Development and Validation of Biotechnology Knowledge Scale (BKS)

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Abstract
Biotechnology is at the heart of STEM education. Assessment of student understandings of biotechnology concepts is essential for designing learning and teaching. Thus, the aim of this study was to develop and validate the Biotechnology Knowledge Scale (BKS) for eighth graders in order to investigate their understandings biotechnology related concepts. The content validity was ensured by experts by comparison to the outcomes included in Turkish eighth grade curriculum. After the biotechnology subject was taught, the BKS was administered to a sample of 155 eighth grade students in three groups in Ankara in 2019-fall semester. The Cronbach alpha reliability coefficient of the BKS was calculated to be .770.

Keywords: Biotechnology; Biotechnology and Genetic Engineering, Elementary 8th grade students, Independent two sample t test.

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Introduction
Today biotechnology has increasingly become "a way of making commercial products using living organisms" to borrow a definition from 1990 by Belzer and Case. Since ancient times humans used fermentation to preserve various foods and to add flavor to them. In time, biotechnology has expanded from medicine to various new techniques in food industry. Today, during the covid-19 pandemic, we hear and see in daily news about the works of biotechnology experts on developing vaccines and medicine to fight the virus. Hence, time has proven the importance of biotechnology for humans (Garrett, 2009; Demirci & Yüce, 2018). At the same time, biotechnology encompasses several branches of science. Physics, chemistry, biochemistry, genetics, physiology, microbiology, molecular biology are common branches of science (Çelik & Erişen, 2010; Akkaya & Pazarlioğlu, 2012). Biotechnology has five core areas: medical, agriculture and livestock, food, environment, and industrial biotechnology (Thieman & Palladino, 2013). Many areas of life, from human health to agriculture, from chemical engineering to environmental protection, from food production to energy production, have been covered by this technology thanks to advances in biotechnology.

Biotechnology as a subject has been included in biology curriculum in secondary education for many years in Turkey (Darçın, 2017; Sinan, 2015). Yet, high school students' biotechnology literacy is not at a desired level (Semenderoğlu & Aydın, 2014). There is ample room for improving teaching and learning of biotechnology (Umamah, et al., 2020).

Biotechnology is a field of science that develops from a scientific interest that is very important to be understood by students because of its potential impact on them and others. When blended with STEM education, in valuing students' skills in biology, especially biotechnology materials require learning that can help students improve their knowledge integrated with technology (Kustiana, et al., 2020). When STEM education is implemented in integration with biotechnology materials, it can foster students' knowledge and skills (Kustiana, et.al, 2020).

By regarding biotechnology education as a strong promoter of STEM education, scholars in Malaysia conducted an investigation and showed that their secondary students have a good level of biotechnology literacy (Bahri, Suryawati, & Osman, 2014). While on the other hand, another investigation with 11th grade students in Australia shows that most students have little or no scientific understanding of the subjects of biotechnology, genetic engineering, cloning, or genetically modified foods (Dawson, 2007). These and similar research findings show that many students do not understand the processes of modern biotechnology at an adequate and desired level.

In an evaluation of the state of biotechnology education in Turkey it was noted back in 2000 that there is a great need for developing it at university level by instituting separate departments by following international examples (Severcan, Ozan, & Haris, 2000). A similar report expressing frustration and concern with the current state of biotechnology education came also from China stating how a relatively new phenomenon it is for the Chinese (Zhou, et al., 2006). Recently, in Turkey, biotechnology, as a school science subject, is included in eighth grade science and technology textbooks in 'DNA and genetic code' chapter without going into much detail.

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The purpose of the current research study was to develop a valid and reliable instrument to probe students' retention and understanding of key biotechnology concepts, as they are included in Turkish science curriculum for grade eight.

Method

Initially we created an item pool of 33 questions. An expert panel reduced the number of items to 17 by making sure that they cover all curriculum outcomes sufficiently. In the questionnaire the demographic data included gender and school name only. In its final form the **'Biotechnology Knowledge Scale'** (BKS) contains 17-questions aiming to measure students' understandings of selected age appropriate and curriculum aligned biotechnology concepts (see **Appendix A** for the Turkish version and **Appendix B** for the English version). The Cronbach's alpha reliability coefficient of BKS is calculated to be .770 which is a good indication of consistency.

In this study, we investigated if student understanding of biotechnology-related concepts varied according to gender or attended school by using the BKS. For that purpose we administered the BKS to 155 students in 3 groups (schools) in two districts of metropolitan Ankara. The sample from 'School 1' included 23 boys and 27 girls (50 total), the sample from 'School 2' had 26 boys and 24 girls (50 total), and the sample from 'School 3' had 23 boys and 32 girls (55 total). While groups from School 1 and 2 regular school cohorts, the School 3 group had students from a weekend tutoring school. Just before administering the instrument, students were informed about the purpose and possible benefits of this study and they were instructed to complete BKS in 40 minutes.

Initially, an item pool of 33 questions was created according to grade 8 curriculum outcomes (NME, 2018, p. 49). Subsequently, as the process described below, the number of items was reduced to 17. **Box 1** shows the curriculum outcomes and the corresponding items in the resulting final instrument.

Box 1. Eight grade science curriculum outcomes and corresponding BKS items.

Outcomes	Items
F.8.2.5.1. Associates genetic engineering and biotechnology.	Q1, Q2, Q3, Q14, Q15
F.8.2.5.2. Discusses the useful and harmful aspects of these applications for humanity with the dilemmas created within the scope of biotechnological applications.	Q4, Q5, Q6, Q7, Q9, Q10, Q13
F.8.2.5.3. Predicts what future genetic engineering and biotechnology applications might be.	Q8, Q11, Q12, Q16, Q17

Data Analysis and Findings

The data were analyzed by using the SPSS 20 software. **Table 1** shows that the mean values of the correct answers given by boys (n=72) to the BKS was 9.0139, while that of girls (n= 83) was 9.1566 (slightly higher).

Table 1. Group Statistics (gender)

	Gender	*n*	Mean	Std. Deviation	Std. Error Mean
Number of total correct answers	Boys	72	9.0139	3.48636	.41087
	Girls	83	9.1566	4.67083	.51269

On the other hand, the significance value *p* is calculated to be .832 (**Table 2**). Since $p > .05$ then we conclude that there is no significant differences between boys and girls in terms of retaining knowledge of key biotechnology concepts. In addition, a significance value greater than .05 indicates that the variances were homogeneously distributed within the sample.

Table 2. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
	Equal variances								Lower	Upper
Total	assumed	9.860	.002	-.213	153	.832	-.14274	.67050	-1.46737	1.18189
	not assumed			-.217	149,793	.828	-.14274	.65701	-1.44095	1.15547

An ANOVA was performed in order to check and see if there exists statistically significant differences between the three groups (schools) (see **Tables 3**). **Table 3** shows the differences between the three groups according to the responses to BKS. A significant value indicates whether there is any differentiation between the groups. This value must be greater than .05. Accordingly, while a significant difference is observed between school 1 and school 2; school 3 did not make a significant difference with both school 1 and school 2 (**Table 3**).

Table 3. ANOVA-Multiple Comparisons Group Statistics (attended school)

(I) School	(J) School	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
School I	School II	-.24000	.63779	.925	-1.7581	1.2781
	School III	-6.40545*	.55556	.000	-7.7314	-5.0795
School II	School I	.24000	.63779	.925	-1.2781	1.7581
	School III	-6.16545*	.51806	.000	-7.4005	-4.9304
School III	School I	6.40545*	.55556	.000	5.0795	7.7314
	School II	6.16545*	.51806	.000	4.9304	7.4005

** The mean difference is significant at the .05 level.*

Confirmatory factor analysis was conducted in order to check the structural validity. Due to Barlett test, it is accepted that there is a relationship between variables $p = .000 < .05$ (p value=Sig.) (**Table 4**). Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy test yielded the value .827 (**Table 4**). In practice, it is accepted that if KMO value is greater than .5 then the sample size is shown to be sufficient for factor analysis. If KMO values greater than .60 are considered to be very good.

Table 4. KMO and Bartlett's Test

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy		.827
Bartlett's Test of Sphericity	Approx. Chi-Square	800.298
	df	136
	Sig.	.000

The average of the correct answers given to the BKS by students in 3 schools are given in **Table 5**. Average student scores in School 3 is seen to be relatively very low.

Table 5. Mean student scores in 3 schools.

School	Boys	Girls	Total
School I	10.43	10.74	10.6
School II	9.81	11.04	10.4
School III	4.39	3.66	3.96

The Varimax method was chosen in factor analysis, and the structure of the variables remained the same (see **Table 6**). The item loaded values (extraction) in **Table 6** are all seen to be over .32. Therefore, it can be concluded that the obtained KMO value was not affected by this.

Table 6. The item loaded values (extraction)

Item Number	Initial	Extraction
1	1.000	.435
2	1.000	.603
3	1.000	.683
4	1.000	.717
5	1.000	.554
6	1.000	.625
8	1.000	.406
10	1.000	.601
13	1.000	.674
12	1.000	.547
11	1.000	.403
9	1.000	.429
17	1.000	.427
15	1.000	.427
7	1.000	.435
16	1.000	.642
14	1.000	.610

The Scree Plot was also examined for factor number verification, and the BKS was found to have a 5-factor structure with an eigenvalue greater than 1 and a steep slope (**Figure 1**).

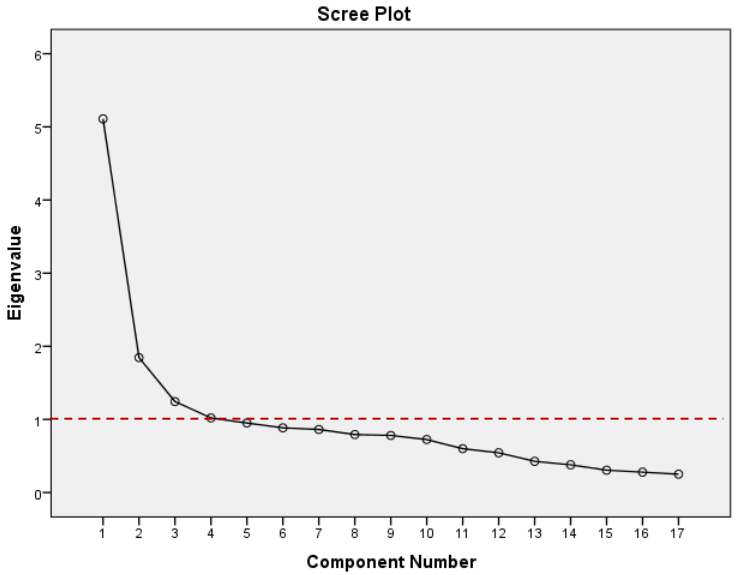

Figure 1. Scree Plot factor numbers

Although it is a common practice to accept factors with eigenvalues greater than 1, we limited the number of factors to five by considering the item distributions. Due to the factor analysis for the virtual loafing scale, 4 factors were determined and these factors were collected in 54.228% of the cumulative variance (see **Table 7**). It is an acceptable value since the variance value is over 50.00%. The Cronbach's alpha and explained total variance values show that the BKS is valid and reliable.

Table 7. Total Variance Explained by the 17-item scale

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.109	30.054	30.054	5.109	30.054	30.054	4.109	24.169	24.169
2	1.845	10.855	40.909	1.845	10.855	40.909	1.961	11.537	35.706
3	1.244	7.316	48.225	1.244	7.316	48.225	1.889	11.112	46.818
4	1.020	6.002	54.228	1.020	6.002	54.228	1.260	7.409	54.228
5	.951	5.593	59.821						
6	.885	5.208	65.028						
7	.862	5.070	70.099						
8	.793	4.662	74.761						
9	.781	4.594	79.355						
10	.725	4.262	83.617						
11	.600	3.529	87.147						
12	.543	3.195	90.342						
13	.427	2.509	92.851						
14	.379	2.231	95.082						
15	.306	1.799	96.881						
16	.279	1.642	98.522						
17	.251	1.478	100.000						

Extraction Method: Principal Component Analysis.

Factor structure and path diagram results are also presented in **Figure 2**. According to the results of CFA analysis; the fit indices obtained were found to be acceptable and the five-factor structure of the biotechnology knowledge questionnaire was confirmed (**Table 8**) (İnce, Çağap, & Deneri, 2020).

Table 8. Rotated Component Matrix[a]

Item Number	Component			
	1	2	3	4
1	.787			
2	.785	.316		
3	.760			
4	.672	.343		
5	.648		.304	
6	.627			
7				.463
8	.492	.406		
9		.612		
10		,537	-.512	
11		.529		
12	.355	.474		
13	.312	.441	.327	
14	-.362		.675	
15			.607	
16			.595	
17				.801

The resulting of SPSS Explanatory Factor Analysis is shown in **Figure 2**.

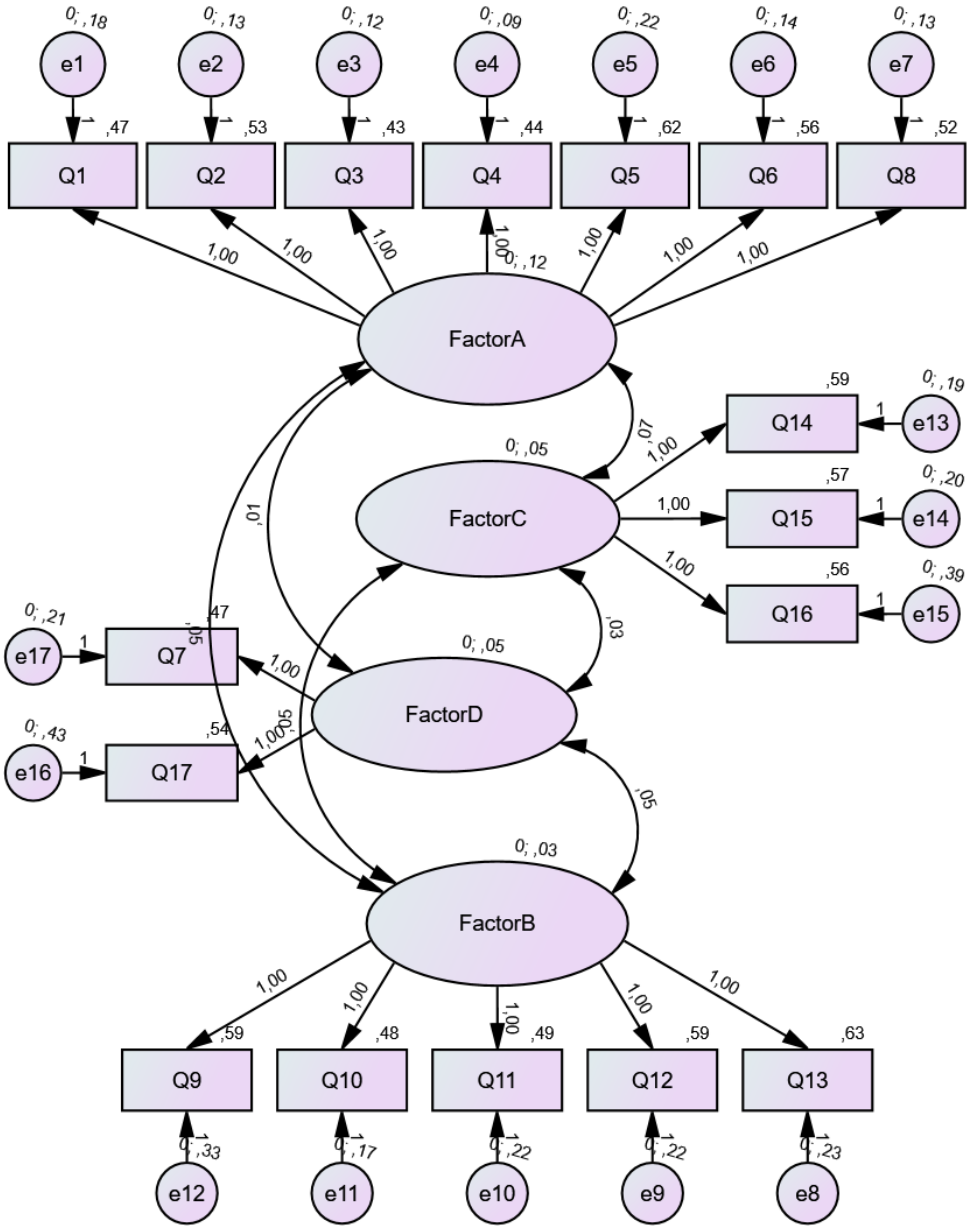

Figure 2. Explanatory Factor Analysis results in SPSS.

Reliability Analysis

For the reliability of BKS, the mean value, standard deviation, variance and Cronbach's alpha values of each item are calculated and presented in **Table 9**. The initial 33 items created in the item pool are hence reduced to 17 items.

Table 9. Total Statistics

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
What is your gender?	8.6194	14.991	.481	.417
1	8.5613	14.793	.566	.562
2	8.6581	14.785	.574	.587
3	8.6516	14.384	.666	.649
4	8.4710	15.744	.289	.392
5	8.5290	15.108	.468	.497
6	8.6194	15.770	.303	.214
7	8.5677	14.416	.672	.559
8	8.5032	17.823	-.198	.200
9	8.6129	14.693	.594	.472
10	8.6000	15.281	.418	.242
11	8.4968	15.745	.305	.228
12	8.4581	15.575	.346	.188
13	8.5032	14.966	.511	.366
14	8.5161	14.927	.503	.368
15	8.5290	17.225	-.070	.114
16	8.5484	16.899	-.029	.279
17	8.6194	14.991	.481	.417

Results

Results of this scale development study can be summarized as follows:

- The BKS is valid and reliable.
- An implementation shows that students retain a moderate or low levels of knowledge after instruction.
- There is no statistically significant differences between girls and boys and according to the schools attended.

Recommendations

The BKS has 4 factors and 17 items. However, in order to increase the reliability and validity more efforts needed to increase the number of items.

Before BKS was administered to 155 students we predicted that there would be 3 factors according to the related curriculum outcomes. However, after BKS administration the items were collected in 4 factors. In order to further develop a BKS instrument a more homogenous student

sample from 8 graders. In addition in the first round of administration of the BKS, which had 33 items, we need 10 times more students taking it. The relatively low number of students (N=155) might have caused a different distribution of the items into the factors. Another limitation came from the fact that 'school 3' was a private tutoring school operating in the weekends. 'School 3' students performed significantly lower scores in BKS (see **Table 3**). A comparable groups statistics could have resulted in more desirable outcomes for the BKS.

For providing an effective biotechnology education at middle school level, concepts must be taught clearly and comprehensively. Biotechnology has been a field developing rapidly. For countries to catch up with the developments and be on the cutting edge, biotechnology education needs to be taught at different grade levels for raising career awareness and foster concept learning. However, there is not much efforts on this subject at lower school grade levels today. Even undergraduate and graduate students are lacking in understanding the concepts related to biotechnology. This is why efforts should be made to cover the subject of 'biotechnology' in primary education by making more comprehensive and practical applications. Including biotechnology education in teacher education can result in satisfactory gains (de la Hoz, 2016) and could be good starting point to obtain improved results in student learning.

Students can be more successful if the teaching of biotechnology and genetic engineering subjects are supported by audiovisual materials (EFB, 1999). At the same time, attitudes towards biotechnology have been determined to show positive changes in various studies. According to Thiemen and Palladino (2013), biotechnology is a broad and interdisciplinary field utilizing knowledge and skills from biology, chemistry, mathematics, computer science, engineering and also other disciplines such as philosophy, economics (Soetaert & Vandamme, 2006; Kılınççıoğlu, et al., 2016).

In order to raise student motivation, interest, curiosity, and positive attitudes modern teaching/learning approaches and techniques should be implemented in biotechnology (Altun et al, 2011). Teachers should adopt a student-centered format and have them examine applications related to biotechnology, and provide problem based and/or project based learning opportunities. Especially in recent years, combining STEM applications with the concept of biotechnology can help students achieve curriculum outcomes and meaningful learning.

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Appendix A: BKS in Turkish

BİYOTEKNOLOJİ BİLGİ ÖLÇEĞİ

Bu araştırmanın amacı, biyoteknoloji konusunun öğrenciler tarafından anlaşılabilirliği ve bu konudaki bilgi düzeylerini ortaya çıkarmaktır.

Bu amaçla veri toplamak üzere hazırlanan bu anket 2 kısımdan oluşmaktadır: İlk kısımda kişisel bilgilerinize erişmek amacıyla hazırlanmış sorular, ikinci kısımda ise biyoteknoloji konusunun anlaşılabilirliği ve bu konudaki bilgi düzeylerini ortaya çıkarmaya yönelik sorular bulunmaktadır. Lütfen hiçbir soruyu yanıtsız bırakmayınız. Anketi tamamlamanız için gerekli süre 40 dakikadır. Katkılarınız için teşekkür ederim.

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Biyoloji öğretmenliği Bölümü

I.KISIM - Kişisel Bilgiler

Aşağıda kişisel bilgilerinize yönelik sorular yer almaktadır. Size uygun olanı seçerek işaretleyiniz. Lütfen yanıtlanmamış soru bırakmayınız.

1. Cinsiyetiniz: Kız ( ) Erkek ( )

2. Okulunuz: .....

II.KISIM - Biyoteknoloji İle İlgili Kavramsal Anlama Anketi

Aşağıdaki anket biyoteknoloji kavramlarının anlaşıla bilirliğini tespit etmeye yönelik 17 adet çoktan seçmeli soru içermektedir. Soruları okuyarak doğru şıkkı yuvarlak içine alınız. Lütfen işaretlenmemiş ifade bırakmayınız.

1) Gelişen teknoloji ile birlikte canlı hücrelerin kullanıldığı ve yeni maddeler/canlılar üretmek için yapılan çalışmalara ne denir?

- **A)** Genetik
- **B)** Moleküler Biyoloji
- **C)** Genetik Mühendisliği
- **D)** Biyoteknoloji

2) Aşağıdakilerden hangisi biyoteknolojinin uygulamalarından biri **değildir?**

- **A)** Parfüm, deterjan gibi kimyasal maddelerin üretilmesi
- **B)** Kutuplarda ve ekvatorda yaşayan ayıların farklı kürk rengine sahip olması
- **C)** Astronotların uzay aracının dışında giydikleri giysilerin kumaşının üretilmesi
- **D)** Kan şekerini düşüren insülin hormonun insan geni aktarılmış bakterilerce üretilmesi

3) Genetik mühendisliği nedir?

- **A)** Genler ve çevrenin etkisi ile oluşan canlının dış görünüşüdür.
- **B)** Canlılara ait özelliklerin ortaya çıkması ve bu özelliklerin nesilden nesile aktarılmasıdır.
- **C)** DNA'yı oluşturan genler ve genleri oluşturan nükleotitlerin dizilişleri ile ilgili araştırmalar yapan bilim dalıdır.
- **D)** Canlıları inceleyen bilim dalıdır.

4) Aşağıdakilerden hangisi genetik mühendislerinin çalışma yaptığı biyoteknolojik uygulamalardan **değildir?**

- **A)** Islah
- **B)** Aşılama
- **C)** Adaptasyon
- **D)** Gen tedavisi

5) Aşağıdakilerden hangisi ya da hangileri biyoteknolojinin kullanıldığı alanlardan biri **değildir?**

I. Adli Tıp
II. Sistematik
III. Çevre
IV. Psikiyatri

A) I ve III
B) II, III ve IV
C) I ve II
D) Yalnız IV

6) Biyoteknoloji birçok bilimsel disiplinle karşılıklı ilişki içinde gelişir. Aşağıdakilerden hangisi bunlardan biri **değildir?**

A) Biyokimya
B) Fizik
C) Genetik Mühendisliği
D) Mikrobiyoloji

7) Aşağıda verilenlerden hangisi biyoteknolojinin çalışma alanına **girmez?**

A) Tohumların toprağa ekilerek mısır üretilmesi
B) Böceklere karşı dirençli bitki yetiştirilmesi
C) Bakterilere insülin geni aktarılarak insülin üretilmesi
D) Sirke, alkol, gazlı içecekler, meyveli yoğurtlar ve vitamin tabletlerinin üretilmesi

8) Aşağıdakilerden hangisi biyoteknolojinin uygulaması **değildir?**

A) DNA parmak izi oluşturulması
B) Endoskopi ile sindirim sistemi hastalıklarının tespiti
C) İnsülin hormonu üretimi
D) Verimli bitki ve hayvanların üretimi

9) Karpuzun tohum oluşturma geni çıkarılarak çekirdeksiz karpuz üretilmiştir. Bu durumda aşağıdakilerden hangileri istendik sonuçlardır?

I. Zaman tasarrufu
II. Kolay yenilebilirlik
III. Karpuz neslinin devamsızlığı

A) Yalnız I
B) I ve II
C) II ve III
D) I, II ve III

10) Genetik mühendisliği ve biyoteknoloji ile ilgili yorum yapan öğrencilerin yorumları aşağıda verilmiştir. Bu yorumlardan hangisi **yanlıştır?**

A) Genetik mühendisliği ve biyoteknolojik çalışmalar birbirini tamamlarlar.
B) Biyoteknolojinin çalışmaları her zaman yararlıdır.
C) Genetik mühendisleri yapay organ oluşturabilmektedir.
D) Genetik mühendisliği çalışmalarında gen klonlaması yapılır.

11) I. Kaliteli tarım ürünlerinin elde edilmesi genetik mühendisliğinin çalışmasıdır.
II. Bitki tohumlarının uzun süre saklanması genetik mühendisliğinin çalışmasıdır.
III. DNA parmak izi, gen klonlanması, gen tedavisi genetik mühendisliği çalışmasıdır.

Yukarıda verilen bilgilerden hangileri doğrudur?

A) I ve II
B) II ve III
C) I ve III
D) I, II ve III

12) I. Hastalıkların tedavisini sağlamayı amaçlar.
II. Sağlıklı yaşamın devamını sağlamayı amaçlar.
III. Canlıların yaşamlarını korumayı amaçlar.

Yukarıdaki çalışmalardan hangileri genetik mühendisliğinin alanına girmektedir?

A) I ve II
B) I ve III
C) I, II ve III
D) II ve III

13) I. Farklı canlı türlerinin ortaya çıkması
II. Gen bankaları kurulması
III. Hastalık genlerinin sağlıklı genlerle değiştirilmesi

Yukarıdaki çalışmalardan hangileri biyoteknolojinin alanındadır?

A) Yalnız I
B) II ve III
C) I ve III
D) I, II ve III

14) Aşağıda verilen bilgilerin hangisinde klonlamanın faydalarından birisi **yoktur**?

A) Türü yok olma tehlikesi olan türlerin klonlama sayesinde hayatta kalabilmesi.

B) Hayvanların klonlanarak çoğaltılabilir.

C) Üstün özellikli canlılar klonlanarak sayısı artırılabilir.

D) Klonlama yöntemi ile üretilen canlının fazla yaşayamaması.

15) Aşağıdakilerden hangisi biyoteknolojinin asıl amacıdır?

A) Toprak ve yer altı suları kirliliğini azaltmak

B) Kalıtsal hastalıklardan uzak, üretken ve insanların yararına kullanılan bitki ve hayvan soyları üretmektir.

C) Farklı genetik yapıdaki besinler üreterek insan vücudunda oluşabilecek reaksiyonları incelemektir.

D) Bitki üretiminde geleneksel yöntemlerden uzaklaşmaktır.

16) Aşağıdakilerden hangisi eksik veya hatalı genlerin işlevini üstlenecek yeni genlerin hücrelere aktarılması ile ilgili uygulamadır?

A) Islah

B) Aşılama

C) Gen aktarımı

D) Gen tedavisi

17) Pamuk bitkisi, gen aktarımı sonucu kendisi ile beslenen kurtlar için zararlı hale getirilmiştir.

I. Bu çalışma sonucu kıyafetlerimizi daha ucuza alıyoruz.

II. Bu çalışma sonucu, pamuk üreticileri zarar etmiyor.

III. Bu çalışma sonucu, çiftçiler pamuk üretimi için teşvik ediliyor.

Bu durumla ilgili yorumlardan hangileri doğrudur?

A) Yalnız I

B) I ve III

C) II ve III

D) I, II ve III

Appendix B: BKS in English

BIOTECHNOLOGY KNOWLEDGE SCALE

The aim of this research is to reveal the understanding of the subject of biotechnology by the students and their level of knowledge on this subject.

This questionnaire, which is prepared to collect data for this purpose, consists of two parts: The first part includes questions prepared to access your personal information, and the second part includes questions about the comprehensibility of the biotechnology subject and the level of knowledge on this subject. Please do not leave any questions unanswered. The time required to complete the survey is 40 minutes. Thank you for your contribution.

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PART I - Personal Information

Below are questions regarding your personal information. Tick the one that suits you. Please do not leave unanswered questions.

1. Your Gender: Female ( ) Male ( )

2. Your school: .....

PART II - The Conceptual Understanding Questionnaire On Biotechnology

The following questionnaire contains 17 multiple choice questions to determine the comprehensibility of biotechnology concepts. By reading the questions, circle the correct answer. Please do not leave unmarked statements.

1) What is science field called in which living cells are used with the developing technology and made to produce new substances / living things?

- **A)** Genetics
- **B)** Molecular Biology
- **C)** Genetic Engineering
- **D)** Biotechnology

2) Which of the following is **not** one of the applications of biotechnology?

- **A)** Production of chemicals such as perfume and detergent
- **B)** Different fur colors of bears living in the poles and at the equator
- **C)** The fabrication of the clothing that astronauts wear outside of the spacecraft
- **D)** The production of insulin hormone, which lowers blood sugar, by bacteria with a human gene.

3) What is genetic engineering?

- **A)** The external appearance of a living thing formed by the influence of genes and the environment.
- **B)** The emergence of the characteristics of living things and the transmission of these features from generation to generation.
- **C)** It is a branch of science that conducts research on the genes that make up DNA and the sequences of the nucleotides that make up the genes.
- **D)** It is the science that studies living things.

4) Which of the following is not one of the biotechnological applications in which genetic engineers work?

- **A)** Breeding
- **B)** Vaccination
- **C)** Adaptation
- **D)** Gene therapy

5) Which of the following(s) is **not** one of the areas where biotechnology is used?

I. Forensic Medicine
II. Systematic
III. Environment
IV. Psychiatry

A) I ve III
B) II, III ve IV
C) I ve II
D) IV only

6) Biotechnology develops in mutual relationship with many scientific disciplines. Which of the following is **not** one of them?

A) Biochemistry
B) Physics
C) Genetic Engineering
D) Microbiology

7) Which of the followings is **not** included in the field of biotechnology?

A) Corn production by planting seeds in the soil
B) Growing plants resistant to insects
C) Production of insulin by transferring the insulin gene to bacteria
D) Production of vinegar, alcohol, carbonated drinks, fruit yoghurts and vitamin tablets

8) Which of the following is **not** the application of biotechnology?

A) DNA fingerprinting
B) Detection of digestive system diseases by endoscopy
C) Insulin hormone production
D) Production of productive plants and animals

9) Seedless watermelon was produced by removing the seed-forming gene of watermelon. In this case;

I. Time saving
II. Easy edibility
III. Absence of the watermelon generation

Which of the above results are desired ones?

A) I only
B) I and II
C) II and III
D) I, II and III

10) Comments of the students about genetic engineering and biotechnology are given below. Which of one these comments is **wrong**?

A) Genetic engineering and biotechnological studies complement each other.
B) Biotechnology studies are always useful.
C) Genetic engineers can create artificial organs.
D) Gene cloning is done in genetic engineering studies.

11) I. Obtaining quality agricultural products is the study of genetic engineering.
II. Long-term storage of plant seeds is the study of genetic engineering.
III. DNA fingerprinting, gene cloning, gene therapy are genetic engineering studies.

Which of the above information is correct?

A) I and II
B) II and III
C) I and III
D) I, II and III

12) I. Aims to provide treatment of diseases.
II. It aims to maintain a healthy life.
III. It aims to protect the lives of living things.

Which of the above studies are included in the field of genetic engineering?

A) I and II
B) I and III
C) I, II and III
D) II and III

13) I. The emergence of different living species
II. Establishing gene banks
III. Replacing disease genes with healthy genes

Which of the above studies are in the field of biotechnology?

A) I only
B) II and III
C) I and III
D) I, II and III

14) Which of the following information is **not** one of the benefits of cloning?

A) The survival of species whose species is in danger of extinction through cloning.

B) Animals can be cloned and reproduced.

C) The number of creatures with superior features can be increased by cloning.

D) Inability of the creature produced by the cloning method to live long.

15) Which of the following is the main goal of biotechnology?

A) To reduce soil and groundwater pollution.

B) To produce plant and animal lineages that are far from hereditary diseases, productive and used for the benefit of humans.

C) To examine the reactions that may occur in the human body by producing foods with different genetic structures.

D) It is to move away from traditional methods in plant production.

16) Which of the following applies to transferring new genes to cells to take over the function of missing or faulty genes?

A) Breeding

B) Vaccination

C) Gene transfer

D) Gene therapy

17) Cotton plant, as a result of gene transfer, has been made harmful for worms that feed on it.

I. As a result of this work, we buy our clothes cheaper.

II. As a result of this study, cotton producers do not hurt.

III. As a result of this work, farmers are encouraged to produce cotton.

Which of the comments on this situation are correct?

A) I only

B) I and III

C) II and III

D) I, II and III