate	17	3.8824	.3321	**Total**	56.933	59			
	Biology Candidate	16	3.0000	1.2649						
	Total	60	3.4667	.9823						

As a result of the one-way analysis of variance, a significant difference was found between the groups by a 95% of reliability level in the statement "I know the meanings and functions of the concepts of "ligation" and "vector" used at this stage." in the skills section. In order to determine between which groups these differences existed, the Tukey analysis was conducted. A significant difference was found between science candidate teachers and biology candidate teachers. Examining the mean scores, related to the skill of "I know the meanings and functions of the concepts of "ligation" and "vector" used at this stage.", biology candidate teachers stated that they knew it both "theoretically" and "practically", while science candidate teachers answered it as "partially".

In order to determine whether there was a significant difference related to the statements in this section after the training, an analysis of variance was carried out at 95% reliability.

Table 4.21 One-way analysis of variance (ANOVA) results of post-test scores of skills statements by the variable of branch.

F, x, ss Values					ANOVA Results					
Score	**Groups**	**N**	**X**	**ss**	**Variation Source**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
D2a	Science	8	4.2500	1.38873	**Intergroup**	30.204	3	10.068	5.151	.003
	Biology	15	2.7333	1.48645	**Intragroup**	101.636	52	1.955		
	Science Candidate	17	2.8824	1.45269	**Total**	131.839	55			
	Biology Candidate	16	4.125	1.25000						
	Total	56	3.4464	1.54825						
D2b	Science	8	4.2500	1.38873	**Intergroup**	31.140	3	10.380	5.909	.002
	Biology	15	2.7333	1.48645	**Intragroup**	89.588	51	1.757		
	Science Candidate	17	2.8824	1.40900	**Total**	120.727	54			
	Biology Candidate	16	4.3125	1.25000						
	Total	56	3.4464	1.53646						
D2c	Science	8	4.0000	1.41421	**Intergroup**	28.826	3	9.609	5.254	.003
	Biology	15	2.8000	1.37321	**Intragroup**	95.102	52	1.829		
	Science Candidate	16	2.6250	1.31022	**Total**	123.929	55			
	Biology Candidate	16	4.3125	1.25000						
	Total	55	3.3636	1.49522						
D4b	Science	8	4.0000	1.41421	**Intergroup**	25.832	3	8.611	5.450	.002
	Biology	14	2.7857	1.36880	**Intragroup**	82.150	52	1.580		
	Science Candidate	17	2.8235	1.18508	**Total**	107.982	55			
	Biology Candidate	15	4.2000	1.42428						
	Total	54	3.3704	1.45753						
D4e	Science	8	4.2500	1.38873	**Intergroup**	32.812	3	10.937	6.712	.001
	Biology	15	2.6667	1.23443	**Intragroup**	84.741	52	1.630		
	Science Candidate	17	2.8235	1.28624	**Total**	117.554	55			
	Biology Candidate	16	4.3125	1.25000						
	Total	56	3.4107	1.46196						
D4f	Science	8	4.2500	1.3887	**Intergroup**	26.388	3	8.796	5.221	.003
	Biology	15	2.8667	1.3557	**Intragroup**	87.612	52	1.685		
	Science Candidate	17	2.9412	1.2485	**Total**	114.000	55			
	Biology Candidate	16	4.3125	1.2500						
	Total	56	3.5000	1.4397						
D4I	Science	8	4.2500	1.38873	**Intergroup**	28.088	3	9.363	5.997	.001
	Biology	15	3.2667	1.33452	**Intragroup**	79.621	51	1.561		
	Science Candidate	16	2.6250	1.08781	**Total**	107.709	54			
	Biology Candidate	16	4.3125	1.2500						

	Total	55	3.5273	1.4123						
D4k	Science	8	4.2500	1.3887	**Intergroup**	40.045	3	13.348	8.024	.000
	Biology	15	2.6000	1.4540	**Intragroup**	86.508	52	1.664		
	Science Candidate	17	2.1765	.8089	**Total**	126.554	55			
	Biology Candidate	16	3.9375	1.4818						
	Total	56	3.0893	1.5169						
	Total	56	3.3214	1.4155						
D4o	Science	8	4.2500	1.3887	**Intergroup**	31.957	3	10.652	6.397	.001
	Biology	15	2.6000	1.2983	**Intragroup**	86.596	52	1.665		
	Science Candidate	17	2.7647	1.0325	**Total**	118.554	55			
	Biology Candidate	16	4.1875	1.4705						
	Total	56	3.3393	1.4681						

As can be understood from this analysis, a significant difference in a 95% confidence level is observable on 9 skills after the training. In order to determine between which groups these skills existed, the results of Tukey analysis were examined.

For the skills D2a, D2b, D2c, D4b, D4e, D4f; biology teachers and science candidate teachers generally answered "yes" both practically and theoretically, while science teachers and science teachers and biology candidate teachers generally answered them as "partially".

While there was a difference in the skill of D4g in pre-test, there was no such finding in the post-test.

A significant difference was found between biology candidate teachers and science candidate teachers in the skill of D4I. While science candidate teachers generally answered "yes" to this skill both practically and theoretically, biology candidate teachers answered it as "partially".

A significant difference was found between science teachers and science candidate teachers in the skill of D4K. While science candidate teachers generally stated that they could perform this skill practically, science teachers answered it as "partially".

A significant difference was found between science teachers and biology teachers in the skill of D4o. While science teachers answered it as "partially", biology teachers gave the answer "yes" both practically and theoretically.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Following the analysis of all the results, it is observed that there is a significant positive increase in each question. This indicates that the training given is successful and biotechnology knowledge supported with applications has developed significantly. As the return of applied biotechnology education, it is an expected result for teachers and teacher candidates to have an increased level of biotechnology knowledge and competence.

Analysing the pre-test/post-test expressions for "Facts" (Table 4.4); there is a significant increase in all of the concepts except for "Penicillin". Since the level of knowledge about the concept "Penicillin" is already sufficient, there are no observable differences. Since this concept is already known even by the general public, it is an expected result that this concept is known by the participants. It is seen that there is a very significant increase in the concepts "green revolution", "chromatography technique", "RFLP technique" and "PCR technique" in particular, and that these concepts were not known by the majority before their training. The increased level of knowledge on these techniques, which are among the most important laboratory applications of biotechnology, proves the success of the work done. Considered in the frame of this table, it is seen that more significant increases are observed in some of these concepts, while less in some others. The reason for this difference can be thought to have arisen from the fact that the participants had sufficient background knowledge in certain subjects, while they have insufficient knowledge in some other subjects and have different levels of knowledge.

One of the most fundamental issues of biotechnology is "ethics". Ethical issues have started to come into question more frequently with the progress of modern biotechnology andhe discussion area has been enlarged. Analysing the answers give in the "Opinions" section (Table 4.5) about production, consumption and the harms to human health concerning GMOs, the proportion of those not sympathetic by answering "I disagree" prior to the education, has decreased, and the proportion of those who are "neutral" has increased after the education. In addition, it is observed that the number of those who answered this question as "I agree" has decreased. According to these data, it is seen that the training process has increased the level of knowledge and interpretation about GMOs, and created a more conscious approach to this issue. It is a fact that the society in Turkey does not have enough information and consciousness about GMOs and are confused about the positive and negative effects of this issue (Ozdemir, 2009). We have reached results that consumers' perspectives and attitudes to GM products and biotechnological applications have positively changed in direct proportion to their level of education and knowledge (Hoban, 1999; Siegrist, 2003; Frewer et al. 1997; Schmidt, 2005). This study supports other scientific findings and shows that the informed approach on GMO increase with increasing level of education. The decisive support for the issue that "GMOs are a resource to biotechnological research and should be supported and monitored." is seen between the results.

When t-Test results are analysed, very significant differences are observed in "miniprep concept", "agarose gel imaging", "interpretation of the laboratory results" and "DNA sequencing", and it is understood that the application is successful.

Professions of the participants are an important point that describes the significant change in the results. Examining the analysis of variance conducted by the branch variable, the reason for this difference can be seen. In the analyses related to "Facts"; it is noteworthy that the significant difference between "Chromatography technique", "RFLP technique" and "PZR technique" is related to the differences between the branches (Table 4.17). It is seen that the knowledge level of biology teachers and teacher candidates on this issue prior to education is more than that of classroom teachers and teacher candidates. Considering the post-test comparison in the same subject, it is noteworthy that biology teachers use more precise and confident expressions than science and classroom teachers. The fact that their curriculum knowledge is closer to the field of biotechnology and that they receive theoretical Genetics and Molecular Biology class during a term can be thought to be a reason for this.

Darcin (2010), in his study, reveals that knowledge levels of science teachers about gene transfer, GMOs and general biotechnology are inadequate. Darcin et al. (2006) state that knowledge level of science teacher candidates about well-known issues and outcomes of biotechnology but not have a detailed level of biotechnological knowledge. Chabalengula et al. (2011) state that elementary pre-service teachers don't conceptually understand what actually goes on during these biotechnology processes (i.e. use of microorganism for specific processes; genetic modification of plants/food; genetic modification of human genes; and genetic modification of animals). Also the pre-service teachers may not be fully aware of the ethical, social and cultural issues related to biotechnology. Examining the pre-test findings of our study, it appears that they support the results of this study.

France (2008) states that for vocational biotechnology education teachers require up to date knowledge, access to modern laboratory equipment and the opportunity to develop expertise and Schibeci et al. (2003) state that a small proportion only of our students will be future scientists or technologists. All of them will be citizens. The science education community must do its best to prepare these future technological citizens. Helping our students understand what biotechnology is and the contested meanings it has, is one important step in the preparation of those future technological citizens.

When we combine these two findings, it is understood that teachers' having adequate knowledge on biotechnology is of great importance for students, that students' having adequate knowledge on biotechnology is of great importance for the society, and that this is of great importance for the progress and development, that is, the future of the society. The results of our study are thought to shed light on students and society with its enlightening aspect for teachers.

Bringing together teachers and teacher candidates from different disciplines, provision of extensive theoretical and applied biotechnology education and the comparative analysis of education efficiency with a pre-test/post-test study is a first in the literature. In this respect, our study offers extremely important and valuable data.

5.2 CONCLUSION

Our results establish that applied biotechnology training developed teachers' knowledge and skills related to biotechnology. The fact that senior teachers do not go beyond the conventional and theoretical training in biotechnology during their undergraduate education, and that they do not receive any in-service training in subsequent years have led to their being outdated in biotechnology. As a result, they can transfer what they could learn on their own to their students to a limited extent that. And, the candidate teachers who are currently being trained are bound by theoretical and practical training they have at university. Given the fact that biotechnology is a comprehensive and constantly updated field, and a field of science that collects a large part of the requirements of the age as an interdisciplinary science, teacher training in this field seems to be inadequate.

Science of biotechnology, which students come across from primary school up to high school, must be presented by a teacher equipped in this field. Evaluating the results of our study from this perspective, it is understood that applied biotechnology course hours at the undergraduate education for teachers should be increased, if non-existent, and be added, if existent. In addition, in-service training should be organized at regular intervals in order for teachers to be aware of the biotechnological developments and knowledge, and to keep their knowledge up-to-date on regular basis.

Given the results of this study, applied biotechnology education seems to affect teachers' knowledge and level of perception in a positive way, to increase their theoretical knowledge and practical skills in the field of biotechnology and to bring their interest in the subject to the required level. It is understood clearly that the required studies should be made in this field, undergraduate programmes for teachers should be developed, in-service applied training programmes should be regulated and that this sample study of ours should be spread and more studies should be made on this field in our country.

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APPENDIX A

QUESTIONAIRRE ABOUT BIOTECHNOLOGY

Date:..../..../2014

This questionnaire has been prepared to receive the views of the participants on biotechnology. The questionnaire does not involve personal information such as names, home addresses or phone numbers. It's not an achievement test, the aim is to determine the general trends based on the average scores given to the questions, but not the personal achievement.

Considering that the questions in this survey may lead the studies that will be conducted on topics such as the development of the curriculum, in-service education etc.; this questionnaire should be answered as objectively and carefully as possible.

We thank you for making contributions to future studies by answering the questions in this survey.

Please mark with “X” where convenient.

A- DEMOGRAPHIC QUESTIONS							
1- Your Gender:		***2- Your Grade:***				***3- Have you received Biotechnology Education Previously?***	
M ( )	F ( )	1 ( )	2 ( )	3 ( )	4 ( )	Y ( )	N ( )

Below are given some options about some facts and to what extent they are known.
State your opinions about these options by marking “X” in the related area.

B- FACTS		**Level of Knowledge**			
		I’ve never heard of -1-	**I heard but I cannot explain. -2-**	**I have enough knowledge to explain. -3-**	**I know exactly. -4-**
1	Biotechnology				
2	Microorganism				
3	Fermentation				
4	Penicillin				
5	Green revolution				
6	Genetic Engineering				
7	Gene cloning				
8	Genetically modified organism (GMO)				
9	Recombinant DNA				
10	Chromatography Techniques				
11	RFLP technique				
12	PZR technique				

Below are given some opinions about sustainable development.
State your status of agreement with these opinions by marking "X" in the related area.

C- OPINIONS		**Level of Agreement**				
		I strongly agree -5-	**I agree -4-**	**I'm neutral -3-**	**I disagree -2-**	**I strongly disagree -1-**
1	Agricultural products with high nutritional power and improved quality of food should be grown by changing the genetic structure of seeds through biotechnological methods.					
2	I can consume the agricultural products (wheat, tomatoes etc.) grown with this method.					
3	Genetically modified (GMO) products may be harmful to human health.					
4	Drugs must be developed with the help of microorganisms by biotechnological methods.					
5	I can use a drug produced with this method.					
6	Biotechnology should be used if it will cure fatal diseases (cancer etc.).					
7	Higher quality and more efficient animal breeds must be created by changing the genetic structure of animal breeds.					
8	I can eat the meat of a genetically modified animal.					
9	Waste released to the environment must be cleaned by biotechnological methods.					
10	Biotechnological methods should be used to purify contaminated water.					
11	Instead of the various materials used in industry, microorganisms and enzymes should be used.					
12	Materials and weapons must be produced in the military field using biotechnology.					
13	More resources should be allocated to biotechnological research all over the world and studies should be supported.					
14	Biotechnological research should be strictly controlled all over the world.					
15	The benefits of biotechnology are more than the risks.					
16	I rely on identifying parents and criminals with forensic DNA testing.					

Some skills performed in the laboratory are given below regarding GMOs.

Specify your thoughts about whether you have these skills or not by marking "X" in the related area.

D- SKILLS		**ANSWER**			
		YES		**PARTIALLY**	**NO**
		theoretically	**practically**		
1)	**I can detect whether it is a GM product using the PCR technique.**				
a)	For this purpose, I can make DNA isolation from the food.				
b)	I can apply the PZR technique.				
c)	I can view the results of PZR technique applied on agarose gel electrophoresis.				
2)	**Using the RFLP method, I can perform criminal detection by applying forensic DNA testing.**				
a)	The restriction of with restriction endonuclease enzymes I can perform the cut of the samples replicated by PZR with the help of restriction endonuclease enzymes.				
b)	I can carry out the results in agarose gel electrophoresis and perform the process of gel staining.				
c)	I can interpret the stained results.				
3)	**With a bacteria transformation experiment, I can perform the process of transferring a gene to a bacteria and producing a new protein it.**				
a)	I can perform the bacteria lysis process with different methods.				
b)	By treating lysed bacteria with centrifuges, I can perform the processes of separating intracellular proteins from other organelles of a cell and from its molecules.				
c)	I can follow (interpret) the result visually.				
4)	**By conducting cloning and indexing experiments, I can perform the cloning of a plant and indexing of its relevant genes.**				
a)	I can make DNA isolation from plants for this purpose.				
b)	Using the GADPH PCR technique, I can perform the process of the replication of GAPC gene region.				
c)	I know what the basic concepts such as "primer", "initial primers", "nested PZR" and "degenerative primer" used at this stage mean.				
d)	I can perform the nested PZR technique.				
e)	I can view the results by agarose gel electrophoresis technique.				
f)	I can isolate PZR products.				
g)	I know the meanings and functions of the concepts of "ligation" and "vector" used at this stage.				

h)	I can perform the operation of transferring the gene region obtained to a vector by means of ligation.				
I)	I can perform the process of making a component bacteria.				
i)	I can perform the vector transfer process prepared for a bacteria in a component state.				
j)	I can replicate the bacteria in a transformed form in a special environment.				
k)	I know the specifics of this particular environment.				
l)	To sequence the bacteria multiplied in a particular environment, I can perform the process of plasmid, that is, re-purification of the vector.				
m)	I know the meaning of the concept of “miniprep” used during this process.				
n)	I can view itin the agarose by cutting with the plasmid enzyme.				
o)	I can interpret the results.				
p)	I have theoretical information on DNA sequencing performed at this stage.				
r)	I know what processes are required in order to take a DNA to sequencing.				

We thank you for your time and wish you success in your academic life.

APPENDIX B

The program of the project.

Order	Name of Activity	Date of Activity	Start and End Time	
1	Seminar	*Day 1*	*11:00*	*12:00*
2	DNA isolation (DNA testing)	*Day 1*	*13:00*	*14:00*
3	DNA duplication (DNA testing)	*Day 1*	*14:00*	*15:00*
4	Electrophoresis (DNA testing)	*Day 1*	*15:30*	*16:30*
5	Interpretation of the test results (DNA testing)	*Day 1*	*16:30*	*17:00*
6	Sample preparation (Gene Cloning)	*Day 2*	*09:00*	*11:00*
7	DNA Isolation (gene cloning)	*Day 2*	*11:00*	*12:00*
8	DNA duplication (Gene Cloning)	*Day 2*	*13:00*	*14:00*
9	Broth preparation (Gene Cloning)	*Day 2*	*14:00*	*17:00*
10	Treatment with exonuclease (Gene Cloning)	*Day 3*	*09:00*	*11:00*
11	DNA duplication (Gene Cloning)	*Day 3*	*11:00*	*12:00*
12	Purification (Gene Cloning)	*Day 3*	*13:00*	*14:00*
13	Binding (Gene Cloning)	*Day 3*	*14:00*	*15:00*
14	Transformation (Gene Cloning)	*Day 3*	*15:30*	*16:00*
15	Incubation (gene cloning	*Day 3*	*16:00*	*17:00*
16	Incubation (gene cloning)	*Day 4*	*09:00*	*10:00*
17	Sample Preparation (GMO Analysis)	*Day 4*	*11:00*	*12:00*
18	DNA isolation (GMO Analysis)	*Day 4*	*13:00*	*14:00*
19	Interpretation of the test results (GMO Analysis)	*Day 4*	*14:00*	*15:00*
20	Interpretation of the test results (Gene Cloning)	*Day 4*	*15:30*	*17:00*

(continued)

Order	Name of Activity	Date of Activity	Start and End Time	
21	PCR preparation (GMO Analysis)	*Day 5*	*09:00*	*11:00*
22	DNA duplication (GMO Analysis)	*Day 5*	*11:00*	*12:00*
23	Electrophoresis (GMO Analysis)	*Day 5*	*13:00*	*15:00*
24	Interpretation of the test results (GMO Analysis)	*Day 5*	*15:30*	*17:00*
25	Broth preparation (Protein Purification)	*Day 6*	*10:00*	*11:00*
26	Transformation (Protein Purification)	*Day 6*	*11:00*	*12:00*
27	Broth preparation (Protein Purification)	*Day 6*	*13:00*	*15:00*
28	Incubation (Protein Purification)	*Day 6*	*15:30*	*17:00*
29	Broth preparation (Protein Purification)	*Day 7*	*09:00*	*10:00*
30	Inoculation (Protein Purification)	*Day 7*	*10:00*	*12:00*
31	SDS-Page (Protein Purification)	*Day 7*	*15:30*	*17:00*
32	Interpretation of the test results (Protein Purification)	*Day 7*	*15:30*	*17:00*
33	Lysis of the cell membrane (Protein Purification)	*Day 8*	*09:00*	*12:00*
34	Bio-nano-tech. R & D centre trip	*Day 8*	*13:00*	*17:00*
35	Protein separation (Protein Purification)	*Day 9*	*09:00*	*12:00*
36	Interpretation of the test results (Protein Purification)	*Day 9*	*13:00*	*15:00*

APPENDIX C

PHOTOS


FATİH ÜNİVERSİTESİ


SafeFAST Classic