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Research Article

Biotechnology Literacy Levels and Biotechnology Knowledge of Prospective Science Teachers *

Fen Bilimleri Öğretmen Adaylarının Biyoteknoloji Okuryazarlık Düzeyleri ve Biyoteknoloji Bilgileri

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ABSTRACT

One of the fastest growing fields in science in the 21st century is biotechnology. Biotechnology affects many areas of human life. Biotechnologically developed countries are also advanced in scientific literacy. Biotechnology literacy is an integral part of scientific literacy. It is believed that the greatest role in the development of scientific literacy and biotechnology literacy in societies belongs to science teachers. Therefore, the biotechnological literacy levels of prospective science teachers, who have a very effective role in creating the biotechnological literacy of students in our country, are wondered. It is aimed via this study to reveal how biotechnology literacy dimensions of prospective science teachers are and how biotechnology knowledge of prospective science teachers is. To reveal these, a biotechnology literacy test prepared in accordance with the test development process was used. Survey research method is preferred among quantitative research methods in this study. The prospective science teachers who were senior students at seven universities were chosen as a sample group of research. After application of test, It is revealed that most of the participants have low level for both biotechnology literacy dimension and biotechnology knowledge. Moreover, lots of misconceptions and misunderstandings were observed related to genetics and biotechnology among participants.

Keywords: Biotechnology literacy, biotechnology literacy level, biotechnology knowledge, prospective science teacher.

ÖZ

21. yüzyılda bilimde en hızlı gelişen alanlardan birisi de biyoteknolojidir. Biyoteknoloji insan yaşamının birçok alanı etkilemektedir. Biyoteknolojik yönden gelişmiş ülkeler aynı zamanda fen okuryazarlığında da gelişmiştir. Biyoteknoloji okuryazarlığı da fen okuryazarlığının ayrılmaz bir parçasıdır. Toplumlarda fen okuryazarlığın, biyoteknoloji okuryazarlığın gelişmesinde en büyük rolün fen bilimleri öğretmenlerine ait olduğu düşünülmektedir. Bu nedenle ülkemizde öğrencilerin biyoteknolojik okuryazarlıklarını oluşturmada çok etkin bir role sahip olan fen bilimleri öğretmen adaylarının kendi biyoteknolojik okuryazarlık düzeyleri merak edilmektedir. Bu araştırmada fen bilimleri öğretmen adaylarının biyoteknolojik okuryazarlık boyutları ve biyoteknoloji bilgilerinin nasıl olduğu ortaya

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çıkarılmaya çalışılmıştır. Fen bilimleri öğretmen adaylarının biyoteknoloji bilgileri ve biyoteknoloji okur yazarlık düzeylerini ortaya çıkarmak için test geliştirme sürecine uygun olarak hazırlanmış biyoteknoloji okuryazarlık testi kullanılmıştır. Araştırmada nicel araştırma türlerinden tarama araştırma yöntemi tercih edilmiştir. Araştırmanın örneklem grubu, yedi üniversitenin son sınıflarında eğitim gören fen bilimleri öğretmen adaylarıdır. Biyoteknoloji okuryazarlık testinin fen bilimleri öğretmen adaylarına uygulanması neticesinde adayların çoğunluğunun biyoteknoloji bilgilerinin ve biyoteknoloji okuryazarlık boyutların her birinde alt seviyede olduğu gözlemlenmiştir. Yapılan analizlerde fen bilimleri öğretmen adaylarında genetik ve biyoteknolojiye ait çok sayıda kavram yanılgısı tespit edilmiştir.

Anahtar Kelimeler: Biyoteknoloji okuryazarlığı, biyoteknoloji okuryazarlık düzeyi, biyoteknoloji bilgisi, fen bilimleri aday öğretmeni.

INTRODUCTION

Biotechnology, to put it simply, includes the utilization of living things or the outputs of them in the interest of human beings (Thieman & Palladino, 2014). There are numerous uses for biotechnology in business, industry and the environment (Ratledge & Kristiansen, 2001). One of the most significant developments in technology in the twenty-first century is that biotechnology has a profound impact on the life of every individual. Biotechnology contains interdisciplinary endeavors such as recombinant DNA technology and cloning as well as involving the production of bread, beer, cheese, antibiotics, etc via microbiological treatments to materials. Biotechnology offers opportunities such as addressing environmental issues, promoting clean technology and curing a wide range of disorders (Ratledge & Kristiansen, 2001).

Biotechnology has been divided into 4 categories according to their usage areas at last times (Pele & Campeanu, 2012; Casanoves de la Hoz, 2015).

Red biotechnology: It includes the applications of biotechnology in the field of health. Medicine, vaccine creation; diagnosis and control of the disease occur through the applications in this field.

Green biotechnology: It covers biotechnological practices in the field of agriculture. It aims to improve agricultural harvest and the plants which are resistant to several environmental circumstances thanks to these practices.

White or gray biotechnology: It illustrates biotechnological practices participated into environment and industry.

Blue biotechnology: This biotechnological field points out biotechnological practices which are applied in hydrophilic regions such as oceans, sea, lake etc. (Pele & Campeanu, 2012; Casanoves de la Hoz, 2015).

The advancements in the biotechnology in medicine, agriculture and business are so rapid that human existence has also been affected by this case(de la Hoz et al., 2022).

Biotechnology daily pogresses in the field of science all over the world. Biotechnology is encountered in many areas of life, from health to agriculture, from sea to industry (Bhatia, 2018). Many of the processes that make our lives easier today occur by means of biotechnology. To illustrate those:

- ✓ insulin utilized by patients,
- ✓ pcr equipment used in gene amplification and to detect virus existence,
- ✓ mRNA vaccines utilized to cope with epidemic diseases,
- ✓ FISH method used to detect chromosomal abnormalities of fetus,

- ✓ DNA or RNA sequencing utilized to identify the gene in question whether it is changed or not,
- ✓ RNA interference utilized to inhibition of gene expression,
- ✓ genome editing which is taken place by crispr-cas9 system such as it is utilized in gene correction
- ✓ Recombinant DNA technology
- ✓ DNA fingerprint utilized in forensic medicine (Thieman & Palladino, 2014; Pham, 2018)

Since biotechnology contribute to economical advancement of societies, authorities insert the biotechnology into their national school schedules (Australia Education Council, 1994; Hin et al., 2019). Also, it is suggested that the biotechnology education should be started from primary school, it should not be left to secondary school (Rota & Izquierdo, 2003; Hin et al., 2019). To grasp the biotechnological expressions, terms and explanations human beings must be literate in the field of biotechnology (de la Hoz et al., 2022). Biotechnological practices both contemporary and to be applied in the future must be evaluated by filtering out socially and ethically by mankind. Hence, the society has to be thoroughly educated about biotechnological activities particularly which are interested in public health, farming and ecology (Pas et al., 2019).

In order to make students literate in biotechnology, the school curriculums should involve biotechnology issues. In this way, the pupils educated and taught biotechnology lessons, would have biotechnology literacy. Therefore these citizens will easily decide about biotechnological issues because of their education in advance (Pas et al., 2019). Teachers have a critical role in making students literate about biotechnology. For this reason, the teachers primarily themselves should be knowledgeable as to biotechnological principles and applications to instruct subsequent generations regarding biotechnology (de la Hoz et al., 2022). Based on this, it is thought that teachers who are well trained in biotechnology will better educate their students about biotechnology (de la Hoz et al., 2022; Casanoves de la Hoz, 2015), in other words, the more equipped teachers are in biotechnology, the better their students will be trained in biotechnology. In addition, prospective science teachers' attitude to biotechnology affects their biotechnology acceptance degree. Their attitude to biotechnology also will impact their biotechnology instruction degree in the future, which means students' biotechnological competency depends on the approaches of science teachers to biotechnology. Therefore, prospective science teacher's attitude to biotechnology should be found out while they study at university (Chabalengula et al., 2011). Briefly, teachers' attitudes towards biotechnology and teachers' knowledge related to biotechnology affect their biotechnology teaching.

School schedules can directly affect biotechnology knowledge of people. Chen and Raffan (1999) in their study compared the school curriculum of UK and Taiwan. The authors indicated that the students of UK at the age of between 16 and 19 were relatively more knowledgeable than Thaiwanese counterparts in biotechnology. In addition, the participation ratio to involve into social issues regarding biotechnology was higher at English students compared to Taiwanese ones. The reasons of those, firstly the UK school schedule was larger and more detailed in terms of biotechnology issues than Taiwanese one. The second reason was that the UK curriculum gave more chance to students to argue controversial issues related to biotechnology than Taiwanese one. The third reason was that some scientific establishments based biotechnology in the UK such as NCBE (National Council for Biotechnology Education), BBSRC,MRC, SAPS enhanced the biotechnology knowledge of students by giving them chance to make biotechnological applications. In these foundations scientist and teachers work together to raise biotechnological knowledge of students (Chen & Raffan, 1999). This study clearly demonstrated that apart form curriculum and textbook, establishments also influence biotechnology education.

The goal of a decent biotechnology training is not just to constitute positive attitude to biotechnology in individuals. However, the purpose of it is to lay out the contemporary biotechnology with all aspects such as advantages, disadvantages and ethical concerns, as well (Chen & Raffan, 1999; Kidman, 2009). High quality biotechnology instruction is required for individuals to put forward an logical idea for controversial social issues or to participate in public debate related to biotechnology (Kidman, 2009). Hence the individuals well-equipped with biotechnology knowledge decide more sensible both for their daily life and for the future of their society.

In 2019, the OECD/PISA briefly defined scientific literacy as knowing scientific thoughts and being interested in scientific issues. Also, a typical characteristic of a scientifically literate person is applying the scientific principles in daily life (OECD, 2019). In a study, it is determined that the countries which contribute the most to biotechnology literature through their publications are USA, China and Germany respectively (Yeung et al., 2019). On the other hand, the common feature of these three countries, which are ahead in terms of biotechnological papers, is that they also located at high ranks in scientific literacy according to 2018 Pisa results (Schleicher, 2019). Thereby it can be thought that there is a positive corelation between scientific literacy and biotechnological literacy in the light of researches.

Bybee (1997) categorize scientific literacy into four levels. Among these scientific literacy levels the lowest one is nominal scientific literacy that includes only the knowledge of scientific words and names related to science. According to Bybee (1997) the second level of scientific literacy is functional scientific literacy in this category someone utilize scientific expressions in a restricted context. On the other hand, someone in procedural literacy can establish connections between concept and scientific field, and in addition can use scientific methods. Finally, Multidimensional scientific literacy, the highest one, comprises history and nature of science as well as the effect of science in the society. (Bybee, 1997; OECD, 2003)

Science education has a crucial function in advancement and development of scientific literacy (Klop & Severiens, 2007). Biotechnology literacy which is a component of scientific literacy is based on information and applications of genetic discipline (de la Hoz et al., 2022). Manner and awareness that concern biotechnology of primary school teachers should be elicited because they possess a great impact on improvement of biotechnology literacy of succeeding generations. Taking these data into consideration the curriculum of biology should be investigated to see whether it can meet biotechnological developments and innovations or not, and after that the biology curriculum should be reconstructed to include recent innovations in case of need. (de la Hoz et al., 2022).

Since teachers are an important factor in forming students' biotechnology literacy, to obtain information about the biotechnology literacy of the teachers, the literature was searched. Thus, the studies related to biotechnology were examined. Sorgo and Ambrozis-Dolinsek (2009) in their study demonstrated that Slovenian teachers knew lots of things in topics of traditional biotechnology in contrast that they knew little about contemporary biotechnology subjects (Sorgo & Ambrozis-Dolinsek, 2009).

Casanoves (2015) found in their study that prospective Spanish elementary teachers were conscious of biotechnology practices but that their knowledge fluctuated, i.e. it shifts from one subject to another one. They are against genetically engineered outputs. However, they are in favour of biotechnology if it is utilized with therapeutic intent. Lastly, the findings of the study indicated that there was affirmative connection between understanding and manner devoted to biotechnology for prospective elementary teachers (Casanoves et al., 2015).

Apart from foreign publications, it is observed that there are some national studies (Darçın, 2007; Yüce, 2011; Açıkgül Fırat, 2015; Orhan, 2019) which examine the biotechnology literacy levels of science teachers and prospective science teachers in Turkey.

These publications revealed that biotechnology literacy levels of science teachers and prospective science teachers were low. It is thought that one of the reasons for the low biotechnology literacy among prospective science teachers in Turkey is due to the curriculum in universities. Because in the curriculum of prospective science teachers, which has been prepared by YÖK, biotechnology topics are given only for two semesters; first one in the “Genetic and Biotechnology” course at sixth term and second one “Special Topics in Biology” course at seventh term at universities. However, these two courses don’t contain any lab-based practices for biotechnology (Orhan, 2019).

In addition, when national and international papers which examine the biotechnology literacy levels of science teachers and prospective science teachers were analyzed, it was identified that most of the biotechnology-related items in the tests directed to the participants did not include current biotechnology applications. It is observed that only Orhan (2019) implemented laboratory-based some contemporary biotechnology activities with science teachers. Furthermore, it was revealed that the prospective science teachers' knowledge related to medical biotechnology applications was not investigated in the literature. In other words, the tests which were prepared to measure the biotechnology literacy levels of science teachers and prospective science teachers in the studies carried out before our research do not contain the following

- ✓ FISH method which is utilized to detect chromosome abnormality especially Down syndrome,
- ✓ GFP which is used to determine the location of protein and gene expression level in the cell,
- ✓ Apoptosis used to eliminate cancerous and unwanted cells,
- ✓ Promoter and UTRs, which affect gene expression
- ✓ RISC, which is utilized to degrade unwanted mRNAs
- ✓ RNA sequencing that reveals the gene expression level and indicates mutation is occurred or not,
- ✓ The heat shock technique, which is utilized to make genetically modified organisms
- ✓ Alternative splicing mechanism, which is one of the important outputs of the human genome project that allows to produce a lot of different proteins from a single gene
- ✓ Model organisms that are utilized in biotechnology and why is E. coli (or other organism) utilized as amodel organism in the biotechnology
- ✓ RNA varieties especially long non-coding RNAs and micro RNAs
- ✓ Genome editing mechanism especially via CRISPR-Cas9 system
- ✓ The tools that are used in biotechnology (for example PCR
- ✓ Reverse trancriptase and restriction enzymes which are used in biotechnological experiments.

For this reason, a novel biotechnology literacy test was prepared to reveal biotechnology literacy levels and biotechnology knowledge of prospective science teachers. None of the tests used in previous studies (Darçın, 2007; Yüce, 2011; Açıkgül Fırat, 2015; Casanoves, 2015; Orhan, 2019) included all the biotechnological methods, techniques and applications mentioned above . When these publications were analyzed thoroughly, it is concluded that none of the biotechnology literacy tests in these publications measuring biotechnology literacy of teachers and prospective teachers contain FISH method (Wieacker & Steinhard, 2010), GFP (Zimmer, 2002; Zimmer, 2009), apoptosis (Elmore, 2007; Singh et al., 2017; Pfeffer & Singh, 2018), promoter (Li & Zhang, 2014), UTRs (Kim et al., 2020), RISC (Zhang, 2013), heat shock technique (Cohen, Chang & Hsu, 1972), alternative splicing (Roy, Haupt & Griffiths, 2013). These biotechnological techniques, methods, topics and applications are integral parts of biotechnology literacy. In other words, it has not been investigated whether these biotechnological topics and contemporary biotechnological applications are known by science teachers or prospective science teachers before. In order to eliminate the openness in the field, the biotechnological methods, techniques, knowledge and applications which are mentioned above were asked to prospective science teachers for the first time via this study. The biotechnological methods, techniques, knowledge and applications mentioned above are important elements of biotechnology literacy.

Moreover through this research it will be revealed to what extent contemporary biotechnological applications, methods, techniques and products are known by prospective science teachers in Turkey. And, also it will be elicited whether the prospective science teachers follow the history of science related to biotechnology or not.

Taking into consideration the data above, it is thought that science teachers have the most important role in providing qualified biotechnology education, creating students' biotechnological literacy, teaching students how to follow the systematics of thinking in socioscientific issues related to biotechnology. For this reason, it is considered that science teachers who will perform these important tasks should be trained very well in biotechnology before service, while studying at the university. In other words, the proficiency of science teachers in biotechnology depends on the biotechnology education they received at universities pre-service. Because, it seems unlikely that prospective science teachers who are not proficient in terms of current biotechnology applications and biotechnology knowledge will train students qualified in biotechnology. Hence, in this study, the biotechnology literacy levels and biotechnology knowledge of prospective science teachers in Turkey were wondered.

Research problem:

1. What are the biotechnology literacy levels of prospective science teachers and how is their biotechnology knowledge?

Sub problems:

1. What is the level of biotechnology literacy of prospective science teachers?
2. How is the biotechnology knowledge of prospective science teachers?

METHOD

2.1. Research Design

In the research, survey research, one of the quantitative research methods, was used to determine the biotechnological literacy levels of prospective science teachers. Survey research was preferred because it allows the collection of information from the sample group at once (Buyukozturk, 2016; Fraenkel et al., 2012).

2.2. Population and Sample

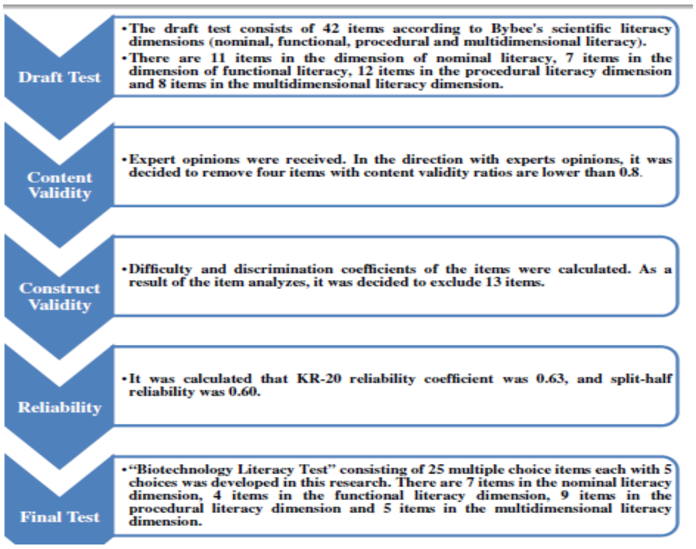
The sample group of the research consists of 4th grade prospective science teachers studying at seven universities in Turkey. The sample group includes 325 prospective science teachers selected by the convenient sampling method.

2.3. Data Collection Instruments

The biotechnology literacy tests (Darçın, 2007; Yüce, 2011; Açıkgül Fırat, 2015; Casanoves, 2015; Orhan, 2019) which examine the biotechnology literacy levels of teachers and prospective teachers in the literature were investigated. After investigation, it is concluded that none of the these tests consist of FISH method, GFP, apoptosis, promoter, UTRs, RISC, heat shock technique and alternative splicing. Therefore, biotechnology literacy levels of prospective science teachers were measured via a novel biotechnology literacy test. In other words, these biotechnology literacy tests in the literature which are mentioned above were insufficient to measure biotechnology literacy of prospective science teachers especially in terms of medical biotechnology applications and techniques (including FISH method, GFP-tagging, DNA element such as promoters and UTRs that are parts of mRNA, which influence gene regulation; RISC, RNA sequencing, heat shock technique that is utilized in transformation process to make transgenic organism, model organisms that are used in biotechnology, alternative splicing mechanism, long non-coding RNAs and micro RNAs which are involved in gene regulation, CRISPR-Cas 9 mediated genome editing, apoptosis, the equipments and enzymes which are participated in recombinant DNA technology) the novel biotechnology literacy test containing contemporary biotechnology applications and techniques was developed during the research process by the reasearcher in the study. The stages followed by Açıkgül Fırat and Köksal (2019) in the "biotechnology literacy test development process" were taken as a model (See Figure 1) on the test development in the study.

Figure 1

*The Stages Followed by Açıkgül Fırat and Köksal during "Biotechnology Literacy Test Creation Process" (*Source: Açıkgül Fırat & Köksal, 2019)



Initially a draft biotechnology literacy test consisting of 40 multiple choice items was prepared by the author after investigation of biotechnology literature. Then, this draft test was evaluated by experts in the field of biotechnology. Field experts stated their opinions on each item as a result of their examination. The item is necessary or not. After the opinions of field experts to calculate the content validity of the each item, content validity formula of Lawshe (1975) was utilized**.** In the study, opinions on content validity for each item were received from five experts in the field of biotechnology. According to Lawshe (1975) for a group of five experts, the minumum content validity ratio for each item should be 0.99 (See Figure 2). The items 2, 15, 18, 24, 26, 33, 38, 39 in the draft biotechnology literacy test were found inadequate in terms of content validity (content validity ratio value under 0.99) by the biotechnology expert group**.** For this reason, the relevant questions have been excluded from the draft biotechnology literacy test.

Figure 2

The Required Content Validity Ratio for Each Item Varies Depending on The Number of Experts (Source: Lawshe, 1975)

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TABLE 1
Minimum Values of CVR and CVR_t
One Tailed Test, p = .05

No. of Panelists	Min. Value*
5	.99
6	.99
7	.99
8	.75
9	.78
10	.62
11	.59
12	.56
13	.54
14	.51
15	.49
20	.42
25	.37
30	.33
35	.31
40	.29

Then, the test was applied to 280 prospective science teachers in order to find out whether each item in the draft biotechnology test, which included 32 items, had construct validity.(A participant gets 1 point for answering the item correctly and 0 point for answering incorrectly.) Also, in order to evaluate the construct validity of the each item, item discrimination index of Ebel and Frisbie (1991) was utilized. The responses of prospective science teachers to the test were analyzed by TAP (Test Analysis Program). According to the analysis result, the item discrimination index of 5 questions was below 0.30. 5. question (item discrimination index 0.07), 12.question (item discrimination index 0.28), 23.question (item discrimination index 0.29), 25.question (item discrimination index 0.22), 29. question (item discrimination index is 0.19.) Items with a discrimination index below 0.30 (Ebel & Frisbie, 1991) will be removed from the test because they cannot distinguish those who have the desired feature from those who do not. After removing 5 items with low item discrimination index from 32 questions of the biotechnology literacy draft test, there were 27 questions left in the test. The control of the construct validity of 27 questions was also carried out by independent t-test in SPSS (See Table 1). According to assumption, it is claimed that if an item included in the biotechnology literacy test can measure the desired construct (property), the relevant construct should be owned by individuals in the upper group of the sample, while the same construct should not be observed in individuals in the lower group of the same sample group. (Peterson et al., 2010) As a natural consequence of this case, if the item is distinctive, a significant score difference would be expected between the arithmetic mean of individuals in the upper group for the relevant item and the arithmetic mean of individuals in the lower group for the same item.

Table 1

Independent T Test Results of 27 Items in The Biotechnology Literacy Test

Item		N	x̄	S	df	t	p
Item 1	Upper % 27	75	.60	.493	149	8.794	.000
	Lower % 27	76	.05	.225			
Item 2	Upper % 27	75	.79	.412	149	7.511	.000
	Lower % 27	76	.26	.443			
Item 3	Upper % 27	75	.57	.498	149	5.841	.000
	Lower % 27	76	.16	.367			
Item 4	Upper % 27	75	.69	.464	149	10.365	.000
	Lower % 27	76	.07	.250			
Item 6	Upper % 27	75	.57	.498	149	6.951	.000
	Lower % 27	76	.11	.309			
Item 7	Upper % 27	75	.93	.251	149	6.680	.000
	Lower % 27	76	.50	.503			
Item 8	Upper % 27	75	.65	.479	149	10.328	.000
	Lower % 27	76	.04	.196			
Item 9	Upper % 27	75	.47	.502	149	7.274	.000
	Lower % 27	76	.03	.161			
Item 10	Upper % 27	75	.68	.470	149	7.333	.000
	Lower % 27	76	.17	.379			
Item 11	Upper % 27	75	.80	.403	149	10.242	.000
	Lower % 27	76	.16	.367			
Item 13	Upper % 27	75	.80	.403	149	6.365	.000
	Lower % 27	76	.34	.478			
Item 14	Upper % 27	75	.67	.475	149	8.626	.000
	Lower % 27	76	.11	.309			
Item 15	Upper % 27	75	.63	.487	149	7.867	.000
	Lower % 27	76	.11	.309			
Item 16	Upper % 27	75	.40	.493	149	6.275	.000
	Lower % 27	76	.03	.161			
Item 17	Upper % 27	75	.49	.503	149	6.006	.000
	Lower % 27	76	.09	.291			
Item 18	Upper % 27	75	.69	.464	149	9.943	.000
	Lower % 27	76	.08	.271			
Item 19	Upper % 27	75	.60	.493	149	5.997	.000
	Lower % 27	76	.17	.379			
Item 20	Upper % 27	75	.68	.470	149	10.963	.000
	Lower % 27	76	.04	.196			
Item 21	Upper % 27	75	.65	.479	149	5.195	.000
	Lower % 27	76	.26	.443			
Item 22	Upper % 27	75	.71	.458	149	9.848	.000
	Lower % 27	76	.09	.291			
Item 24	Upper % 27	75	.72	.452	149	10.162	.000
	Lower % 27	76	.09	.291			
Item 26	Upper % 27	75	.60	.493	149	4.835	.000
	Lower % 27	76	.24	.428			
Item 27	Upper % 27	75	.63	.487	149	9.320	.000
	Lower % 27	76	.05	.225			
Item 28	Upper % 27	75	.83	.381	149	13.321	.000
	Lower % 27	76	.09	.291			
Item 30	Upper % 27	75	.53	.502	149	5.249	.000
	Lower % 27	76	.16	.367			
Item 31	Upper % 27	75	.99	.115	149	6.537	.000
	Lower % 27	76	.61	.492			
Item 32	Upper % 27	75	.57	.498	149	5.115	.000

According to the independent t test results, all items in Table 1 can distinguish between the lower and upper groups since $p < 0.05$, therefore it can be said that the items have construct validity.

After removing items which threaten content and construct validity of the test, finally the reliability of the test was calculated. KR-20 reliability index of the test was 0.89. As a result of the test development, the Final Biotechnology Literacy Test consisting of 27 questions and a reliability of 0.89 was obtained. The 27 questions in the test were prepared to reveal the biotechnology literacy levels categorized by Bybee (1997).

Table 2

Biotechnology Literacy Test Includings Items for Investigation of Subdimesions of Biotechnology Literacy of Prospective Science Teachers

Subdimension of Biotechnology Literacy	Questions	Total Number of Questions
Nominal	Q1, Q2, Q6	3 items
Functional	Q3, Q4, Q7, Q8, Q10, Q11, Q19, Q22	8 items
Procedural	Q9, Q12, Q13, Q14, Q15, Q16, Q18, Q20, Q23, Q24, Q25, Q26, Q27	13 items
Multidimensional	Q5, Q17, Q21	3 items

The biotechnology literacy test, which consists of 27 questions including biotechnology literacy sub-dimensions and was prepared according to the test development processes, has taken its final form.

2.4. Data Collection Process

First of all, permission was obtained from some universities in Turkey to collect data from prospective science teachers through YÖK. The data collection process took place in two stages. In the first step, the data was taken from the participants to reveal the validity and reliability of the draft biotechnology literacy test. Hence, firstly this draft test was applied to 280 prospective science teachers. Then in the second step, biotechnology literacy test of 27 questions whose validity and reliability has been ensured, was applied to 325 prospective science teachers to measure their biotechnology literacy levels and biotechnology knowledge. Prospective science teachers were informed about the aim of the research and the participation of the participants in the study was based on volunteering. The data collection process occurred during 2021-2022 academic years.

A lot more prospective science teachers were desired to participate in the research. However, the research coincided pandemic period. Therefore this circumstance led to decrease in the number of prospective science teachers' participation to the study.

2.5. Data Analysis

Subsequent to application of both draft and final biotechnology literacy test to the sample group, the obtained data was investigated by TAP (test analysis program) and SPSS. TAP program was utilized to acquire item statistics (such as item discrimination index, item difficulty index) and to calculate the score of each prospective science teacher in response to biotechnology literacy test. SPSS program was used to identify descriptive statistics of sample group and to determine how score distribution of prospective science teachers occurred and also to calculate the mean of each dimension of biotechnology literacy. After investigation, data has been introduced by means of figures and a table.

2.6. Ethical Issues

Prior to start to the study, permission was obtained from Hacettepe Ethics Commission. Subsequent to approval, permission was asked from other universities to conduct the biotechnology literacy test to prospective science teachers. All the participants were informed related to the research and it was declared the participation in the research is not compulsory.

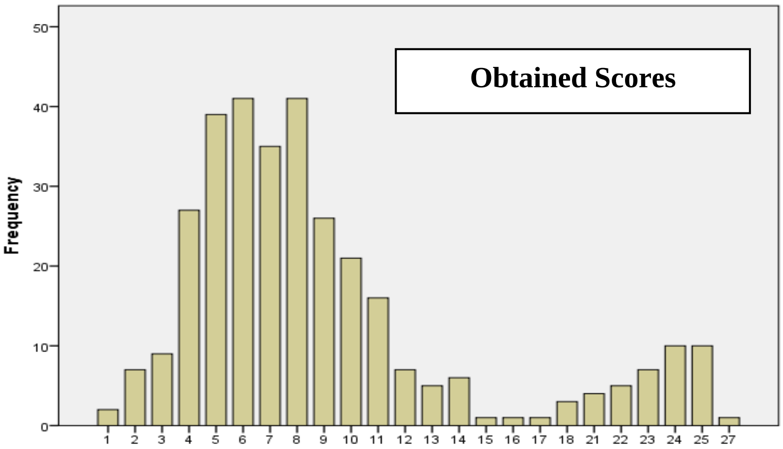
This study was approved by Hacettepe University Etics Commission in 14 September 2021 with the number of E-35853172-300-00001768587.

FINDINGS

The biotechnology literacy test, consisting of 27 questions, which includes items examining nominal, functional, procedural and multidimensional literacy, was applied to 325 prospective science teachers. A participant gets 1 point for answering the item correctly and 0 point for answering incorrectly. The maximum score a prospective teacher can get by answering all the questions in the test is 27.

Figure 3

The Scores Obtained by the Prospective Science Teachers



After 325 prospective science teachers answered the biotechnology literacy test, it was observed that most of the group stacked up on the right side of the graph in terms of the scores they got (See Figure 3). As a result of the analysis of the participants' responses to the test using SPSS, the arithmetic mean was found to be 9.21, the median 8, and the standard deviation 5.91. While the lowest score received by the participants was 1, the highest score was 27. It is observed that the distribution of the scores obtained by the prospective science teachers is skewed to the right.

Table 3

Table Indicating the Scores of Prospective Science Teachers with Frequency and Percentage

Score	Number of participant	Percentage	Validated Percentage	Total Percentage
1	2	.6	.6	.6
2	7	2.2	2.2	2.8
3	9	2.8	2.8	5.5
4	27	8.3	8.3	13.8
5	39	12.0	12.0	25.8
6	41	12.6	12.6	38.5
7	35	10.8	10.8	49.2
8	41	12,6	12,6	61,8
9	26	8.0	8.0	69.8
10	21	6.5	6.5	76.3
11	16	4.9	4.9	81.2
12	7	2.2	2.2	83.4
13	5	1.5	1.5	84.9
14	6	1.8	1.8	86.8
15	1	.3	.3	87.1
16	1	.3	.3	87.4
17	1	.3	.3	87.7
18	3	.9	.9	88.6
21	4	1.2	1.2	89.8
22	5	1.5	1.5	91.4
23	7	2.2	2.2	93.5
24	10	3.1	3.1	96.6
25	10	3.1	3.1	99.7
27	1	.3	.3	100.0
Total	325	100.0	100.0	

After the application, the arithmetic mean of the answers given by the prospective science teachers to the questions (Q1, Q2, Q6) on the test examining nominal biotechnology literacy was 1.36; the arithmetic mean of the functional questions (Q3, Q4, Q7, Q8, Q10, Q11, Q19, Q22) was 2.64; The arithmetic mean of the procedural questions (Q9, Q12, Q13, Q14, Q15, Q16, Q18, Q20, Q23, Q24, Q25, Q26, Q27) was 4.28; The arithmetic mean of multidimensional questions (Q5, Q17, Q21) was also 0.90.

In the research;

- 65.5% of the prospective science teachers (213 participant) in the sample group consider that there are only three varieties of RNA.
- 51.4% (167 participant) of prospective science teachers asserted that RNA is unable to convert into DNA.
- 20% of prospective science teachers stated that RNA can convert into double-stranded DNA via reverse transcriptase enzyme.
- 7.1% of the prospective science teachers suppose that the whole DNA participates in protein coding.
- 12.3% of the prospective science teachers pointed out that only 1.5% of DNA is responsible for regulation.
- 31.1% (101 people) of prospective science teachers specified that the restriction enzymes, which are normally not located in viruses, are naturaly derived from bacteria, and each of these enzymes recognizes specific area in DNA, then specific cleavage takes place from certain region via the enzyme, due to this feature these enzymes also utilize in genetic engineering applications.

- 68.3% (222 people) of prospective science teachers indicated the order in the central dogma mechanism is replication, transcription and translation, respectively.
- 16.9% (55 people) of prospective science teachers suppose that the start code is located in the promoter region.
- 37.5% (122 people) of the prospective science teachers correctly knew the steps which are applied to achieve insulin through recombinant DNA technology.
- 41.8% of the prospective science teachers claimed that copies of nucleic acids can be acquired with a PCR device.
- Some living organisms are used as model organisms in biotechnology because of their unique properties. 48.9% of prospective science teachers selected E.coli as model organism for the rapid gene amplification.
- 17.5% of the participants claimed that one gene can encode just one protein.
- In order to obtain transgenic organism (GMO) scientist utilize the heat shock technique (Cohen, Chang & Hsu, 1972) during transformation process. 31.4% of the participants knew the correct temperatures which are required for heat shock technique in transformation.
- 13.8% of prospective science teachers selected FISH method to detect whether fetus has down syndrome or not.
- 19.4% of participants stated that RNA sequencing may determine the gene expression quantity.
- 12.3% of participants claimed that the weak promoter region leads to more RNA transcripts inside the cell.
- To identify the murder in the scenario 29.8% of the participants preferred DNA fingerprinting method which is an application of forensic medicine.
- 27.7% of participants asserted mRNAs in question can be destroyed by RISC complex, which is also an application of medical biotechnology.
- 40.9% of participants stated that CRISPR are located in the bacterial genome.
- In addition, 34.2% of the participants selected CRISPR-cas9 system which is utilized in genome editing to correct defective gene.
- 29.8% of science prospective teachers claimed that Emmanuelle Charpentier and Jennifer Doudna were awarded the Nobel Prize in 2020 for declaration the CRISPR-Cas 9 system to the World. CRISPR-Cas 9 system is also another crucial application of medical biotechnology.
- 10.2% of the participants defined apoptosis as autophagy**.**
- 31.4% of the participants stated that the GFP is utilized as a marker in biotechnological experiments.
- 82.8% of prospective science teachers claimed that vaccines, antibiotics, interferons and antibodies may be manufactured via biotechnology.

DISCUSSION, CONCLUSION AND SUGGESTIONS

After the analysis of responses of prospective science teachers to the biotechnology literacy test, the following results have been obtained:

The mean of nominal, functional, procedural and multidimensional biotechnology literacy respectively was 1.36, 2.64, 4.28 and 0.90. Based on this data, it is observed that the biotechnology literacy levels of prospective science teachers are low in each dimension, from the lowest level of literacy to the most advanced multidimensional literacy categorized by Bybee (1997). Similarly, Açıkgül Fırat (2015) also indicated that in each dimension; including nominal, functional, procedural and multidimensional of biotechnological literacy of prospective science teachers wasn’t sufficient. In addition, Açıkgül Fırat (2015) to solve this matter in the study applicated web 2.0 based biotechnology teaching to experimental group which contains prospective science teachers.

In the study, 65.5% of the prospective science teachers (213 people) in the sample group think that there are only 3 types of RNA. When the literature is examined, it is stated that there are other types of RNA besides these three RNAs: Micro RNAs, long non-coding RNAs, small inhibitory RNAs, etc. (Zhang et al., 2019). In this situation, it is thought that 65.5% of the candidates are unaware of other RNA varieties.

51.4% (167 people) of prospective science teachers claimed that DNA cannot be obtained from RNA. 20% of prospective science teachers pointed out that the function of the reverse transcriptase enzyme enables the production of double-stranded DNA from RNA. The single stranded cDNA can be created from mRNA by utilizing the reverse transcriptase enzyme and oligothymidine nucleotides (Krug & Berger, 1987) It is understood that the candidates who think that DNA cannot be obtained from RNA are unaware of the reverse transcriptase enzyme. 20% of the candidates state that the function of the reverse transcriptase enzyme is “providing the production of double-stranded DNA from RNA”. Based on this statement, it is concluded that these candidates are at fault because the enzyme provides the production of single-stranded cDNA from RNA (Krug & Berger, 1987).

This question, in the test “What percentage of the average human genome produces our current proteins?” was asked to the participants. 7.1% of the prospective science teachers think that the entire DNA is responsible for protein coding. Another question on the test is, “On average, what percentage of the human genome consists of the non-protein-coding region responsible for regulation?” 12.3% of the prospective science teachers expressed that the part responsible for regulation is 1.5% of DNA. While protein coding section of human genome constitute merely 1.5 percentage of the genome, the rest part of the genome makes up the noncoding section (Lander et al., 2001; Mu et al., 2011). Based on this data, it is understood that some prospective science teachers do not know what percentage of the human genome is responsible for protein coding and what percentage is responsible for regulation.

31.1% (101 people) of prospective science teachers stated that the name of the restriction enzyme comes from bacteria, it does not cut DNA nucleotides randomly, it is not found in viruses, it is not used only in genetic engineering applications, its function is not to connect two separate DNA chains. The responses of these candidates truthfully overlap with the literature of genetics (Arber & Linn, 1969; Kelly & Smith, 1970; Pray, 2008).

Science teacher candidates were asked about the order of events in the central dogma mechanism through the test. 68.3% (222 people) of prospective science teachers correctly stated the events in the central dogma mechanism as replication, transcription and translation, respectively.

16.9% (55 people) of science teacher candidates claim that there is a start code in the promoter region of DNA. The promoter part on the DNA is crucial for the initiation of transcription. However, the start code is not found in the promoter DNA sequence (Watson et al., 2013). Based on this data, it is thought that some prospective science teachers have faulty information concerning promoter region.

In order to obtain insulin with recombinant DNA technology, 37.5% (122 people) of the prospective science teachers took the procedure as follows:

“Insulin gene is amplified from genomic DNA by PCR” step 1,

“Plasmid is cut via proper restriction enzyme; then inserting the insulin gene into plasmid" step 2, "The insulin gene carrying plasmid transfer to bacteria" step 3,

"Growing transgenic bacteria in a petri dish medium at 37°C" step 4,

“Removing insulin protein from transgenic bacteria by protein purification” step 5.

This order applied to obtain insulin with recombinant DNA technology is consistent with the biotechnology literature (Pham, 2018).

In the study, science teacher candidates were asked how to reproduce the DNA sequence through the test. 3.4% of the science teacher candidates responded that DNA would be amplified by agarose gel, 22.8% of them stated it occurs by DNA gel electrophoresis, 8.6% of them stated that this event takes place by electrospectrophotometry and 9.8% of them stated it occurs by centrifugation. DNA can be amplified in the PCR device via primers, DNA polymerase enzyme and deoxyribonucleotides (Pham, 2018). Ultimately, 41.8% of the candidates correctly knew that DNA could be amplified by PCR.

These prospective science teachers were asked "Which organism should be chosen by researcher, who wants to reproduce a gene rapidly in Biotechnology". For this question, 5.5% of prospective science teachers preferred parasol mushroom; 24.3% of them selected yeast; 13.2% of them picked Drosophila melanogaster (fruit fly) and 2.2% of candidates chose zebra fish, as well. The quick proliferation ability of E.coli (Taj et al., 2014) will ensure rapid replication of nucleic material or part of it (such as a gene). Some candidates chose parasol mushroom, yeast, Drosophila melanogaster (fruit fly) and zebra fish as model organisms to serially amplify the gene, which means these candidates do not possess the knowledge about the characteristics of model organisms used in biotechnology. Their responses indicate that 48.9% of candidates properly selected E.coli to serially amplify the gene.

17.5% of the candidates still assume “1 gene 1 protein” hypothesis as correct. These candidates are thought to be unaware of the Alternative Splicing mechanism (Roy, Haupt, & Griffiths, 2013), which enables the production of multiple proteins from one gene.

According to 24,6% of the candidates, in the course of transformation, introduction of plasmid into cell take place at a temperature of 25 ^{0}C; 15.7% of them suppose it occurs at -4^{0}C; 8.6% of them claim that this takes place at a temperature of 70 ^{0}C. In the transformation process, one of the techniques that offers the plasmid (vector) to be introduced into the cell is heat shock (Cohen, Chang & Hsu, 1972). Based on their response 31.4% of the candidates know the heat shock procedure which is needed for transformation.

This item, “Which method may assist us to understand whether fetus has down syndrome or not by amount of emitting light when 21. Chromosomes bound to probes?” was asked to prospective science teachers. In response to this question, 42.8% of the participants preferred DNA gel electrophoresis. By using fish technique, abnormalities in chromosomes of fetus can be identified (Wieacker & Steinhard, 2010). Only 13.8% of prospective science teachers knew the FISH method.

19.4% of prospective science teachers point out that the gene expression level can be measured by RNA sequencing. Gene expression degree can be quantified through RNA sequencing (Finotello & Di Camillo, 2015) and this data indicate that only 19.4% of prospective science teachers are aware of the function of RNA sequencing. Moreover, interestingly 12.3% of participants stated that relatively more RNA transcripts can be obtained from the weak promoter region. In contrast to that, strong promoter leads to more gene expression (Li & Zhang, 2014). 29.8% of the candidates mentioned correctly that DNA fingerprinting method is used in DNA profiling. 8.3% of the prospective science teachers think that mRNA can be degraded by PCR, 6.5% of them suppose this degradation occurs by DNA fingerprinting, 20% of them state this degradation takes place by DNA gel electrophoresis, 14.5% of them point out this degradation is carried out by FISH, and 27.7% of them claim that cleavage of target mRNA is provided by RISC. Targeted mRNA could be destroyed via RISC complex (Zhang, 2013). Based on this data, 27.7% of prospective science teachers are aware of how the RISC complex work.

Palindromic repeat sequences that form a defense system against viruses; and 27.4% of the candidates think that it is included in the genome of animals, 5.2% of them claimed it is in the genome of plants, 6.5% of them stated that it is in the genome of fungi, 10.5% of them mentioned it is in the genome of protista and 40.9% of prospective science teachers pointed out that it exists in the genome of bacteria. Bacterial genome naturally contains CRISPR, which prevents bacteria from invading viruses (Barrangou et al., 2007). In the view of such information, 40.9% of the prospective science teachers comprehend which organism genome includes CRISPR. CRISPR-Cas9 compound is a vital instrument for reorganizing the genome (Zhang et al., 2021). 34.2% of the prospective science teachers know that CRISPR is a tool used in genome editing with genetic engineering applications, and 19.1% of them recognize that cas9 recognizes PAM in the CRISPR-Cas 9 system.

29.8% of the participants know that Emmanuelle Charpentier and Jennifer Doudna, who announced the CRISPR-Cas 9 system to the world, were awarded the Nobel Prize (Soysal, 2021), which indicates that the remaining 70.2% of the candidates do not follow the history of science in terms of biotechnological aspect.

As a result of the analysis of the responses to the test; It is understood that prospective science teachers are lowly aware of the essential elements of medical biotechnology including PCR (polymerase chain reaction), FISH (Fluorescence in situ hybridization), RNA sequencing, RNA induced Silencing Complex (RISC), DNA gel electrophoresis, DNA fingerprinting, Genome Editing (such as the CRISPR-Cas9 system)

Apoptosis was untruly characterized as autophagy by 10.2% of the candidates. 31.4% of the candidates truly considered GFP (green fluorescent protein) as a marker (reagent). 64.6% of the candidates do not know that the name of the mechanism that leads to controlled programmed death in the cell is apoptosis. In addition, only 31.4% of the candidates are aware of the use of GFP as an indicator.

82.8% of the candidates stated that vaccines, antibiotics, interferons, antibodies can be produced by biotechnology. 36% of prospective science teachers claimed that transduction is gene transfer to bacteria by virus; in the transformation process the bacterium takes the plasmid from the outside of the cell in some way; also plasmid transfer from one bacterium to another bacterium via a cytoplasmic bridge is called conjugation. 36% of prospective science teachers were able to correctly define the concepts of transduction, transformation and conjugation (Schneider, 2021) used in gene transfer in biotechnology. However, 82.8% of the candidates are aware that vaccines, antibiotics, interferons, antibodies can be produced through biotechnology.

This study demonstrated that the significant topics of biotechnology aren't adequately recognized by prospective science teachers. These crucial biotechnology topics and techniques which are not known sufficiently by prospective science teachers are those:

- ✓ Recombinant DNA technology,
- ✓ The methods used to make transgenic organism (GMO),
- ✓ DNA fingerprint which is also an application of forensic medicine,
- ✓ Biotechnological tools such as PCR,
- ✓ Model organisms (including zebra fish, Drosophila melanogaster, E.coli etc.),
- ✓ The enzymes which are utilized to manufacture biotechnological products are reverse transcriptase and restriction enzymes,

- ✓ The RNA varieties, such as long noncoding RNAs and micro RNAs which affect gene expression level are used to treat some illnesses, hence these RNAs are thought an important part of medical biotechnology.
- ✓ The UTRs (untranslated regions) which are part of mRNA transcript are involved in regulation of gene expression level.

Similarly, Orhan (2019) revealed that the biotechnology literacy and biotechnology knowledge of science teachers is low. Orhan (2019) advocates the idea that biotechnology subjects should be given with laboratory effectiveness in order to increase the biotechnology knowledge of science teachers. To prove this, Orhan (2019) applied biotechnology evaluation test to seventeen science teachers before application of laboratory based-biotechnological activities (pretreatment $\bar{x}$ = 8.12). Then, these science teachers exposed to laboratory based-biotechnological activities. After treatment, these science teachers were reevaluated by this biotechnology evaluation test (posttreatment $\bar{x}$ = 27.71). It is concluded that there was a meaningful increase between pre-treatment and post-treatment ($z = 3.626^*$, $p < 0.05$) among science teachers. As a result, these biotechnological activities improved the biotechnology knowledge of science teachers (Orhan, 2019). In addition, Açıkgül Fırat (2015) also states that the biotechnological literacy of prospective science teachers who study with web 2.0 technology will increase.

Lamanauskas and Makarskaitė-Petkevičienė (2008) in their study indicated that the biotechnology knowledge of prospective teachers in Lithuania including both educating at biology department and other departments was too low. According to the result of their research, they stated that the teacher education in the discipline of biotechnology must be reorganized to improve biotechnology knowledge of teacher candidates. (Lamanauskas & Makarskaitė-Petkevičienė, 2008)

The quick progressions in the field of biotechnology has led to consistently renewal of the national school programs such as more incorporation of biotechnology topics and morality issues related to biotechnology (Chabalengula et al., 2011). It is not adequate only incorporation novel biotechnology topics into school program but also teachers and pupils should be scientifically literate regarding biotechnology. Thanks to scientifically literacy, individuals who have it can make more reasonable decisions for controversial issues in science (Klop & Severiens, 2007; Chabalengula et al., 2011). Socioscientific issues in biotechnology can be readily taught students via modules, also these instructive modules influence both their knowledge about biotechnology and their attitude to biotechnology (Klop et al., 2010).

Socio-scientific issues related to biotechnology are given more weight in the UK's school program than in the Taiwan school program. This allows students in England to better argue a socioscientific issue with all aspects. However, Taiwanese students don’t discuss socioscientific issues sufficiently, due to school schedule in Taiwan (Chen & Raffan, 1999). Hence, it can be theoretically claimed that the British generation is thought to be able to make a more logical decision on a controversial biotechnology-related issue in the future than the Taiwanese ones, depend on training difference. In the light of this information, increasing biotechnological literacy occurs through qualified and contemporary biotechnology education.

When all these data in the study are taken into account, it is concluded that the biotechnology knowledge and biotechnology literacy of the prospective science teachers is low. Performance of prospective science teachers in each subdimension of biotechnology literacy is not adequate. Most of the prospective science teachers don’t follow the changes that occur in biotechnology from contemporary genetic applications to basic principles of the field. Briefly, this study indicates that prospective science teachers don’t sufficiently follow history of science related to biotechnology. They barely know about the medical applications which are directly connected with human life. Furthermore, a great number of misconceptions and misunderstandings about genetics and biotechnology were observed among science teacher candidates.

RECOMMENDATIONS

Subsequent to analyzing of responses of prospective science teachers, it is revealed prospective science teachers both have a lot of misconceptions about biotechnology and their biotechnology literacy is so low. These misconceptions and misinformation which belong to some prospective science teachers are those: Most of the prospective science teachers supposed that there are only three types of RNA (mRNA, tRNA, rRNA) and some prospective science teachers claimed that one gene encodes only one protein. Some of the science prospective teachers states DNA can not be derived from RNA. Some of the prospective science teachers supposed that whole DNA is responsible for protein coding. It is thought the main source of these misconceptions and misinformation related to biotechnology is they do not know the current biotechnology topics and applications. Hence, it is considered that the biotechnology curriculum in science education program of universities should be updated to include modern biotechnology applications. For instance, prospective science teachers should be introduced by following topics and applications in biotechnology:

- Recombinant DNA technology, the methods which are needed to make transgenic organisms, DNA fingerprint method, biotechnological tools such as PCR that replicates DNA and RNA,
- Model organisms (E. coli, zebra fish, Drosophila melanogaster etc.),
- The enzymes which are used to make biotechnological products such as reverse transcriptase, ligase, restriction enzymes,
- The RNA varieties, especially long non-coding RNAs and micro RNAs that influence gene expression level are utilized to treat some disorders, therefore these RNAs are considered vital elements of medical biotechnology,
- Importance of promoter in gene expression, the UTRs which are part of mRNA transcript and these 3’ UTR and 5’ UTR determine the fate of mRNA,
- CRISPR- Cas 9 mediated genome editing, which provides gene correction;
- Apoptosis to eliminate undesired cells,
- Alternative splicing mechanism,
- RISC,
- RNA sequencing,
- Labelling with GFP.

And these modern biotechnology applications and topics should be given to prospective teachers in the form of laboratory-based activities that will give them first-hand experiences. Through this qualified biotechnology education, their misconceptions and misinformation related to biotechnology will be eradicated. For example, when they learn alternative splicing mechanism which allows a single gene to encode many proteins they will perceive automatically that one gene one protein hypothesis is incorrect. Similarly, when they learn long noncoding RNAs and micro RNAs and function of these RNA varieties, prospective science teachers will grasp spontaneously existence of other RNA types apart from mRNA, tRNA and rRNA. Additionally, by utilization of reverse transcriptase enzyme which provides convertion of RNA to cDNA in biotechnological lab experiments by prospective science teachers, prospective science teachers can automatically find out that DNA can be obtained from mRNA. In addition, by understanding of outputs of human genome project in contemporary biotechnology lessons by prospective science teachers, they spontaneously find out that only 1.5 % of DNA is responsible for protein coding.

On the other hand it is thought that when prospective science teachers find out contemporary biotechnology applications, techniques and topics (including recombinant DNA technology, DNA gel electrophoresis, FISH, DNA fingerprint, RNA sequencing, heat shock tecnique etc.) their biotechology literacy will increase naturally from nominal biotechnology literacy to multidimensional one. For instance; FISH, DNA fingertprint and other methods related to biotechnology can be taught to prospective science teachers by scenarios in case study. It is considered when they find out FISH method that is an application of medical biotechnology and DNA fingerprint that is a practice of forensic medicine, procedural biotechnology literacy of prospective science teachers will boost. Besides all these, according to literature, the most important factor in qualified biotechnology education is to conduct biotechnology-based experiments in the laboratory. Also, it is thought lab-based learning is resistant to forgetting. For this reason, DNA gel electrophoresis and other similar activities should be applicated at laboratory by prospective science teachers.

In addition, apart from inclusion of current biotechnological topics into curriculum, the cirruculum should contain socioscientific issues related to biotechnology and the curriculum should give a chance to prospective science teachers to discuss socioscientific issues thoroughly with all aspects. And biotechnology lessons should be taught to prospective science teachers by active learning approaches which provide them to learn by doing – by living such as problem-based learning, project-based learning, inquiry-based learning, argumentation-based learning, web-based teaching etc. When the findings in the study are taken into account , it is revealed that the current curriculum in the universities which is applied to prospective science teachers is not adequate in terms of achievements. Also, these achievements related to biotechnology are incompatible with biotechnological applications in daily life. Therefore, the achievements should be updated and these achievements should make it easy to understand contemporary biotechnology applications for students. Moreover biotechnology based establishments like in UK such as National Council for Biotechnology Education (NCBE), Biotechnology and Biological Sciences Research (BBSRC), Medical Research Center (MRC) and Science and Plants for Schools (SAPS) should be also established in Turkey in order to improve biotechnology literacy of teachers and students. In addition, it would also be a good idea to spread biotechnology applications to four academic years within the spiral program, which contributes to the biotechnology literacy of prospective science teachers. Since teachers with advanced biotechnological literacy will educate students with advanced biotechnological literacy, the relevant society will also be developed from a biotechnological point of view.

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GENİŞLETİLMİŞ TÜRKÇE ÖZET

Giriş

Biyoteknoloji, her bireyin yaşamını etkileyen 21. yüzyılın en önemli teknolojilerinden biridir. Biyoteknoloji; rekombinant DNA teknolojisi, klonlama benzeri geniş yelpazede çok disiplinli aktiviteleri içermesinin yanında maddelerden ürün üretilmesini sağlayan (ekmek, bira, peynir, antibiyotik vb.) mikrobiyolojik uygulamaları da kapsamaktadır. Biyoteknoloji; çevresel sorunlarla mücadele etme, temiz teknoloji sağlama ve birçok hastalığı tedavi etme gibi olanaklar sunmaktadır (Ratledge & Kristiansen, 2001).

Tıp, tarım ve sanayideki biyoteknolojinin gelişim hızı insanlığın yaşamını değiştirmektedir. İnsanlar, bu biyoteknolojik gelişmeleri anlayabilmek için biyoteknoloji okuryazarlığına gereksinim duymaktadır (de la Hoz vd., 2022).

Modern biyoteknolojik uygulamalar, uygulamaların etik ve sosyal yönden irdelenmesi gereksinimini doğurmuştur. Özellikle insan sağlığını, çevreyi ve tarımı ilgilendiren biyoteknolojik uygulamalar hakkında toplum iyice bilgilendirilmelidir (Pas vd., 2019).

Çağdaş toplumlarda genç bireylerin, modern biyoteknoloji ile gelen durumları etik yönden inceleyebilmeleri için biyoteknoloji alanına ait yeterli bilgiye sahip olmaları gerekmektedir. Okullarda biyoteknoloji konularıyla yapılan eğitimler öğrencilerin biyoteknolojik okuryazar vatandaş olmalarına yardımcı olacaktır. Biyoteknoloji okuryazarı olan bu öğrenciler biyoteknolojinin temel ilkelerini bilmelerinin yanında ve biyoteknoloji kavramlarını da algılayabilecektir (Pas vd., 2019).

Temel eğitim seviyesindeki öğretmenlerin de gelecek nesilleri yetiştirebilmeleri için biyoteknoloji okuryazarlığına ihtiyaçları bulunmaktadır (de la Hoz vd., 2022).

Fen eğitimi, bilimsel okuryazarlığın ilerlemesinde merkezi bir rol oynamaktadır (Klop & Severiens, 2007). Biyoteknoloji okuryazarlığı bilimsel okuryazarlığın bir alt kümesidir. Bununla birlikte genetik alanın bilgileri de biyoteknolojinin temelini oluşturmaktadır. (de la Hoz vd., 2022).

Temel okul öğretmenleri, gelecek nesillerin biyoteknoloji okuryazarlık gelişimlerinde büyük bir etkiye sahip olduğundan bu öğretmenlerin biyoteknolojiye karşı tutum ve bilgileri ortaya çıkarılmalıdır. Bu durumda gerekirse biyoloji programı gözden geçirilmeli, biyoloji programının gelişime ihtiyacı varsa eksiklikleri giderilmelidir (de la Hoz vd., 2022).

Chabalengula (2011) çalışmasında hizmet öncesi fen bilgisi öğretmen adaylarının biyoteknolojiye karşı tutumları incelenmesi gerektiğini belirtmiştir. Gerekçe olarak da öğretmen adaylarının tutum olarak biyoteknolojiyi kabul etme derecelerinin, onların öğrencilerine biyoteknolojiyi öğretip öğretmeme durumunu etkileyeceğini ifade etmiştir (Chabalengula vd., 2011).

Öğretmenlerin biyoteknoloji okuryazarlık seviyelerine dair bilgi edinebilmek için alanyazın taranmış, yapılmış çalışmalar incelenmiştir. Sorgo ve Ambrozis-Dolinsek (2009) çalışmalarında Slovenyalı öğretmenlerin klasik genetik konularında bilgi düzeylerinin yüksek, biyoteknolojinin modern konularında ise bilgi düzeylerinin düşük seviyede olduğunu tespit etmişlerdir. (Sorgo & Ambrozis-Dolinsek, 2009) Casanoves, 2015 yılında İspanya'da hizmet öncesi temel okul öğretmen adaylarıyla bir çalışma gerçekleştirmiştir. Bu çalışmaya göre, öğretmen adayları biyoteknolojik uygulamaların farkındadır ancak teknolojik işlem süreçleri hakkında daha az bilgiye sahiptir. Ayrıca bu öğretmen adayları biyoteknolojinin medikal amaçlar için kullanılmasına pozitif tutum sergilemektedir (Casanoves vd., 2015).

Öğretmenlerin, öğrencileri biyoteknoloji alanında okuryazar yapmada önemli bir role sahip olmalarından öncelikle kendilerinin biyoteknolojiin temel ilke, kavram ve uygulamaları hakkında bilgili ve donanımlı olması gerekmektedir (de la Hoz ve ark., 2022). Bu bilgiler ışığında; biyoteknoloji alanında iyi yetişmiş bir öğretmenin, öğrencilerini biyoteknoloji konularında daha iyi eğiteceği düşünülmektedir (de la Hoz et al., 2022; Casanoves de la Hoz, 2015). Bu nedenle araştırmada ülkemizdeki öğrencilerinin biyoteknoloji okuryazarlığını oluşturacak dördüncü sınıf fen bilimleri öğretmen adaylarının biyoteknoloji okuryazarlık düzeyleri ve biyoteknoloji bilgileri merak edilmiştir . Bu durumdan hareketle Türkiye'de yapılmış fen bilimleri öğretmenlerinin ve öğretmen adaylarının biyoteknoloji okuryazarlıklarını inceleyen çalışmalar (Darçın, 2007; Yüce, 2011; Açıkgül Fırat, 2015; Orhan, 2019) irdelenmiştir.

Fen bilimleri öğretmenlerinin ve öğretmen adaylarının biyoteknoloji okuryazarlıklarını inceleyen ulusal ve uluslararası çalışmalar analiz edildiğinde, katılımcılara yöneltilen biyoteknolojiyle ilgili maddelerin çoğunun güncel biyoteknoloji uygulamalarını içermediği saptanmıştır. Yalnızca; Orhan (2019) tarafından yapılan çalışmada, fen bilimleri öğretmenleriyle laboratuvar temelli, bazı güncel biyoteknoloji etkinliklerinin gerçekleştirildiği gözlenmektedir. Alanyazın incelendiğinde medikal biyoteknolojiyle ilintili aşağıda belirtilen biyoteknolojik konuların, yöntem ve tekniklerin çoğunluğunun fen bilimleri öğretmen adayları tarafından bilinirliğinin daha önce sorgulanmadığı tespit edilmiştir.

- ✓ FISH,
- ✓ GFP
- ✓ Apoptosis
- ✓ Gen ekpresyonunu etkileyen Promoter, UTR'lar
- ✓ RISC
- ✓ RNA sekanslama
- ✓ GDO elde edilmesinde kullanılan ısı şoku tekniği
- ✓ Alternatif splicing mekanizması
- ✓ Biyoteknolojide kullanılan model organizmalar (E.coli, zebra balığı vb.)
- ✓ Biyoteknolojik aletler (PCR vb.)
- ✓ Genom düzenlemesinde kullanılan CRISPR-Cas9 sistemi
- ✓ Biyoteknolojide sıklıkla kullanılan enzimler (Reverse transkriptaz ve restriksyon enzimleri)

Ayrıca alanyazında yukarıdaki bütün güncel biyoteknoloji uygulamalarını ve konularını kapsayan hali hazırda bir test bulunmamaktadır. Alandaki bu açıklığın giderilmesi için de test geliştirme sürecine uygun olarak yazar tarafından çağdaş biyoteknoloji konularını ve uygulamalarını barındıran bir biyoteknoloji okuryazarlık testi üretilmiştir.

Araştırma problemi:

Fen bilimleri öğretmen adaylarının biyoteknoloji okuryazarlıkları hangi düzeydedir ve biyoteknoloji bilgileri nasıldır?

Alt problemler

1- Fen bilimleri öğretmenlerinin biyoteknoloji okuryazarlıkları hangi düzeydedir?
2- Fen bilimleri öğretmenlerinin biyoteknoloji bilgileri nasıldır?

Yöntem

Araştırmada, fen bilimleri öğretmen adaylarının biyoteknolojik okuryazarlık düzeylerinin belirlenmesi amacıyla nicel araştırma yöntemlerinden tarama araştırması kullanılmıştır. Tarama araştırması örneklem grubundan tek seferde bilgi toplanmasına imkân sağladığından tercih edilmiştir**.** (Büyüköztürk vd., 2016; Fraenkel vd., 2012)

Araştırmanın örneklem grubunu, Türkiye'deki yedi üniversitenin fen bilgisi öğretmenliği dördüncü sınıfında okuyan öğretmen adayları oluşturmaktadır. Örneklem grubu, uygun örneklem metodu ile seçilmiş 325 fen bilgisi öğretmen adayından oluşmaktadır. Araştırmada, fen bilimleri öğretmen adaylarına Bybee'nin (1997) kategorize ettiği (nominal, fonksiyonel, prosedürel, çok boyutlu) okuryazarlık düzeylerini ortaya çıkaracak 27 sorudan oluşan, geçerlik ve güvenirliği sağlanmış biyoteknoloji okuryazarlık testi uygulanmıştır. Uygulama sonuçları TAP ve SPSS programları ile analiz edilmiştir.

Bulgular

Uygulama sonrasında fen bilgisi öğretmen adaylarının testteki nominal biyoteknoloji okuryazarlığını inceleyen sorulara verdikleri yanıtların aritmetik ortalaması 1,36; fonksiyonel soruların aritmetik ortalaması 2,64; prosedürel soruların aritmetik ortalaması 4,28; çok boyutlu soruların aritmetik ortalaması da 0,90'dır. Örneklem grubundaki fen bilgisi öğretmen adaylarının teste verdikleri yanıtların SPSS ile yapılan analizleri neticesinde aritmetik ortalama 9,21, medyan 8, standart sapma 5,91 bulunmuştur. Katılımcıların aldıkları en düşük puan 1 iken; en yüksek puan 27'dir. Ayrıca, fen bilgisi öğretmen adaylarının aldıkları puanların dağılımının sağa çarpık olduğu gözlenmektedir.

Tartışma ve Sonuç

Araştırmada örneklem grubundaki fen bilgisi öğretmen adaylarının biyoteknoloji okuryazarlık testine verdikleri yanıtların aritmetik ortalamasının 9,21 olması, fen bilgisi öğretmen adaylarının biyoteknoloji okuryazarlıklarının düşük seviyede olduğunu göstermektedir.

Çalışmada örneklem grubunda bulunan fen bilgisi öğretmen adaylarının nominal biyoteknoloji okuryazarlık aritmetik ortalaması 1,36; fonksiyonel boyutun aritmetik ortalaması 2,64; prosedürel boyutun aritmetik ortalaması 4,28 ve çok boyutlu okuryazarlığın ortalaması da 0,90 olarak bulunmuştur. Bu veriden hareketle Bybee'nin (1997) kategorize ettiği en düşük okuryazarlık olan nominal boyuttan, en gelişmiş okuryazarlık olan çok boyutlu okuryazarlığa kadar fen bilgisi öğretmen adaylarının her bir boyuttaki okuryazarlık düzeyleri düşük olarak gözlemlenmektedir.

Teste verilen yanıtların analizi neticesinde; PCR, FISH, RNA sekanslama, RISC, DNA jel elektroforez, DNA parmak izi, genom düzenlemesi, genom düzenlemesinde kritik bir role sahip olan CRISPR-Cas9 sistemi gibi medikal biyoteknolojinin temel öğelerinden fen bilgisi öğretmen adaylarının düşük oranda haberdar olduğu anlaşılmaktadır.

Araştırma neticesinde fen bilimleri aday öğretmenlerin biyoteknoloji konusunda yeteri kadar bilgi sahibi olmadıkları konular şunlar olarak tespit edilmiştir:

- ✓ Recombinant DNA teknolojisi
- ✓ Transgenik organizma(GDO) yapımında kullanılan yöntemler
- ✓ Bir adli tıp uygulaması olan DNA parmakizi

- ✓ PCR gibi biyoteknolojide kullanılan aletler
- ✓ E.coli, meyve sineği, zebra balığı gibi biyoteknolojide kullanılan model organizmalar
- ✓ Reverse Transkriptaz, Restriksyon Enzimleri
- ✓ Medikal biyoteknolojide işlev gören mikro RNA ve uzun kodlama yapmayan RNA'lar
- ✓ mRNA'nın kaderini belirleyen UTR'lar

Bütün bu veriler dikkate alındığında fen bilgisi öğretmen adaylarının biyoteknoloji bilgilerinin düşük olduğu sonucu ortaya çıkmaktadır.

Fen bilgisi öğretmen adaylarının biyoteknoloji okuryazarlıklarının artırılması için öncelikle üniversitelerdeki biyoteknoloji müfredatının modern biyoteknoloji uygulamalarını içerecek şeklinde güncellenmesi, ayrıca modern biyoteknoloji uygulamalarının da laboratuvar temelli etkinlikler şeklinde öğretmen adaylarına ilk elden yaşantılar kazandıracak şeklinde verilmesi gerektiği düşünülmektedir.