

| Research Article / Araştırma Makalesi |

## Biotechnology Literacy Inventory: Development, Validity and Reliability<sup>1\*</sup>

### Biyoteknoloji Okuryazarlık Envanteri: Geliştirme, Geçerlik ve Güvenirlik Çalışmaları

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#### Keywords

1. Biotechnology literacy
2. Inventory development
3. Science education

#### Anahtar Kelimeler

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2. Envanter geliştirme
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#### Abstract

*Purpose:* In this study, it is aimed to develop a biotechnology literacy inventory that deals with the different dimensions of literacy to determine the biotechnology literacy of 8<sup>th</sup>-grade students and to make validity/reliability studies.

*Design/Methodology/Approach:* The participants of the study consisted of 566 8th grade students determined by convenience sampling method.

*Findings:* The first measurement tool is the Biotechnology Awareness Test, which consists of 24 questions, which was developed to determine the biotechnology awareness of students, and includes yes / no answers. The difficulty index of the final test was 0.66, the discrimination index was 0.43. The second measurement tool is the Biotechnology Products Preference Scale, which was developed to determine the biotechnology products that students prefer in their daily lives, and consists of 13 items and 4 sub-dimensions. According to the results of the confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.30, and RMSEA value was calculated as 0.035. The third measurement tool is the Biotechnology Opinion Scale, which was prepared to determine students' opinions about biotechnology on factors such as ethics, risk, and consists of 12 items and 4 sub-dimensions. According to the results of the confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.04, and RMSEA value was calculated as 0.012. According to the findings, it was concluded that the measurement tools in the developed inventory were valid and reliable.

*Highlights:* Biotechnology Literacy Inventory consisting of three measurement tools including different dimensions of literacy was developed with this study. These tools are; Biotechnology Awareness Test, The Biotechnology Products Preference Scale, and Biotechnology Opinion Scale. Besides, a scoring table is included in the study to calculate a single biotechnology literacy score according to the data obtained from this scale.

#### Öz

*Çalışmanın amacı:* Bu çalışmada, 8. Sınıf öğrencilerinin biyoteknoloji okuryazarlıklarını belirlemek amacıyla okuryazarlığın farklı boyutlarını ele alan bir Biyoteknoloji Okuryazarlık Envanteri geliştirmek ve geçerlik/güvenirlik çalışmalarını yapmak amaçlanmıştır.

*Materyal ve Yöntem:* Araştırmanın katılımcılarını uygun örnekleme yöntemi ile belirlenen 566 8. Sınıf öğrencisi oluşturmaktadır.

*Bulgular:* Birinci ölçme aracı, öğrencilerin biyoteknoloji farkındalıklarını belirlemek amacıyla oluşturulan ve evet/hayır şeklinde yanıtları içeren 24 sorudan oluşan Biyoteknoloji Farkındalık Testi'dir. Testin güçlük indeksi 0.66 ve ayırt edicilik indeksi 0.43 olarak bulunmuştur. İkinci ölçme aracı, öğrencilerin günlük hayatlarında tercih ettikleri biyoteknoloji ürünlerini belirlemek amacıyla oluşturulan Biyoteknoloji Ürünleri Tercih Ölçeği'dir. Bu ölçek, 13 madde ve 4 alt boyuttan oluşmaktadır. Yapılan doğrulayıcı faktör analizi sonuçlarına göre  $\chi^2/df$  değeri 1.30 olarak bulunurken RMSEA değeri 0.035 olarak hesaplanmıştır. Üçüncü ölçme aracı ise öğrencilerin biyoteknoloji hakkındaki etik ve risk gibi faktörlere ilişkin görüşlerini belirlemek amacıyla hazırlanan Biyoteknolojiye İlişkin Görüş Ölçeği'dir. Bu ölçek, 12 madde ve 4 alt boyuttan oluşmaktadır. Yapılan doğrulayıcı faktör analizi sonuçlarına göre  $\chi^2/df$  değeri 1.04 olarak bulunurken RMSEA değeri 0.012 olarak hesaplanmıştır. Elde edilen bulgular doğrultusunda, geliştirilen envanterde yer alan ölçme araçlarının geçerli ve güvenilir olduğu sonucuna ulaşılmıştır.

*Önemli Vurgular:* Bu çalışma ile okuryazarlığın farklı boyutlarını içeren üç ölçme aracından oluşan Biyoteknoloji Okuryazarlığı Envanteri geliştirilmiştir. Bu araçlar; Biyoteknoloji Farkındalık Testi, Biyoteknoloji Ürünleri Tercih Ölçeği ve Biyoteknoloji Görüş Ölçeğidir. Ayrıca çalışmada, bu ölçeklerden elde edilen puanlar ile tek bir biyoteknoloji okuryazarlık puanı hesaplamak için puanlama tablosu yer almaktadır.

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## Introduction

Biotechnology, one of the most important scientific developments of the 21st century, allows us to change the genetics of organisms in different ways and use the products obtained by biotechnology applications to improve the quality of our life (Campbell & Reece, 2005). Biotechnology is a technology that aims to present living organisms or products belonging to these organisms to the use of humanity by using genetic engineering methods (Eroğlu, 2006). Therefore, biotechnology improves the quality of life and helps individuals to cope with the problems they face (Doğru, 2010). As a result, biotechnology can be considered as a discipline used by any technique that creates or regulates the products of living organisms to improve the quality of life (White, 1999).

Biotechnology is not only a discipline in which products are obtained systematically. It is an area associated with scientific disciplines such as microbiology, molecular biology, biochemistry, cell biology, and enzymology (Bruschi et al., 2011). Many people use biotechnology regularly unintentionally in simple tasks such as bread, winemaking, and gardening (Porter, 2007). When the history of biotechnology applications is examined, it is seen that it is very old. Biotechnology applications began with the use of microorganisms and fermentation methods in the production of bacteria, bread, beer, wine to produce yogurt, collecting and storing the seeds of the best quality plants for sowing in the following year (Şentürk, 2009). It is classified as classical and modern biotechnology (Çetiner, 2009; Sürmeli, 2008). Vinegar produced from wine produced by bacteria that have been produced for centuries and the use of yeast in bread making are examples of classical biotechnology applications. Modern biotechnology has emerged with the conduct of studies and advances in biotechnology. Modern biotechnology is recognized as one of the key areas in the development of high technologies (Lamanauskas & Makarskaitė-Petkevičienė, 2008). Modern biotechnology applications are also widely used. Genetic engineering and biotechnology make the transfer of genetic material possible by separating the boundaries of genetic material and making some changes on the genetic material without making any discrimination of microorganisms, plants, animals, or humans (Bal, Keskin Samancı & Bozkurt, 2007). As genetic sciences develop, genes with hereditary diseases have been discovered and thus modern biotechnology has the opportunity to be more beneficial for human health (Doğru, 2010). Therefore, the rapid development of modern biotechnology and the applications of recombinant DNA technology and genetic engineering represent some of the most exciting developments of this century (Sohan, 1998). In short, biotechnology applications are encountered in many areas ranging from food to clothing (Bal et al., 2007).

As in other disciplines, biotechnology can have beneficial or harmful consequences for human beings for their intended use (Doğru, 2010). In particular, individuals are concerned that scientists will overcome ethical boundaries through practices such as human cloning (Porter, 2007). These ethical problems are caused by real-life problems and decisions taken to find solutions to ethical problems that affect human health, society, environment and international politics (Sürmeli, 2008). Therefore, individuals need to make informed decisions in this process. Individuals can make decisions about biotechnology by being aware of the risks and benefits of biotechnology (Sohan, Waliczek & Briers, 2002). Students should be more knowledgeable about the social, ethical, and economic effects of genetic engineering, cloning, genetically modified organisms with the developments in biotechnology (Dawson & Soames, 2006). Therefore, students need to be informed not only on issues related to biotechnology applications but also on the assessment of social and ethical issues (Sürmeli, 2008). Because students make informed decisions about biotechnology requires that they be aware of the risks and benefits of these applications (Sohan et al., 2002).

Individuals have to interact with their environment in order to continue their lives and meet their needs (Yılmaz & Aydın, 2019). Therefore, they must be sensitive to their environment and understand the events in their environment. Individuals who are aware of biotechnology will be able to better understand the scientific processes and the news they see in the media about biotechnology (Harlen, 2001). However, access to information about biotechnology through the media and the internet can generally lead to the adoption of inaccurate ideas and prejudice because of incorrect information (Demirci & Yüce, 2018). In this way, the biotechnology awareness of the students who will take on various social roles in the future will be prevented and thus biotechnology will become less understandable for people. This problem can be solved by educating individuals who are biotechnology literate. The integration of developments in science and technology into educational environments has led to the emergence of new skills and concepts (Yılmaz, 2021). Biotechnology literacy is one of these skills. Therefore, it is important to determine and develop students' biotechnology literacy in science education. Because the fact that students will use the knowledge they have acquired about biotechnology in their daily lives has made biotechnology important in science teaching (Sönmez & Pektaş, 2017). Science education aims to increase students' scientific literacy (Uşak, Erdoğan, Prokop & Özel, 2009). Science literacy is a concept that has become an indispensable part of science education policies in the world in recent years and its importance is emphasized in programs (Öztürk & Kaptan, 2014). For this reason, biotechnology literacy is considered important in terms of contributing individuals to make informed decisions in debatable situations such as biotechnology applications carrying risks for people (Özel, Erdoğan, Uşak & Prokop, 2009).

When studies on biotechnology are examined, it is seen that students' knowledge levels and attitudes are generally investigated (Fonseca, Costa, Lencastre & Tavares, 2012; Klop, Severiens, Knippels, Mil & Geert, 2010; Lamanauskas & Makarskaitė-Petkevičienė, 2008; Özel et al., 2009; Sürmeli & Şahin, 2010). However, since biotechnology is generally the subject of discussions focusing on risks, ethical concerns, or economic expectations (Bogner & Torgersen, 2014), biotechnology awareness, as well as ethics and risks, are discussed. Also, Roberts (2007) considered scientific literacy in two visions, and in his second vision,

he mentioned the necessity of individual decision making in socio-scientific issues encountered in real life. From this point of view, it can be said that students' preferences regarding biotechnology products in daily life constitute a dimension of literacy. Hence, students' preferences regarding biotechnology products are also included in the study. Therefore, this study aims to develop a biotechnology literacy inventory that deals with different dimensions of literacy to determine the biotechnology literacy of 8<sup>th</sup>-grade students and to ensure its validity/reliability. With the biotechnology literacy inventory developed in the study, it was aimed to determine the students' awareness of biotechnology, preferences of using biotechnology products, and their views on ethics and risks of biotechnology.

## METHOD

In this study, it is aimed to develop a valid and reliable inventory to determine the biotechnology literacy level of 8<sup>th</sup>-grade students. Biotechnology Literacy Inventory consists of three measurement tools; Biotechnology Awareness Test, The Biotechnology Products Preference Scale, and Biotechnology Opinion Scale. The participants of the research, the application process, and the analysis of the data are as follows.

### Participants

The research was conducted with 8<sup>th</sup>-grade students from six different secondary schools. The implementation for exploratory factor analysis was carried out with the participation of 315 students, who were selected by convenience sampling method, in 8<sup>th</sup>-grades of 4 different secondary schools in Adiyaman. 251 middle school 8<sup>th</sup>-grade students from 2 different secondary schools in Adiyaman were included in the study to perform the confirmatory factor analysis. The reason for selecting the participants from the 8<sup>th</sup>-grade students is that the subjects related to biotechnology are included in the 8<sup>th</sup>-grade in the Science Curriculum in Turkey. 62% of the students who participated in the study were males while 58% were female students.

### Inventory development process

Inventory development; literature review and creation of item pool, content validity study, implementation, and analysis of data. During the development of the inventory, 79 items (awareness test = 28 items, preference scale = 18 items, and opinion scale = 33 items) were included in three different dimensions to determine the biotechnology literacy levels of 8<sup>th</sup>-grade students by first benefiting from the literature and science curriculum. It was paid attention to be clear and understandable. Content validity was obtained from four experts. These experts consist of two faculty members in science education and two graduate science teachers. After obtaining expert opinions, the content validity index (CGI) of the items was calculated by the Davis technique, and 6 items with CGI values less than 0.80 were removed from the item pool. As a result of expert opinion, a draft form of The Biotechnology Literacy Inventory consisting of three measurement tools was created. The Biotechnology Awareness Test consists of 24 items that can be answered as yes/no; Biotechnology Products Preference Scale consists of 13 items prepared in five-likert type (never, rarely, occasionally, often, always); and Biotechnology Opinion Scale consists of 12 questions prepared in a five-point Likert type (strongly disagree, disagree, partially agree, agree, fully agree). Ten 8<sup>th</sup>-grade students were given a draft Biotechnology Literacy Inventory and asked to write down what they understood from each item. As a result of the evaluation of the students, corrections were made in the item statements and the final test was created. The final form was applied to 315 students in the 8<sup>th</sup>-grade to perform exploratory factor analysis. The data obtained after the application were analyzed separately for three measuring instruments.

### Data Analysis

Firstly, the data were converted to z values and the extreme values were cleared to analyze the data. After data cleaning, the ITEMAN program was used for Biotechnology Awareness Test, and item difficulty/discrimination indexes, and reliability coefficients were calculated. Exploratory factor analysis was performed for Biotechnology Products Preference Scale and Biotechnology Opinion Scale. With this analysis, whether items were collected under factors, factor loadings of each item, and the relationship between them were examined. Varimax Rotation method was used in the exploratory factor analysis process. The varimax rotation method used to reach the specified number of factors is made to simplify and clarify the data structure (Costello & Osborne, 2005). Confirmatory Factor Analysis (CFA) was applied to the data obtained to examine the results obtained from exploratory factor analysis and to support these results (Çokluk, Şekercioğlu & Büyüköztürk, 2010). The fit index values were calculated ( $\chi^2 / sd$ , GFI, AGFI, NFI, CFI, RMSEA, SRMR) and the values were evaluated according to the criteria determined in the literature to test the obtained factor structures (Hu & Bentler, 1999; Schermelleh-Engel, Moosbrugger & Müller, 2003; Tabachnick & Fidell, 2001). Cronbach alpha and KR20 coefficients were calculated to determine the reliability of the scales.

The scoring system of McBeth, Hungerford, Marcinkowski, Volk and Meyers (2008) was adapted to this study to obtain a single literacy score of students' biotechnology literacy by using data obtained from three measurement tools.

**Table 1. Biotechnology literacy scoring table**

	Score	Number of Items	Multiplier Value	Sample Calculation
Biotechnology Awareness Test	33,3	24	$33,3/24=1,38$	$18 \times 1,38=24,8$
Biotechnology Products Preference Scale	33,3	13	$33,3/5=6,67$	$3,85 \times 6,67=24,8$
Biotechnology Opinion Scale	33,4	12	$33,3/5=6,67$	$3,10 \times 6,67=20,8$
Sum	100	49		70,4

## FINDINGS

In this section, the results of exploratory and confirmatory factor analysis, item analysis and reliability analysis are presented to support the validity and reliability of three different measurement tools developed in the study.

### Findings for Biotechnology Awareness Test

In this section, the results of the item analysis of the data obtained from the implementation of the test to ensure the construct validity of the Biotechnology Awareness Test are given. The difficulty and discriminative indexes of the questions included in the test are given in Table 2.

**Table 2. Difficulty and discrimination indices of the items included in the biotechnology awareness test**

Item	Difficulty Index	Discrimination Index	Item Difficulty	Item discrimination
1	0.87	0.16	Too easy	Removed
2	0.86	0.22	Too easy	Removed
3	0.50	0.39	Moderate	Good
4	0.77	0.30	Easy	Good
5	0.84	0.32	Too easy	Good
6	0.61	0.33	Easy	Good
7	0.65	0.29	Easy	Developed
8	0.49	0.33	Moderate	Good
9	0.38	0.20	Difficult	Developed
10	0.77	0.33	Easy	Good
11	0.79	0.32	Easy	Good
12	0.80	0.34	Too easy	Good
13	0.74	0.33	Easy	Good
14	0.75	0.31	Easy	Good
15	0.77	0.23	Easy	Developed
16	0.67	0.32	Easy	Developed
17	0.56	0.33	Moderate	Developed
18	0.49	0.35	Moderate	Good
19	0.52	0.20	Moderate	Developed
20	0.69	0.32	Easy	Good
21	0.66	0.36	Easy	Good
22	0.75	0.34	Easy	Good
23	0.79	0.38	Easy	Good
24	0.62	0.30	Easy	Good
25	0.58	0.27	Moderate	Developed
26	0.74	0.38	Easy	Good

According to Table 2, 2 items whose item discrimination index was less than 0.20 were excluded from the test and re-item analyzes were performed with the remaining items. Items with a discrimination index of 0.20-0.30 were included in the test with regulation. The difficulty and discriminative indices of the 24-item final test are given in Table 3.

**Table 3. Difficulty and discrimination indices of the items in the final test**

Item	Difficulty Index	Discrimination Index	Item discrimination	Item	Difficulty Index
3	0.50	0.40	15	0.77	0.30
4	0.77	0.22	16	0.67	0.34
5	0.84	0.31	17	0.56	0.34
6	0.61	0.35	18	0.49	0.35

7	0.65	0.30	19	0.52	0.23
8	0.49	0.34	20	0.69	0.34
9	0.38	0.29	21	0.66	0.36
10	0.77	0.32	22	0.75	0.34
11	0.79	0.31	23	0.79	0.36
12	0.80	0.34	24	0.62	0.31
13	0.74	0.32	25	0.58	0.29
14	0.75	0.30	26	0.74	0.37
3	0.50	0.40	15	0.77	0.30
4	0.77	0.22	16	0.67	0.34

Difficulty indexes of the items in the obtained test ranged from 0.38 to 0.84, while discrimination indices ranged from 0.22 to 0.40. The ITEMAN analysis of the final test is given in Table 4.

**Table 4. Item analysis results of Biotechnology Awareness Test**

Statistics	
Number of Items	24
N	315
Mean	16.04
Variance	12.29
Minimum	6
Maximum	24
Alpha (KR-20)	0.63
Difficulty	0.66
Discrimination	0.43

When Table 4 is examined, it is seen that the reliability coefficient of the test is 0.63, the average difficulty is 0.66 and the average discrimination is 0.43.

### Findings for Developing Biotechnology Products Preference Scale

In this section, factor analysis and reliability analysis findings which are performed to determine the construct validity of the scale are presented. Factor analysis was performed in two stages: Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). The findings obtained from the analysis were examined under separate headings to express their integrity.

#### Exploratory factor analysis (EFA)

Before the factor analysis, Kaiser-Mayer-Olkin (KMO) and Barlett's Test analysis were performed to check the suitability of the data set for factor analysis. KMO value of 0.60 to test sample suitability indicates that it is suitable for factor analysis (Akgül & Çevik, 2003). KMO value was found to be 0.66. The Chi-Square value ( $\chi^2 = 473.16$ ,  $sd = 105$ ,  $p < .00$ ) obtained from the Barlett test, which was used to examine whether the data was normally distributed or not, was also significant. These results show that the data are suitable for factor analysis. The exploratory factor analysis was started with 18 items and it was observed that the items were collected under 5 factors which explained 51.32% of the scale and had an eigenvalue greater than 1.

**Table 5. Difficulty and discrimination indices of the items included in the biotechnology awareness test**

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	2.529	16.863	16.863	2.529	16.863	16.863	1.949	12.994	12.994
2	1.627	10.844	27.707	1.627	10.844	27.707	1.636	10.905	23.899
3	1.333	8.885	36.591	1.333	8.885	36.591	1.575	10.499	34.398
4	1.16	7.734	44.326	1.16	7.734	44.326	1.291	8.608	43.006
5	1.05	7.002	51.328	1.05	7.002	51.328	1.248	8.321	51.328

The scree plot which is another method than eigenvalue statistics was examined to determine the appropriate factor number. Figure 1 shows the scree plot of factors.

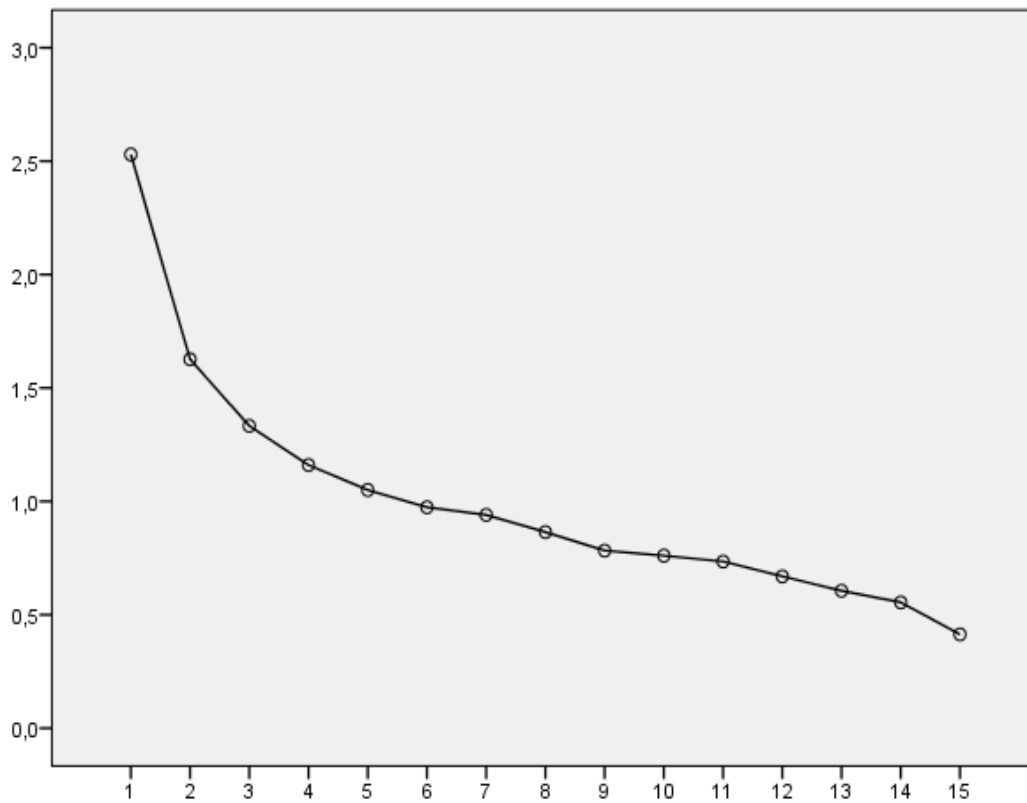


Figure 1. Scree plot

When the scree plot was examined, it was decided that the scale should have four factors because the graph began to lose its slope after the fourth factor (Büyüköztürk, Akgün, Karadeniz, Demirel & Kılıç, 2009). It was decided that factor loads should be over 0.40.

Table 6. Factor loadings of items

Item	Components			
	1	2	3	4
2	0.789			
3	0.718			
1	0.704			
11		0.723		
4		0.677		
5		0.627		
8			0.64	
6			0.638	
7			0.605	
15			0.532	
13				0.723
10				0.559
9				0.486

In the analysis process, rotation started with 18 items, and a final test of 13 items consisting of four factors was obtained. The factor loadings of the items in the scale ranged between 0.486 and 0.789.

Table 7. The total variance values explained for the items of the scale after factor analysis

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	2.491	19.15	19.15	2.491	19.15	19.15	1.879	14.45	14.45
		9	9		9	9		7	7
2	1.546	11.89	31.05	1.546	11.89	31.05	1.636	12.58	27.04
		5	4		5	4		3	
3	1.206	9.279	40.33	1.206	9.279	40.33	1.615	12.42	39.46
			3			3		3	3
4	1.143	8.795	49.12	1.143	8.795	49.12	1.256	9.665	49.12
			8			8			8

When Table 7 is analyzed, after the exploratory factor analysis, the contribution of the first factor to the total variance is 14.457 percent, the second factor contributes 12.583 percent, the third factor contributes 12.423 percent, and the fourth factor contributes 9.665 percent. Besides, the total variance ratio explained by the four-factor structure was calculated as 49.128 percent. The final reliability of the scale was determined by using Cronbach's alpha ( $\alpha$ ) reliability coefficient. After determining the whole scale and sub-dimensions, Cronbach's alpha internal consistency coefficients calculated for each sub-dimension were 0.61; 1. Size for 0.66; 2. Size is 0.51; it was calculated as 0.47 for the 3rd dimension and 0.52 for the 4th subdimension.

**Confirmatory factor analysis (CFA)**

The goodness of fit values obtained as a result of confirmatory factor analysis is given in Table 8.

**Table 8. Standard fit criteria and fit indexes obtained from CFA**

Goodness of Fit	Good fit	Acceptable	4-D model	Result
p	> .01 ya da .05	< .01 ya da .05	0.054	Good fit
$\chi^2/df$	$0 \leq \chi^2/sd \leq 2$	$2 \leq \chi^2/sd \leq 3$	1.30	Good fit
RMSEA	$0 \leq RMSEA \leq 0.5$	$0.5 \leq RMSEA \leq .08$	0.035	Good fit
SRMR	$0 \leq SRMR \leq .05$	$0.5 \leq SRMR \leq .10$	0.053	Acceptable
GFI	$.95 \leq GFI \leq 1.00$	$.90 \leq GFI \leq .95$	0.95	Good fit
AGFI	$.90 \leq AGFI \leq 1.00$	$.85 \leq AGFI \leq .90$	0.93	Good fit
CFI	$.97 \leq CFI \leq 1.00$	$.95 \leq CFI \leq .97$	0.95	Acceptable

According to confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.30,  $p = 0.054$ , and RMSEA value was calculated as 0.035. When the other fit indexes were examined, CFI = 0.95, GFI = 0.95, AGFI = 0.93, RMR = 0.11, SRMR = 0.053. These values indicate that the model is accepted (Schermelleh-Engel et al., 2003). The standardized item factor loadings of the four-dimensional model obtained as a result of DFA were between 0.32 and 0.76, while t values ranged between 3.72 and 10.59.

**Findings for Developing Biotechnology Opinion Scale**

In this section, factor analysis is conducted to determine the construct validity of the developed Biotechnology Opinion Scale. Factor analysis was carried out in two stages. In the first stage, Exploratory Factor Analysis (EFA) and in the second stage Confirmatory Factor Analysis (CFA) was performed. The findings obtained from the analysis was handled under separate headings to express their integrity.

**Exploratory factor analysis**

Kaiser-Mayer-Olkin (KMO) and Barlett's Test analysis were performed to check the fit of the data obtained from the sample without factor analysis. KMO value of 0.60 to test sample suitability indicates that it is suitable for factor analysis (Akgül & Çevik, 2003). KMO value was found to be 0.69. The Chi-Square value ( $\chi^2 = 427.32$ ,  $Sd = 91$ ,  $p < .05$ ) obtained by the Barlett test, which was used to examine whether the data were normally distributed or not, was also significant. These results show that the data are suitable for factor analysis. Explanatory factor analysis was started with 29 items. It was observed that the items were collected under 5 factors with an eigenvalue greater than 1, explaining 53.92% of the total variance.

**Table 9. Total variance explained for the 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	2.621	18.72	18.72	2.621	18.72	18.72	1.547	11.05	11.05
		4	4		4	4		3	3



2	1.426	10.18 8	28.91 2	1.426	10.18 8	28.91 2	1.544	11.03 2	22.08 4
3	1.358	9.698	38.61	1.358	9.698	38.61	1.543	11.02 3	33.10 7
4	1.099	7.851	46.46	1.099	7.851	46.46	1.493	10.66 7	43.77 5
5	1.045	7.461	53.92 1	1.045	7.461	53.92 1	1.421	10.14 7	53.92 1

The scree plot was used to determine the appropriate number of factors.

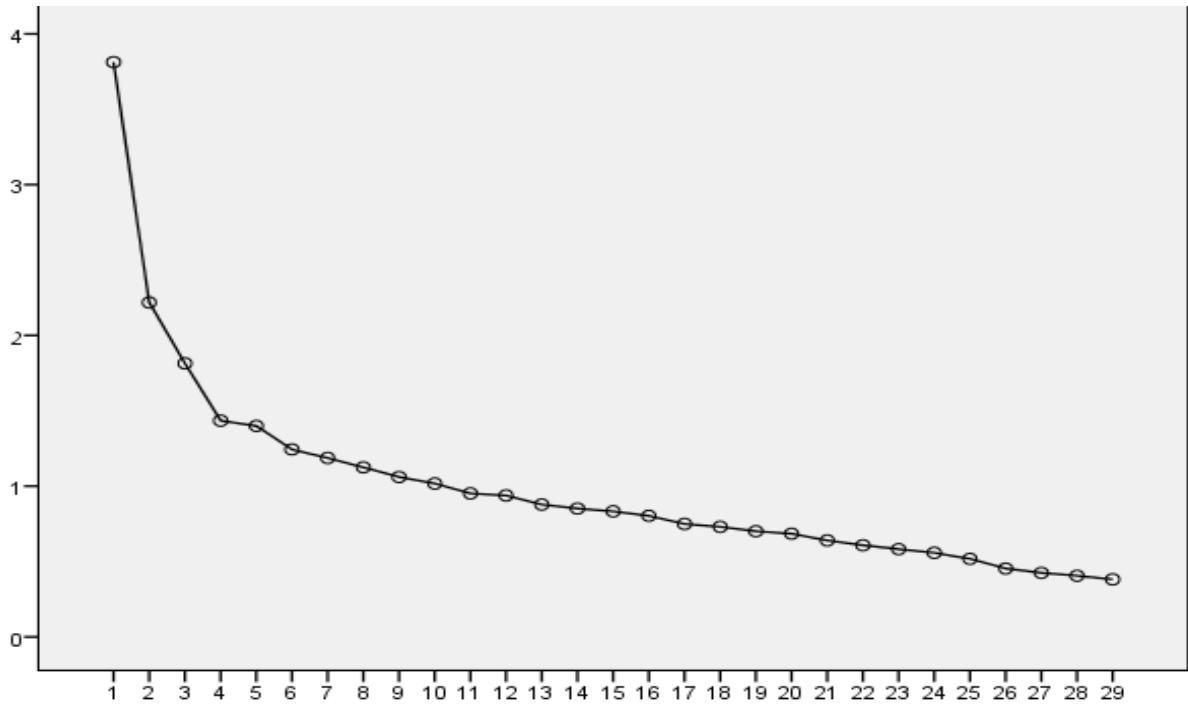


Figure 2. Scree plot

When the graph in Figure 2 is analyzed, it is seen that there is a high acceleration decrease up to the fourth factor and the graph slope starts to lose from the fourth factor. Therefore, the number of factors was determined to be 4. Varimax rotation technique was used for determining factors with strong correlations of variables, frequency of use, and ease of interpretation (Tabachnick & Fidell, 2001). Table 10 shows the item factor loadings.

Table 10. Factor loadings of items

Item	Components			
	1	2	3	4
5	0.717			
21	0.686			
7	0.530			
1		0.748		
2		0.732		
18		0.550		
29			0.775	
28			0.646	
15			0.605	
9				0.610
26				0.557
23				0.527

The exploratory factor analysis was started with 29 items and a final scale consisting of 12 items and four sub-dimensions was obtained. Item factor loadings in the scale ranged from 0.527 to 0.775. The total variance values explained after exploratory factor analysis are given in Table 11.

Table 11. The total variance values explained for the items of the scale after factor analysis



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	2.559	21.323	21.323	2.559	21.323	21.323	1.576	13.136	13.136
2	1.376	11.466	32.789	1.376	11.466	32.789	1.556	12.966	26.102
3	1.104	9.201	41.999	1.104	9.201	41.999	1.52	12.667	38.769
4	1.086	9.049	51.039	1.086	9.049	51.039	1.472	12.270	51.039

As a result of Varimax rotation, the contribution of the first factor to the total variance is 13.136 percent, the second factor contributes 12.966 percent, the third factor contributes 12.667 percent, and the fourth-factor contributes 12.270 percent. Also, the total variance explained by four factors is 51.039 percent. After determining the whole scale and sub-dimensions, Cronbach's alpha internal consistency coefficients for each sub-dimension were; 0.65, 0.47, 0.54, 0.48 and 0.51.

### Confirmatory factor analysis (CFA)

Path diagram and goodness of fit index results were examined in the confirmatory factor analysis conducted for the adaptation of the four-factor model obtained from the exploratory factor analysis (Table 12).

**Table 12. Standard fit criteria and fit indexes obtained from CFA**

Goodness of Fit	Good fit	Acceptable	4-D model	Result
p	$> .01$ ya da $.05$	$< .01$ ya da $.05$	0.39	Good fit
$\chi^2/df$	$0 \leq \chi^2/sd \leq 2$	$2 \leq \chi^2/sd \leq 3$	1.04	Good fit
RMSEA	$0 \leq RMSEA \leq 0.05$	$0.05 \leq RMSEA \leq 0.08$	0.012	Good fit
RMR	$0 \leq RMR \leq 0.05$	$.05 \leq RMR \leq 0.08$	0.081	Acceptable
SRMR	$0 \leq SRMR \leq 0.05$	$0.05 \leq SRMR \leq 0.10$	0.043	Good fit
GFI	$.95 \leq GFI \leq 1.00$	$.90 \leq GFI \leq .95$	0.97	Good fit
AGFI	$.90 \leq AGFI \leq 1.00$	$.85 \leq AGFI \leq .90$	0.95	Good fit
CFI	$.97 \leq CFI \leq 1.00$	$.95 \leq CFI \leq .97$	0.99	Good fit

According to confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.04,  $p = 0.39$ , and RMSEA value was calculated as 0.012. When the other fit indexes were examined, CFI = 0.99, GFI = 0.97, AGFI = 0.95, RMR = 0.081, SRMR = 0.043. These findings show that the four-dimensional model obtained in exploratory factor analysis is accepted (Schermelleh-Engel et al., 2003). The standardized item factor loads of the four-dimensional model obtained as a result of CFA were between 0.31 and 0.82, while the  $t$  values ranged between 4.91 and 7.

## DISCUSSION, CONCLUSION, AND IMPLICATIONS

This study was carried out to develop a biotechnology literacy inventory consisting of three measurement tools including different dimensions of literacy to determine biotechnology literacy of 8<sup>th</sup>-grade students. These measuring tools; The Biotechnology Awareness Test, The Biotechnology Products Preference Scale, and The Biotechnology Opinion Scale. As a result of the analysis, the 26-item draft test for the biotechnology awareness test, the reliability coefficient of the 24-item final test was 0.63, the average difficulty was 0.66 and the average discrimination was 0.43. Difficulty indexes of the items in the obtained test ranged from 0.38 to 0.84, while the discrimination indexes ranged from 0.22 to 0.40. Based on these results, when the item difficulty index of the test is examined, it can be said that the difficulty level is moderate (Diederich, 1973). Diederich (1973) emphasized that the test should be moderately difficult, while the difficulty coefficients of a test at a medium level should be between 0.20 and 0.80. Therefore, it was determined that the items included in the test, and the average difficulty of the test were moderate and met this requirement. Ebel and Frisbie (1991), and Downing and Haladyna (2006) also stated that the difficulty of the developed test should be moderate. When the literature on the discriminative indices of the test items was examined, Downing and Haladyna (2006) stated that the discrimination was excellent as it closed 1. However, for a test in the classroom, it is preferred that  $r_{pbis}$  is higher than 0.20 in all items (Wells & Wollack, 2003). Thus, it was determined that the items included in the test, and the average discriminant of the test were appropriate.

The reliability coefficient of The Biotechnology Awareness Test was 0.63. Based on this value, it can be said that the reliability coefficient of the test applied in the research is sufficient. Because Ebel and Frisbie (1991) also stated that the reliability coefficient should be around 0.85 if the test scores are used to make decisions about the individuals for the tests applied in the classroom, whereas this decision should be 0.65 for the scores of a group of individuals like the class. Diederich (1973) reported that reliability coefficients were generally obtained between 0.60 and 0.80 in good and useful tests.

The other measurement tool developed within the scope of the research is The Biotechnology Products Preference Scale to determine the preferences of the students about which biotechnology products they use. For this purpose, exploratory factor analysis and confirmatory factor analysis were used in the data obtained from the application of the final scale. In the analysis process, the rotation was started with 18 items and a final test of 13 items consisting of four factors was obtained. If the factor load values of the items are above 0.40, the items can be considered very good and if the factor load values are above 0.70, the items can be considered excellent (Tabachnick & Fidell, 2001). For this reason, the item factor loadings above 0.40 were sought. The factor loadings of the items in the scale obtained ranged between 0.486 and 0.789 and this condition was provided. The scale consists of four factors. The contribution of the first factor to the total variance is 14.457%, the contribution of the second factor is 12.583%, the contribution of the third factor is 12.423% and the contribution of the fourth factor is 9.665%. Besides, the total variance ratio explained by the four-factor structure was calculated as 49.128% and this value is considered sufficient (Kline, 2010). The Cronbach's alpha reliability coefficient of the scale was 0.61 for all; 1. dimension for 0.66; 2. dimension is 0.51; It was calculated as 0.47 for the 3rd dimension and 0.52 for the 4th sub-dimension. The four-dimensional model obtained as a result of the exploratory factor analysis of the scale was tested by confirmatory factor analysis. As a result of confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.30,  $p = 0.054$ , and RMSEA value was calculated as 0.035 according to the confirmatory factor analysis results. RMSEA value less than 0.05 is an indicator of the model's fit (Arbuckle, 2005; Hu & Bentler, 1999). The fact that  $\chi^2 / df$  value is less than 2 indicates that there is perfect agreement between the model and the data (Çokluk et al. 2010; Schermelleh-Engel et al., 2003). When the other fit indexes were examined, CFI = 0.95, GFI = 0.95, AGFI = 0.93, RMR = 0.11, SRMR = 0.053. These values indicate that the model is accepted (Hu and Bentler, 1999; Schermelleh-Engel et al., 2003; Tabachnick and Fidell, 2001). As a result, the Biotechnology Products Preference Scale consisting of 13 items with 4 dimensions was developed.

The last measurement tool developed within the scope of the study is the Biotechnology Opinion Scale which was developed to determine the students' views on the ethical aspects and risks of biotechnology applications. For this purpose, exploratory factor analysis was started with exploratory factor analysis with 29 items, and a final scale of 12 items, and four sub-dimensions was obtained. Since item factor loads of the items in the scale ranged from 0.527 to 0.775, these items were found to be suitable for testing (Tabachnick & Fidell, 2001). The scale consists of four factors. As a result of Varimax vertical rotation, the contribution of the first factor to the total variance is 13.136 percent, the second factor contributes 12.966 percent, the third factor contributes 12.667 percent and the fourth factor contributes 12.270 percent. Also, the total variance explained by four factors is 51.039 percent and this value is considered sufficient (Kline, 2010). After determining the whole scale and its sub-dimensions, the Cronbach's alpha internal consistency coefficient for each sub-dimension was calculated as 0.65. The four-dimensional model obtained as a result of the exploratory factor analysis of the scale was tested by confirmatory factor analysis. According to the confirmatory factor analysis,  $\chi^2 / df$  value was found to be 1.04,  $p = 0.39$  and RMSEA value was calculated as 0.012. RMSEA value was less than 0.05 (Arbuckle, 2005; Hu & Bentler, 1999), and  $\chi^2 / df$  value is less than 2 shows the compatibility of the model (Multitude et al. 2010; Schermelleh-Engel et al., 2003). When the other fit indexes were examined, CFI = 0.99, GFI = 0.97, AGFI = 0.95, RMR = 0.081, SRMR = 0.043. These findings show that the four-dimensional model obtained in exploratory factor analysis is accepted (Hu & Bentler, 1999; Schermelleh-Engel et al., 2003; Tabachnick & Fidell, 2001).

As a result, with the biotechnology literacy inventory developed with this study, students' literacy can be measured in a multidimensional way. In this context, three different measures are Biotechnology Awareness Test, Biotechnology Products Preference Scale, and Biotechnology Opinion Scale. Besides, a scoring table is included in the study to calculate a single biotechnology literacy score according to the data obtained from this scale. Thus, the total literacy scores of students can be determined. Only 8<sup>th</sup>-grade students were included in this study. Validity and reliability studies of the scale can be done by conducting research with students at different grade levels with other studies. Also, the predictive effects of the three dimensions in this inventory can be examined with correlational research.

### **Ethics Committee Approval Information**

All stages of the study were carried out in accordance with ethical principles. Since the implementation of the study was carried out before 2020, the Ethics Committee Approval Document was not received.

Conflict of Interest: The authors declare that they have no conflict of interest.

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