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Research Article

Development of Basic Biotechnology Knowledge Scale (BBKS) with Rasch Measurement Model

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Abstract – The purpose of this study was to develop a scale to measure basic biotechnology knowledge, examine the psychometric properties of the scale, and investigate whether there are differences in the test performances of high school students in terms of school, grade, and gender. The development phase of this scale was carried out with a sample of 388 high school students in a province in the west of Turkey. The psychometric properties of the scale were examined using the Rasch model. The K-R internal consistency coefficient of the final scale consisting of 17 items was calculated as 0.77. It was observed that item-total correlations varied between 0.25 and 0.48 except for one item (item 1, 0.13). The results of the Rasch analysis indicated that the scale fits the Rasch model and can differentiate between low and high-performing test takers. Three-Way ANOVA results demonstrated a significant main effect for the school. There were no statistically significant differences for grade and gender variables in terms of their biotechnology knowledge scores. However, the grade*gender interaction was statistically significant, favouring males with a small effect size. This observed effect was possibly due to the uneven sample size of 12th-grade students. The overall results suggest that Basic Biotechnology Knowledge Scale (BBKS) can be used to assess the biotechnology knowledge level of high school students.

Keywords: biotechnology, knowledge measurement, Rasch measurement model, scale development

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Introduction

Biotechnology is a branch of science that arose from scientific curiosity and is critical for students to comprehend because of its possible influence on them and others (Kustiana, Suratno, & Wahyuni, 2020). By providing a wide range of products, rapid developments in biotechnology and genetic engineering have shown their impact on our lives directly or indirectly in many areas, such as health, agriculture, the environment, and food production (Ayar & Hasipek, 2003; Lyson, 2002; Özgen, 1995). However, not knowing the future results of the biotechnological developments (Ho, 2001) caused biotechnological applications to be accepted as risky, particularly in areas such as health and the environment (Kahveci & Özçelik, 2008; Shaw, 2002). In general terms, medical procedures, studies of microorganisms, plants, and environmental studies are perceived positively, but human cloning, direct human work, and non-compulsory and more arbitrary (such as making food more caloric) applications are viewed negatively (Akman, 2007; Bayoğlu & Özgen, 2010; Chabalengula, Mumba, & Chitiyo, 2011; Demir & Pala, 2007; Frewer, Shepherd, & Sparks, 1994; Frewer, Howard, & Shepherd, 1997; Gardner & Jones, 2011; Gardner, Jones, Taylor, Forrester, & Robertson, 2010; Morris & Adley, 2001; Schilling, Hallman, Hossain, & Adelaja, 2003). Studies also indicate that individuals have gained some of their knowledge through informal means such as TV and newspapers and usually have low-level and simple information about biotechnology (Gaskell et al., 2006; Sjöberg, 1996, Sparks & Shepherd, 1994). For example, Bonfadelli (2005) states that the amount of biotechnology information covered in the media is directly proportional to the knowledge of biotechnology. Therefore, the information individuals obtain informally may not be of the nature to raise awareness, and in this case, they need structured ways of learning. This requires societies of conscious individuals in the field of biotechnology (Harms, 2002).

Teaching biotechnology topics in schools can help students become 'biotechnologically literate people' who grasp both the concepts of current biotechnology and the fundamental principles of biotechnology. This provides opportunities for them to build views and consequences of biotechnology that will allow them to make educated personal and social decisions (Gonzalez, Casanoves, Salvado, Barnett, & Novo, 2013; Paš, Vogrinc, Raspor, Kneževič, & Zajc, 2019). However, despite its significance and rapid development, studies (e.g. Fonseca, Costa, Lencastre, & Tavares, 2012) indicate that individuals generally have poor knowledge of biotechnology. It has not been a popular topic, particularly in public schools, due to teachers' inadequate academic skills, limited time and to the lack of resources available (Fonseca et al., 2012; Gelamdin, Alias, & Attaran, 2013).

The Assessment of Biotechnology Knowledge

In Turkey, from elementary school to post-secondary education, science courses include the multidisciplinary area of biotechnology (MoNE, 2018a, b). In the Primary Science Course Curriculum, biotechnology topics are included in the 8th grade 2nd Unit called "DNA and Genetic Code" (MoNE, 2018a). In the High School Biology Course Curriculum, they are included in the 12th grade 1st unit called "From Gene to Proteins" (MoNE, 2018b). In the high school Genes to Proteins Unit, Gene Technologies, DNA Fingerprint, Stem Cell Technologies, Model Organisms, Genetic Consulting, Cloning, Gene Therapy Applications, Vaccines, Bioethics and Biosecurity topics are covered (MoNE, 2018b). One of the observable ways in which the applied programs accomplish their goals is to evaluate how well the knowledge and competencies of the students following this curriculum improve in line with their abilities. However, the studies on the knowledge of genetic engineering and biotechnology are diverse in terms of various factors such as the target audience, the type of data collection tools used, the breadth of the data collection tool and data analysis methods. To examine if individuals have the basic knowledge of biotechnology, accurate and efficient biotechnology knowledge measurement is needed. Over the past twenty-five years, numerous scales for measuring different aspects of biotechnology have been developed worldwide. When the studies are examined, it is seen that a substantial number of studies are about the attitudes towards biotechnology (Bal & Keskin, 2002; Bilen & Özel, 2012; Massarani & Moreira, 2005; Sürmeli & Şahin, 2010a,b; Turan & Koç, 2012) and knowledge of genetic engineering and biotechnology (Acarlı, 2016; Ağaç, 2019; Akman, 2007; Chen & Raffan, 1999; Dawson, 2007; Dawson & Schibeci, 2003; Gürkan & Kahraman, 2019; Konak & Hasancebi, 2021; Keskin et al., 2010; Prokop et al., 2007; Sıcaker & Öz Aydın, 2015; Sıcaker, Öz Aydın, & Saçkes, 2020; Sönmez & Pektaş, 2017; Yüce & Yalçın, 2012).

There are various measurement tools using different types of questions to evaluate students' knowledge of biotechnology. Examples of these are open-ended questions (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Kinderlerer & Beyleveld, 1998; Lock & Miles, 1993), true-false questions (Casanoves, González, Salvadó, Haro, & Novo, 2015; de la Hoz, Solé-Llussà, Haro, Gericke, & Valls, 2022; Gürkan & Kahraman, 2019; Klop & Severiens, 2007; Prokop, Leskova, Kubiatko, & Diran, 2007; Sıcaker, Öz Aydın, & Saçkes, 2020), Likert type scales (Lamanauskas & Makarskaitė-Petkevičienė, 2008; Yüce & Yalçın, 2012) and multiple choice questions (Atasoy, Atıcı, Taşar, & Taflı, 2020) tested on various samples including university students, pre-service teachers, elementary school and secondary school students. It seems from the measurement tools that there is a wide variety of measures in different countries for different samples and covering various topics of biotechnology. When the topics, samples and contexts questioned in biotechnology knowledge studies conducted in various countries are examined, it is seen that the instruments cover a wide range of topics such as the meaning of biotechnology and related concepts with examples, food biotechnology, cloning, genetically modified organisms, animal reproduction, animal reproduction, bioremediation, biotechnology ethics, electrophoresis, environmental and microbial biotechnology, gene splicing, growth hormones, hybridization, human genomics, plant-tissue culture, recombinant DNA, resistant plant species, transgenic species and various applications of biotechnology (Chen & Raffan, 1999; Lock & Miles, 1993; Mowen, Roberts, Wingenbach, & Harlin, 2006; Priest, Bonfadelli, & Rusanen, 2003; Prokop et al., 2007; Sıcaker & Öz Aydın, 2015).

This above-mentioned diversity in the studies calls for a need to design a tool that focuses on both the Turkish elementary science and high school Biology curriculum and on the other areas needed to ensure biotechnological literacy. In this case, issues such as validity, reliability and statistical methods become much more important. While it is very difficult to fully provide these with classical test methods (Boone & Scantlebury, 2006) as in the many existing scales guided, one of the item response theories, the Rasch measurement model, is one of the methods recommended to solve all these problems (Wright & Mok, 2004).

Recently, several authors (Sıcaker et al., 2020) have expressed the need for different measurement approaches, such as Item Response Theory (IRT) and Rasch analysis. Rasch measurement model has some advantages in developing and validating scales investigating the extent to which an item set meets several criteria essential for accurate measurement (Woudstra et al., 2019). First, it helps researchers to make critical corrections while using raw test score data allowing nonlinear raw data to be converted to a linear scale (Boone, 2016). Second, it provides the opportunity to evaluate the individuals according to their abilities and the items according to their difficulties.

In addition, Rasch Measurement Model evaluates every individual independently from the sample (Boone & Scantlebury, 2005; Wright & Mok, 2004). There are Rasch steps that may be employed to investigate more significant instrumentation issues such as item reliability, person reliability, and differential item functioning (Boone, 2016). All these advantages indicate that Rasch models can be easily used for two-category scales, such as True/False and Yes/No (), by overcoming the chance factor (Boone & Scantlebury, 2006; Wright & Mok, 2004). Recently, there seems to be a growing interest in using Rasch analysis in the science education field for scale development (Saefi et al., 2020; Testa et al., 2022; Tyas, Senam, Wiyarsi, & Laksono, 2020). Experimental studies and scale development studies using the Rasch model are also available in the fields of medicine and educational sciences (Baştürk, 2010; Elhan & Atakurt, 2005; Kaptan, 1994; Kaskatı, 2011; Koparan & Güvenen, 2013; Semerci, 2011a, b). Almost all these studies show that the use of Rasch models leads to better and more effective outcomes in evaluation and assessment (Sıcaker, 2013).

The Present Study

The purpose of the present study is to develop a Basic Biotechnology Knowledge Scale (BBKS) using Rasch Measurement Model and examine whether there is a statistical difference in biotechnology knowledge among students in terms of school, grade, and gender. The specific research questions for the present study are:

(1) What is the evidence to suggest the validity and reliability of measures of the Biotechnology Knowledge Scale?

(2) Is there a statistically significant difference in biotechnology knowledge between female and male students among students of different high school grades and different high schools?

Method

Study Model

The present study is a scale development study structured based on a survey model. Usually, at a specific point in time, surveys collect data to explain the existing conditions, define criteria against which existing conditions can be measured, or assess the relationships that occur between events. Surveys are also useful in generating accurate instruments through piloting and revision (Cohen, Manion, & Morrison, 2018).

Development Process of the Scale

The following steps were used to develop the BBKS: Conceptualizing the construct; creating the initial item pool; evaluating and modifying the items; conducting cognitive interviews; developing the pilot test; and validating the scale. A Three-Way ANOVA was used to analyze the differences in biotechnology knowledge among students from various schools, genders, and grade levels. For collecting valid evidence for BBKS to answer the first research question, AERA (American Educational Research Association), APA (American Psychological Association) and NCME (National Council on Measurement in Education) 2014 standards and guidelines were referred.

Conceptualizing the Scale

The advancements in biotechnology have had a significant positive impact on society and modern science. Nevertheless, despite the importance of the area, biotechnology receives scant attention in curricula and classrooms (Borgerding, Sadler, & Koroly, 2013; Hanegan & Bigler, 2009). For example, In Turkey, biotechnology topics are only covered in 12th grade, and despite the mentioned importance, only students who are enrolled in science-based courses encounter this subject. This brings the situation to the point that other students only encounter biotechnology subjects in 8th grade, only for four hours and with limited outcomes (MoNE, 2018a). Considering the effect of learning about biotechnology and resulting skills on students' interest and motivation in science (Hanegan & Bigler, 2009; Nordqvist & Aronsson, 2019), the fact that biotechnology is included in the programs so narrow and that not all students encounter these subjects sufficiently guided the development. Therefore, in the conceptualization of BBKS, attention was paid to include both elementary and high school biotechnology outcomes and other current developments in the biotechnological field.

Creating the Initial Item Pool

To generate the scale items, the first Turkish High School Biology Curriculum and curriculum-related textbooks were reviewed. Also, not limited to the program alone, some items, including current biotechnology topics that are thought to be known by all high school students, were also added to the scale. Based on the first review, the fourth author's discussions with her students and the researchers' experience, 37 short answer and true/false questions were prepared for the biotechnology and genetic knowledge of high school students. These 37 questions were informally tested on high school students in the fourth author's classrooms. In the second step, 84 items in True-False format were prepared as an initial item pool according to the results of multiple-choice questions. To examine items with lower and higher content validity, three experts in biology education with more than 20 years of experience were invited to review the initial item pool and asked to evaluate each item in the initial scale if the item is suitable to measure the biotechnology knowledge. First, opinions were received from field experts to gather evidence based on test content. In this initial review, items such as "*DNA can be completely cloned out of Vivo by PCR method*" and "*Methods such as mutation and crossing-over are the biotechnological methods of nature*" were excluded according to experts' opinions since they stated there were similar and more suitable items measuring the same content.

Conducting Cognitive Interviews

To provide construct-related validity evidence, think-aloud procedures were conducted with 15 high school students and two master's students in biology education. The cognitive interview process is an iterative process in scale development research to revise the content with one-on-one interviews (Willis, 2005). This interview process helped the researchers to that the items in BBKS were interpreted in the way that it is intended to measure and that the selected options of students reflected their thoughts. After this think-aloud procedure, some items were excluded, and the 84-item scale became a four main-topic, 16 sub-topics, 44-item scale named Basic Biotechnology Knowledge Scale (BBKS).

Developing the Pilot Test-First Application

Rasch analysis assumes that the probability of a person choosing a category of any item is a logistic function of the difference between the level of ability of the person and the level of difficulty of the item (Koparan & Güvenen, 2013). There are some problems encountered when trying to evaluate any questionnaire or test using the raw scores obtained by collecting the correct answers given to the items. One of them is the inability to determine the unexpected answers given to the items, that is, an item that is answered correctly by chance (especially in True/False tests). It is not possible to predict whether the correct answer was given knowingly or unknowingly. The Rasch measurement model has a structure that can overcome these problems (Wright & Mok, 2004). In this study, the following assumptions are examined to check the suitability of the Rasch analysis for sampling: Examining fit indices (item reduction), unidimensionality, local independence of items, person raw score reliability, separation indices, analysis of biased items, and examining the Wright Item-person map. WINSTEPS 3.65.0 is used to analyze the data with the Rasch Measurement Model.

For the pilot study, the 43-item version of BBKS was conducted on a sample of 150 11th and 12th-grade students from two public high schools in a province in the west of Turkey. The data were analyzed using Rasch analysis. These 43 items were grouped under four main topics: Basic Knowledge (12 items), Real-Life Practices (8 items), Laboratory Methods Techniques (14 items), and Effects (8 items). The evaluation of the Wald test for item elimination and item (category) difficulty parameters (Beta) results showed that 12 items were not fit the model. The researchers decided to keep five of these 12 items since the content validity is affected by their elimination. After reviewing the five items and excluding seven unsuitable items, the pilot analysis resulted in having 36 items in BBKS. The K-R20 internal consistency coefficient of this version of BBKS consisting of 36 items was calculated as 0.70. The five items that were edited and added to the BBKS and the seven items that were removed are presented in Table 1.

Table 1. Excluded and reviewed items after the pilot analysis

Item Numbers	Item Statement	Reviewed statement of the item
Item 1	Gene transfer cannot be made between organisms that are genetically quite different from each other (such as bacteria and humans).	Gene transfer can be made between living things (such as bacteria and humans) that are genetically quite different from each other.
Item 8	Gene therapy is a very easy and effective method	Gene therapy in humans is an easily applicable method
Item 10	Plants cannot produce animal proteins, even with genetic changes	By transferring genes to plants, they can be made to produce animal proteins.
Item 13	Cloning studies are not applicable to plants.	Excluded
Item 17	Biotechnological methods can only be applied in the laboratory	Excluded
Item 18	Genetic engineering only works on animal organisms	Excluded
Item 21	Stem cells are not found in all multicellular organisms	Excluded
Item 25	Gene (DNA) transfer to all plants occurs only through soil bacteria	Excluded
Item 28	Developing DNA technology does not pose significant ethical problems	Developing DNA technology may pose significant ethical problems
Item 31	Humans have fewer genes than most plants and invertebrates	Excluded
Item 33	Eggs and sperm of mammals cannot be combined outside of a living thing	Excluded
Item 35	DNA cannot be replicated outside the cell; in the laboratory	DNA cannot be replicated outside the living cell (under laboratory conditions)

Validating the Scale-Second Application

To provide valid evidence based on internal structure, the 36-item version of BBKS was subsequently applied to 388 high school students enrolled in various high schools in a province in the west of Turkey, and Rasch analysis tested the psychometric properties of the scale items. Of this sample, 209 were female (53.86%), and 179 were male (46.14%). HS1 and HS2 are Anatolian High Schools, and HS3 is a Science High School. The difference between HS1 and HS2 is the high school acceptance scores of students, which is higher for HS1 than HS2. Also, HS3 is a science-intensive high school, and its acceptance scores are higher than the other two. Table 2 shows the demographics of the sample.

Table 2. Demographics of the second application sample

Variables				N	(%)
School	HS1	10th grade	59	165	42.53
		11th.grade	59		
		12th grade	47		
	HS2	10th grade	59	77	19.84
		11th grade	18		
		12th grade	0		
	HS3	10th grade	119	146	37.63
		11th.grade	27		
		12th grade	0		
Grade	10th grade			237	61.08
	11th.grade			104	26.81
	12th grade			47	12.11
Gender	Female			209	53.86
	Male			179	46.14
Total				388	100

The difficulty of each item (β) was calculated, and items that did not fit the Rasch model were determined and excluded from the scale by examining the Wald test results, and the analyses were repeated. Nineteen items were excluded from the scale as a result of eliminating the items incompatible with the model. As a result of the second application analysis, 17 items were identified in the final version of the scale three main topics emerged: (1) Laboratory Methods and Techniques (Items 9, 13, 14, 19, 30, 36), (2) Real Life Practices (Items 1, 7, 18, 28, 33), and (3) Effects of Biotechnology (Items 2, 10, 16, 29, 31, 35)

Analysis of the Variance

In order to test the second research question to examine the practicability of BBKS, a three-way ANOVA was performed to compare the differences in biotechnology knowledge using three levels of school, three levels of grade (10, 11 and 12) and two levels of students' gender (boys and girls) to examine school, grade, and gender as between-subject factors. Inspection of the test assumption suggested no major deviations. Analyses were performed using SPSS version 26.

Findings

Psychometric Properties of the Items in BBKS

Here, the difficulty of each item (β) was calculated with Rasch analysis, and by examining Wald test results, items that did not fit the Rasch model were determined and removed from the scale, and the analyzes were repeated. Nineteen items incompatible with the model were excluded from the scale. The K-R20 internal consistency coefficient of the final scale consisting of 17 items was calculated as 0.77. It was observed that item-total correlations varied between 0.25 and 0.48 except for one item (Item 1, 0.13).

Rasch Analysis Findings of the Items in BBKS

Table 3 presents the item difficulty (b), or location, parameters for the 17-item BBKS. Item difficulty (b) shows where the item functions best along the trait scale. When the b value is lower, it means the item is "easier and expected to be endorsed at lower trait levels." (Nguyen, Han, Kim, & Chan, 2014, p.3). The item with a value of zero is of medium difficulty, and the item's difficulty level increases as it moves away from zero in the (+) direction, and its ease level increases as it moves away from zero in the (-) direction. As also shown in Table 4, according to Rasch's analysis, the most difficult item in the scale is "Item 13", and the easiest item is "Item 7". Also, "Item 31" is closest to medium difficulty. When the item map is examined in general, it is seen that the distribution of the number of easy and difficult items in the scale is equal. When it is examined according to Item 31, and it is accepted that the scale is close to medium difficulty, It is seen that eight items are more difficult than medium level and eight items are less difficult than medium level. The fact that each of the items is at different levels indicates that the scale has a homogeneous distribution in terms of item difficulties.

Table 3. Item Difficulty Parameters (b) and Item Statements in BBKS

Item Numbers	Item Statements	Est (b) (Logit)	Std. Error	Lower CI.	Upper CI.	Item- Total Correlation
Item 13	By comparing the genome sequences of cattle and peas, it has been determined that they have common genes.	.919	.129	.665	1.172	.302
Item 19	The DNA obtained as a result of combining DNA fragments from two different living things is called Recombinant DNA.	.762	.131	.504	1.019	.375
Item 1	By gene transfer it is possible for plants to produce animal proteins by gene transfer.	.304	.140	.029	.579	.125
Item 30	Enzymes are responsible for cutting and joining DNA.	.262	.141	-.015	.539	.376
Item 16	The question of knowing the information on the human genome and who has the right to examine it is a matter of biosecurity.	.220	.143	-.060	.499	.377
Item 36	The basic gene cloning workflow consists of determining the gene-isolation of DNA fragments to be cloned- insertion of isolated DNA and multiplication.	.133	.145	-.152	.417	.427
Item 35	Events such as mutation and crossing over are natural events that cause genetic changes without human intervention.	.088	.146	-.199	.374	.247
Item 28	Microorganisms obtained by genetic engineering can be used to clean toxic wastes in the environment.	.019	.148	-.272	.310	.338
Item 31	Foods obtained from genetically modified organisms can cause allergic reactions.	-.004	.149	-.297	.288	.439
Item 9	Stem cells are cells that can transform into many types of cells and have the ability to divide continuously.	-.028	.150	-.322	.266	.370
Item 33	Determination of paternity, determination of genetic diseases and similar processes can be done by DNA analysis.	-.028	.150	-.322	.266	.334
Item 18	One purpose of gene transfer to tomatoes is to extend their shelf life.	-.101	.152	-.400	.198	.456
Item 10	One of the aims of the biosafety law is to prevent the risks that may arise from organisms and their products obtained using modern biotechnology.	-.255	.158	-.565	.055	.410
Item 29	If modern biotechnological methods are not done in the right way, they can threaten the future of the world.	-.255	.158	-.565	.055	.405
Item 14	Organisms that have artificially altered one or more genes are called genetically modified organisms.	-.513	.170	-.845	-.180	.484
Item 2	Developing DNA technology may pose significant ethical problems.	-.544	.171	-.879	-.208	.276
Item 7	DNA technology methods allow us to identify genetic diseases even when the baby is in the womb.	-.977	.196	-1.362	-.592	.367

Table 4 shows the percentages of school-based correct responses for item 13, the most difficult item on the scale. It is seen that more students in HS3 answered Item 13 than in HS1 and HS2, respectively.

Table 4. School-based correct responses for Item 13

		HS1	HS2	HS3	Total	Item 13
Correct Answers to Item 13	N	116	41	124	281	By comparing the genome sequences of cattle and peas, it has been determined that they have common genes.
	%within Item 13	41.3%	14.6%	44.1%	100.0%	
	%within school	70.3%	53.2%	84.9%	72.4%	
	% of total	29.9%	10.6%	32.0%	72.4%	

Table 5 shows the percentages of school-based correct responses for item 7, the easiest item on the scale. It is seen that more students in HS3 answered Item 7 than in HS1 and HS2, respectively. The schools' ranking in terms of the percentage of correct responses to item 7 did not change, but the percentage gap between them decreased. In addition to these findings, the order of the percentage of correct answers in all the other items except for the Items 18, 28 and 29 is HS3 > HS1 > HS2, while the order of the percentage of correct answers for these three items is HS1 > HS3 > HS2.

Table 5. School-based correct responses for Item 7

		HS1	HS2	HS3	Total	Item 7
Correct Answers to Item 7	N	156	63	142	361	DNA technology methods allow us to identify genetic diseases even when the baby is in the womb.
	% within Item 7	43.2%	17.5%	39.3%	100.0%	
	% within school	94.5%	81.8%	97.3%	93.0%	
	% of total	40.2%	16.2%	36.6%	93.0%	

Comparisons of BBKS Scores by School, Grade and Gender

A factorial (three-way) ANOVA test was used to compare students' BBKS scores based on their school (HS1, HS2, HS3), grade (10th grade, 11th grade, 12th grade), and gender (male, female). The descriptive statistics findings indicated that students from HS3 (M= 15.29, SD= 2.37) gained higher scores on average than students from HS1 (M=14.67, SD= 2.65) and HS2

(M=11.68, SD= 2.94). Also, female students (M=14.77, SD=2.45) gained higher scores on average than male students (M=13.77, SD=3.18). Students in 12th grade (M=14.49, SD=2.76) gained higher scores on average than students in 11th grade (M=14.33, SD=2.83) and 10th grade (M=14.27, SD=2.89).

Three-Way ANOVA results indicated a significant main effect for the school effect (F2,380= 50.91, p=.0001, η2=.21). There were no statistically significant differences for grade (F2,380=0.17, p.0.85) and gender (F2,380=1.92, p=0.17) variables in terms of their biotechnology knowledge scores. Table 6 presents the Three-Way ANOVA analysis results for BBKS.

Table 6. Three-Way ANOVA Analysis Results for BBKS

Source	Type III Sum of Squares	Df	Sum of Squares	F	p-value
Corrected Model	801.356a	7	114.479	18.563	.0001
Intercept	36474.078	1	36474.078	5914.218	.0001
School	627.951	2	313.976	50.911	.0001
Grade	2.080	2	1.040	.169	.845
Gender	11.851	1	11.851	1.922	.166
Error	2343.530	380	6.167		
Total	82590.000	388			
Corrected Total	3144.887	387			

LSD post-hoc test results regarding the source of the observed difference in the school variable indicated that students from HS3 had significantly higher scores than students from HS1 (p=0.028) and HS2 (p=0.001). Likewise, students from HS1 had significantly higher scores than students from HS2 (p=0.001). Table 7 and Figure 1 present the LSD post-hoc results.

Table 7. LSD post-hoc test results for school variable

(I) school	(J) school	Mean Difference (I-J)	Std. Error	p-value
HS1	HS2	2.9784*	.34274	.001
	HS3	-.6210*	.28217	.028
HS2	HS1	-2.9784*	.34274	.001
	HS3	-3.5994*	.34976	.001
HS3	HS1	.6210*	.28217	.028
	HS2	3.5994*	.34976	.001

The main effects for the grade ($F_{2,380}$= 0.17, p=.845) and gender ($F_{1,380}$= 1.92, p=.17) were not statistically significant. However, the grade*gender interaction was statistically significant ($F_{2,380}$= 4.09, p=.018, η^2=.02). As can be seen in Figure 1, while females in 10th and 11th grade tend to obtain higher scores than males, males obtained higher scores than females in 12th grade.

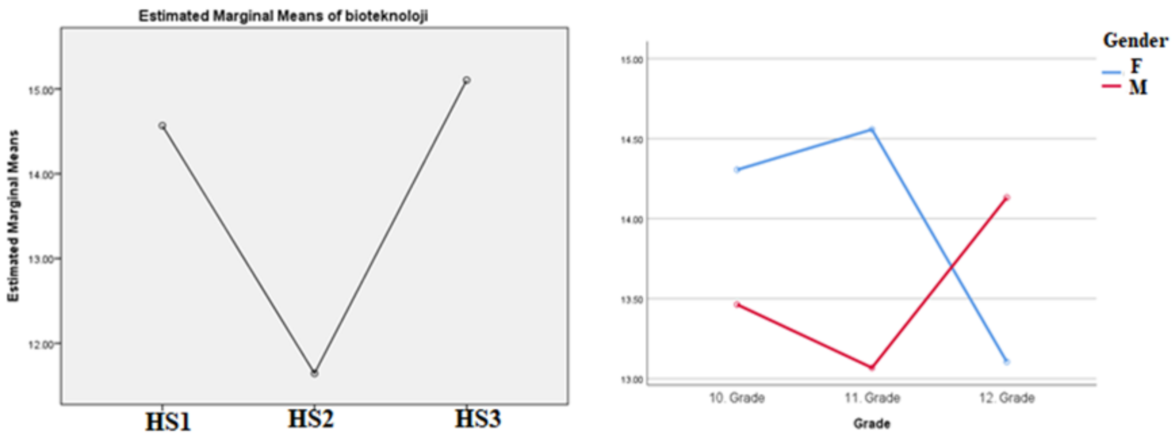

Figure 1. Estimated Marginal Means of BBKS by school and gender

Conclusions and Discussion

Validation of Basic Biotechnology Knowledge Scale (BBKS)

Being able to make use of the opportunities biotechnology offers depends largely on the accuracy and adequacy of the acquired knowledge. Evaluation of the accuracy and adequacy of the information requires the existence of accurate, valid and reliable measurement tools. In this study, a standardized scale in biotechnology and gene engineering (BBKS) was developed for all individuals who have completed secondary education. Rasch Measurement Model was used in the development of the scale and analysis of the data to compare gender, school and grade.

BBKS resulted in a 3-sub-topic, 17-item True-False Type Knowledge scale. According to Rasch analysis results, the most difficult item in the scale is "Item 13", and the easiest item is "Item 7". Also, "Item 31" is found as the closest to medium difficulty. Item 13 was the most difficult item on the scale, as students might not have an evolutionary perspective to understand that the ancestors of animals and plants are commonly based on their low apparent similarities. Item 7, on the other hand, was the easiest, as the information in the item can be frequently encountered in social media and daily life experiences. In some studies, the positive effects of social media on learning are also expressed (Özgen, Güngör, Emiroğlu, & Taş, 2007; Sıcaker, 2013).

When various instruments in many studies (Agaç, 2019; Arvanitayannis & Kystallis, 2005; Bayoğlu & Özgen, 2010; Bilen & Özel, 2012; Demir & Pala, 2007; Ergin, Gürsoy, Öcek & Çiçeklioğlu, 2008; Gürkan & Kahraman, 2018; Gürkan & Kahraman, 2019; Keskin, 2003; Keskin et al., 2010; Koçak, Türker, Kılıç, & Hasde, 2010; Konak & Hasancebi, 2021; Olsher & Dreyfus, 1999; Öcal, 2012; Özdemir, Güneş, & Demir, 2010; Özgen et al., 2007a, b; Priest et al., 2003; Prokop et al., 2007; Sönmez & Pektaş, 2017; Subrahmanyan & Cheng, 2000; Sürmeli & Şahin, 2009; Wie, Strohbehn, & Hsu,1998; Yılmaz & Öğretmen, 2014; Yüce & Yalçın, 2012) in the field of biotechnology education are examined, it is seen that BBKS differs from these studies in terms of the target audience, scope, type of data collection tool, and data analysis methods. For example, the Biotechnology Knowledge Test prepared by Yüce and Yalçın (2012) is different in terms of the target audience since they examined pre-service science teachers' biotechnology knowledge. Sönmez and Pektaş (2019) examined the effect of extracurricular activities on middle school students' views of the nature of science and biotechnology knowledge using Prokop et al.'s (2007) 16 Likert-type questions and also requested to explain their answers. In a different scale developed by Fonseca et al. (2012) to make a multidimensional analysis of secondary school students' perceptions of biotechnology, knowledge questions, mostly true/false questions, were also included. These knowledge questions contained items suitable for the topics of the developed scale, but there are differences in the distribution of items under the topics. This study is similar to our study in terms of the sample, but the scale also includes different dimensions apart from the knowledge test. In another study conducted in Slovenia (Paš, Vogrinc, Raspor, Udovč Kneževič, & Čehovin Zajc, 2019), in the first stage, content analysis was conducted on 15 biotechnology topics selected from the entire high school curriculum, and in the second stage, a measurement tool was designed to determine students' knowledge of traditional and modern biotechnology. The measurement tool applied to high school students in the 17-18 age group was compiled from the questions in previous studies and consists of two parts. In the first part, knowledge of 18 modern biotechnology and seven traditional biotechnology items, and in the second part, attitudes towards modern biotechnology and biotechnology products were tried to be examined.

A scale also developed in Turkey, which is very similar to BBKS, was presented by Sıcaker et al. (2020). This study was prepared according to the secondary school biology curriculum. Curriculums have difficulty keeping up with the pace of development and change in biotechnology and may take some time to update. Some topics that need to be known today may take their place in the curricula over time. In this respect, there is a fundamental difference between BBKS and this scale; when there is a need for a scale to measure biotechnology knowledge at the secondary education level, one of the two scales can be preferred in line with the purposes of the studies to be conducted, and it provides an opportunity for the researchers in this respect. In addition, knowledge measured with a few questions in the previous study can be measured with a single item in the present study. In the present study, the subject has been handled in a more general structure since it was prepared in order to question the biotechnology knowledge of an individual who graduated from different secondary education departments (social field, science field, sports field, fine arts field, etc.). In addition, the fact that it consists of 17 items provides ease of answering. It is hoped that BBKS, which was developed without being completely dependent on the curriculum, will also lead to a development in the direction of making changes in the curriculum by noticing the deficiencies that can be seen with the items.

Comparison of High School Students' Biotechnology Knowledge with BBKS in terms of School, Gender, and Grade

Comparison of school, gender and grade results indicated that students attending the science-intensive high school (HS3) gained higher scores than HS1 and HS2, and the difference between their knowledge of biotechnology was significant. Considering the highest score that can be obtained from the scale is 17, it is obvious that students from HS3 and HS1 gained higher scores from BBKS; however, HS2 was lower than the other two schools. Here, it is possible to say that students' scores are directly proportional to their high school entrance scores since HS3 and HS2 require higher scores to enter. Also, it is possible to say that students' total average score is above average (M=13,88). These results are not consistent with other biotechnology knowledge studies. For example, Chen and Raffan (1999), in their study of 352 post-16 students studying in England and Taiwan, stated that the students had limited biotechnology knowledge in terms of the meaning and examples of genetic engineering. Similarly, Yüce and Yalçın (2012) showed that the biotechnology education pre-service science teachers received at high schools did not provide them with sufficient and permanent knowledge, while university education provided them with a medium level of knowledge. A recent study by de la Hoz et al. (2022) indicated that Swedish and Spanish pre-service primary school teachers showed a lack of knowledge about basic genetics that could negatively influence their ability to address biotechnological applications in their teaching. Since BBKS is aimed at examining students' basic knowledge, the higher scores they gained did not come as surprising and showed that BBKS is an appropriate scale to examine high school graduates' biotechnology knowledge regardless of gender, grade, and school.

In terms of the items in BBKS, for 14 out of 17 items, the answering rate of schools resulted as HS3>HS2 and HS1; however, for items 18, 28 and 29, the answering rate was HS2>HS3> HS1. This result might be the consequence of having 12th-grade students. This might be the result of two situations. Firstly High School Biology curriculum in Turkey adopts a spiral curriculum approach, and students get more detailed knowledge of biotechnology as they pass to 12th grade. Secondly, the students in 12th grade are preparing for university entrance exams, which require them to review their previous lessons. The main effect of gender was not statistically significant. However, the grade*gender interaction was statistically significant, favouring males with a small effect size. This observed effect was possibly due to the uneven sample size of 12th-grade students. More studies with 12th-grade samples are needed to reveal whether the grade*gender interaction observed in the current study exists in the population of 12th-grade Turkish High School students.

With the developed Basic Biotechnology Knowledge Scale (BBKS), it will be possible to determine the knowledge level of individuals and, accordingly, their deficiencies related to the subject. In this way, it is thought that it can be a guide for the improvement of high school programs. This scale will contribute to the achievement of distant goals in biotechnology education.

Limitations of the Study-Future Research

Although there were questions about vaccines and microorganisms in the early stages of scale development, the absence of questions on this subject in the final form of the scale was regarded as a limitation of BBKS. It is important to re-evaluate the questions about vaccines and viruses after the SARS-CoV-2 pandemic to eliminate the limitations of the scale.

Furthermore, this study is limited to the Turkish national setting. As a result, future research should broaden the scope of the study to evaluate the generalizability of the findings in various educational and cultural situations.

Temel Biyoteknoloji Bilgi Ölçeğinin (TBBÖ) Rasch Ölçüm Modeline Göre Geliştirilmesi

Özet:

Bu çalışmanın amacı, temel biyoteknoloji bilgisini ölçmek için bir ölçek geliştirmek, ölçeğin psikometrik özelliklerini incelemek ve öğrencilerin test performanslarında okul, sınıf ve cinsiyete göre farklılık olup olmadığını incelemektir. Bu ölçeğin geliştirme aşaması Türkiye'nin batısındaki bir ilde 388 lise öğrencisi örneklemi ile gerçekleştirilmiştir. Ölçeğin psikometrik özellikleri Rasch modeli kullanılarak incelenmiştir. 17 maddeden oluşan son ölçeğin K-R iç tutarlılık katsayısı 0,77 olarak hesaplanmıştır. Madde-toplam korelasyonlarının bir madde (Madde 1, 0.13) dışında 0.25 ile 0.48 arasında değiştiği görülmüştür. Rasch analizinin sonuçları, ölçeğin Rasch modeline uyduğunu ve düşük ve yüksek performanslı sınava girenleri ayırt edebildiğini göstermiştir. Üç Yönlü ANOVA sonuçları, okul değişkeni için önemli bir ana etki göstermiştir Ayrıca, biyoteknoloji bilgi puanları açısından sınıf ve cinsiyet değişkenleri arasında istatistiksel olarak anlamlı bir fark bulunamamıştır. Bununla birlikte, sınıf*cinsiyet etkileşimi, küçük etki boyutuna sahip erkeklerin lehine istatistiksel olarak anlamlı bulunmuştur. Gözlenen bu etkinin, 12. sınıf öğrencilerinin eşit olmayan örneklem büyüklüğünden kaynaklandığı düşünülmektedir. Bu da Temel Biyoteknoloji Bilgisi Ölçeğinin (TBBÖ) lise öğrencilerinin bilgi düzeylerini değerlendirmek için kullanılabileceğini göstermektedir

Anahtar kelimeler: biyoteknoloji, bilgi ölçeği, Rasch ölçüm modeli, ölçek geliştirme

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