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Development and Validation of an Instrument to Measure University Students' Biotechnology Attitude

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Abstract The impact of biotechnologies on peoples' everyday lives continuously increases. Measuring young peoples' attitudes toward biotechnologies is therefore very important and its results are useful not only for science curriculum developers and policy makers, but also for producers and distributors of genetically modified products. Despite of substantial number of instruments which focused on measuring student attitudes toward biotechnology, a majority of them were not rigorously validated. This study deals with the development and validation of an attitude questionnaire toward biotechnology. Detailed information on development and validation process of the instrument is provided. Data gathered from 326 university students provided evidence for the validity and reliability of the new instrument which consists of 28 attitude items on a five point likert type scale. It is believed that the instrument will serve as a valuable tool for both instructors and researchers in science education to assess students' biotechnology attitudes.

Keywords Biotechnology · Validation · Attitude · Instrument development

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Introduction

One of the essential elements of science education is scientific literacy, as proposed by Goodrum et al. (2001), which is defined as to help students develop a deeper understanding of the world around them, and be able to engage in relevant discourse about science in everyday life (Goodrum et al. 2001, p. 165). Mainly, it concerns one's being "learned" or "knowledgeable" about the science content, and being able to critique scientific debates (Coll et al. 2008). This characteristic of scientific literacy insures one's being made informed on decisions about the scientific debates in the science curriculum. It is generally accepted that there is considerable interest among science educators on the importance of scientific debates in science curriculum. Biotechnology can be viewed as a typical example of one of these scientific debates, and represents a new and rapidly evolving area of scientific and technological innovation (Sturgis et al. 2005). It is global and increase concern worldwide. Hence, the issue of people's attitudes towards biotechnology is arousing a growing interest in many countries and it is the focus of many studies.

Biotechnology and its applications are considerable growing due to its enormous potential to affect many facets of society. A variety of instruments have been developed to measure attitude toward and beliefs on biotechnology and there is much less agreement about how to measure them. Unfortunately, an extensive review of the literature on biotechnology attitude research also indicated that there are very few instruments that can provide valid and reliable data on students' attitudes toward biotechnology.

While an extensive review of literature have been considered people's general attitudes towards biotechnology (Hamstra and Smink 1996; Aerni 2002; Pardo et al. 2002; Moon and Balasubramanian 2004), other studies have focused on specific applications of biotechnology such as perceptions of human genetic information, genetically modified (GM) foods, and agricultural biotechnology (Subrahmanyan and Cheng 2000; Mangusson and Hursti 2002; Saba and Vassalo 2002; Arvanitoyannis and Krystallis 2005; Moerbeek and Casimir 2005; Human Genetics Commission 2001; Shanahan et al. 2002). Also, numerous of research was conducted by science educators to determine students' attitudes toward various applications of biotechnology (Lock and Miles 1993; Chen and Raffan 1999; Dawson and Schibeci 2003a, b; Gunter et al. 1998; Dawson 2007; Klop and Severiens 2007; Prokop et al. 2007; Sáez et al. 2008).

The majority of instruments existing in the literature have been developed by researchers to measure public attitude toward biotechnology. Among these instruments, the Eurobaromater surveys have got considerable attention. These surveys, which are part of an extensive survey on society, science, and technology in European countries conducted several times in the past decade, includes a number of questions on content views among the public regarding different applications of biotechnology (Eurobaromater 2001, 2003). There are six specific applications of biotechnology in the Eurobaromater surveys. These applications are medical, agricultural, food production, genetic modification in plants, genetic modification in animals, and genetic modification in humans. The Eurobaromater surveys have been used in public attitude research (i.e., Massarani and Moreira 2005).

Biotechnology attitude was also measured in a survey of Australian high school students (Dawson 2007). This survey listed 15 biotechnology applications ranked from benign uses such as "using yeast in the production of wine and beer" to more controversial procedures such as "inserting genes from humans into the fertilized egg of mammals". Students gave their responses to each statement as acceptable or unacceptable. The kind of the survey may not be specific enough to mention various facets of attitude that might lead to reveal students' views in biotechnology. She did not mention reliability analysis and factor analysis of the survey in her study. Another survey aimed to investigate Slovakian students' attitudes toward biotechnology in sample of preservice teachers (Prokop et al. 2007). The survey includes only three applications of biotechnology with 17 Likert-type items. These are public awareness of GM products, control of genetically modification and shopping of GM products. These dimensions in this survey were a priory divided by authors without providing any factor analysis of student score.

Lock and Miles (1993) investigated the views of 188 students aged 14–16 year old in order to determine their attitude toward biotechnology and genetic engineering. They used a Likert-type scale including 27 statements which indicate the extent of their agreement or disagreement with each statement. Their survey was measured one dimension and measured students' attitudes as general. Another study by Chen and Raffan (1999) compared UK and Taiwan high school students' attitudes toward biotechnology and genetic engineering. They used, as data collection tool, a Likert type scale with 27 items. They did not present any information about their scale and, however, mention the factor structures and reliability of the instrument.

A recent study by Klop and Severiens (2007) aimed to determine Dutch secondary school students' attitudes toward biotechnology by using a questionnaire comprised of three dimensions, namely, cognitive and affective evaluation, and behavioral intention. The attitude survey contained 48 items that dealt with cognitive, affective and behavioral attitudes. They did not mention the factor analysis and reliability of the instrument as previous researchers and include full version of the questionnaire in their paper. The use of attitude items used by Klop and Severiens (2007) is hardly possible. Another study by Sáez et al. (2008) aimed at exploring secondary school students' views of biotechnology. The researcher developed a questionnaire including nine questions, five of which were formulated in a multiple choice format and four in open-ended questions format. The open-ended questions were covered social implications and values associated with biotechnology.

Massarani and Moreira (2005) carried out a research study with Brazilian high school students in order to investigate students' attitudes toward genetics through the use of a questionnaire containing nine items which dealt with genetic modification, genetic manipulation and genetic testing about genetics. They used the survey based on the Eurobarometer 1996 survey (Durant et al. 1998). However, they investigated only three applications of the Eurobarometer 1996 survey, including modern genetics. The students were asked to indicate to what extend they agreed or disagreed with each of the applications with respect to (1) their actual use, (2) their benefits to society, (3) the risks involved in their application, (4) their moral acceptability and (5) whether they should be encouraged.

Gunter et al. (1998) examined understanding and opinions of teenagers aged 16–19 years in the United Kingdom using the survey based on interviews. They focused on teenagers' general opinions about biotechnology and used only 15 likert-type items to determine teenagers' attitudes toward GM foods. However, their research does not provide enough information about how many items contain their questionnaire and factors regarding biotechnology.

Student attitudes affect individual's behavior, particularly their choice of action, and persistence to give a decision. For example, in schools, students who have high scientific literacy tend to choose more appropriate decisions and seem more knowledgeable (Goodrum et al. 2001). Researches have also confirmed the relationship between socio-scientific issues and scientific literacy (Goodrum et al. 2001; Coll et al. 2008). From this view, it is important to examine student attitudes in the evaluation of science curriculum (Bennett et al. 2007; Fraser 1979). Fraser (1977) emphasized three importance criteria in selecting of attitude instruments for curriculum evaluation. These are educational importance, multidimensionality, and economy of time for administration. However, the multidimensionality of many attitude instruments developed or used in the literature has been not provided by empirical research. In addition, no researcher used the factor analysis in their instrument development process.

Tapia and Marsh (2004) emphasized that 'Attitude scales must withstand factor analysis, tap important dimensions of attitudes, and require a minimum amount of time for administration' (p. 17). Also, Munby (1997) have emphasized the importance of a factor analysis to test the construct validity of attitudinal data. Hence, it is most critical the systematic examination of the construct validity of attitudinal data. Unfortunately, most science educators have used a descriptive approach than a factor analysis to validation in their attitude studies (Lock and Miles 1993; Chen and Raffan 1999; Dawson and Schibeci 2003a, b; Gunter et al. 1998; Dawson 2007; Klop and Severiens 2007; Prokop et al. 2007; Sáez et al. 2008). The validity of many attitude instruments is so notorious.

The review of the literature reveals that the research studies conducted in the context of biotechnology applications and genetic engineering have measured general attitudes of students regarding genetic, genetic engineering and biotechnology. However, there is a lack of instrument on biotechnology that deals with various applications of biotechnology which basically has lead to the emergence of the present study. Special emphasis should be given to the enhancement of science literacy toward socio-cultural issues such as biotechnology regarding learner's own community in university years. Besides, previous instruments that focused on measuring public attitude of biotechnology are not specific enough to measure various dimension of biotechnology. In addition, surveys which have been developed so far seem to be inappropriate for undergraduate students. The surveys have measured biotechnology attitude in a very general sense. The attitude that an undergraduate students might gain through a biotechnology education is more specific including terminology associated with biotechnology and applications of biotechnology. Additionally, previous surveys did not make a strong distinction among the dimensions of biotechnology. Each sub-dimension can provide information us with students' views about different applications of biotechnology. The present study reports on the development and refinement of an instrument to measure various constructs that were explored on important dimensions of people's biotechnology attitudes. The survey was conducted on a sample of pre-service students who will become a teacher of the near future.

The Purpose of the Study

The purpose of the present study was to develop a valid and reliable instrument to be used for measuring university students' attitudes toward biotechnology and its applications. With this instrument, it is believed that the gap in the professional literature indicated above will be partially met.

Method

This instrument development study was realized in the spring semester of 2007–2008 academic years with the participation of 326 students selected from three universities at varied grades and departments in Turkey.

Participants

326 male and female students participated in this study from three different universities in Turkey in 2007. The numbers of male and female university students were 156 and 170, respectively. The age of students ranged from 18 to 26 years ($M = 20.4$ years, $SD = 1.59$). The students were from various grades in faculty of education of the selected universities. The students were studying to become a teacher in the area of elementary and secondary education. They study various disciplines, while a half of them (163 of 326) were enrolled in biology courses at various levels. First-year students had just started to study university biology, so they were experienced mostly in the general biology course, which include DNA replication, mutation, protein synthesis, but no topics directly related to biotechnology. In contrast, secondary pre-service teachers

were experienced with genetics, which includes genetic engineering in general. Although they did not study biotechnology explicitly, they can be expected to be better informed about biotechnology compared with students who do not study any biology. The remaining students were enrolled mostly in humanities disciplines. Because the sample contained the students who are more aware of biotechnology and the students who are less aware of biotechnology, it allows comparing more (enrolling biology classes) and less (enrolling humanities) educated students in terms of their attitudes toward biotechnology.

Development Process of Biotechnology Attitude Questionnaire (BAQ)

Eight-step model was used in order to develop Biotechnology Attitude Questionnaire (BAQ). These steps were illustrated in Fig. 1.

Step 1. Review of Literature

In the first step of the instrument development, a comprehensive review of literature was conducted in an attempt to identify the existing instruments available in the literature (Arvanitoyannis and Krystallis 2005; Lock and Miles 1993; Olsher and Dreyful 1999; Priest et al. 2003; Subrahmanyan and Cheng 2000; Wie et al. 1998). A pool of possible assessment items were needed for development of an instrument which addressed both biotechnology attitude and the level of university students. Also, as directed by framework, items were needed to address for affectiveness of biotechnology.

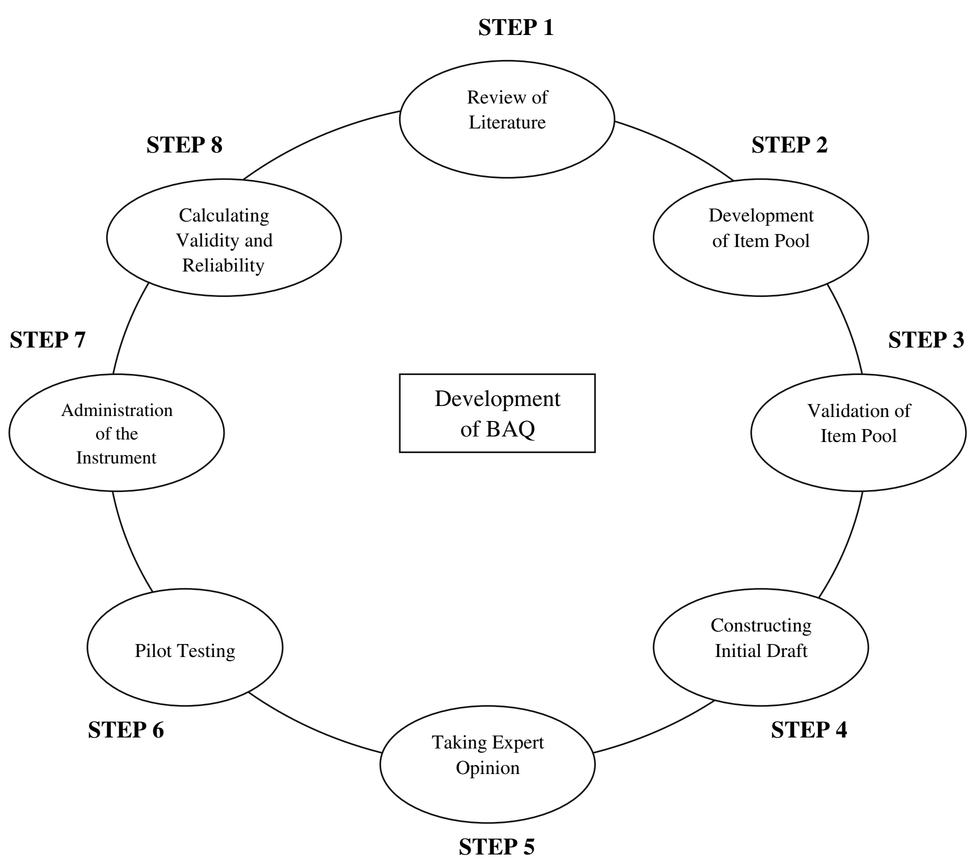
Step 2. Development of Item Pool

An item pool was constructed by selecting the appropriate items from the reviewed instruments according to the relevance to the purpose. Only a few items were revised from biotechnology instruments already developed and used in other studies. Ultimately, the item pool was drafted by the authors. The pool consists of several items which measured outcomes of biotechnology awareness such as control of genetic modification, consumptions of GM food, using GMO product in medicine and agriculture, and ethics of GM. These various areas were then treated as potential subscales.

Step 3. Validation of Item Pool

Draft items were sent to relevant three specialists for formal review. Each item was placed into matrix and then asked for a response to evaluate for four areas: *content*

Fig. 1 Eight step model for developing BAQ



validity, clearness and understandability, accuracy and *distracters*. As a result of this external review, numerous items were rewritten or eliminated.

Step 4. Constructing Initial Draft

A total number of 53 items were selected from the item pool according to their relevance of the content of the instrument to be developed. All of the items were designed as Likert-type ranging from strongly agree to strongly disagree. Thus, an initial draft of the instrument was ready for the pilot testing.

Step 5. Taking Expert Opinion

Initial draft of the instrument with 53 items on a five point Likert type scale was given to a group of seven experts in biology, biology education, educational psychology, and educational measurement for taking their opinions about whether the selected items were valid items for assessing students' attitudes toward biotechnology. The experts were asked to examine items with regard to their relevance to purpose of the instrument, content coverage, understandability and consistency among one another.

Step 6. Pilot Testing

An initial form of the instrument revised by the experts was administrated to a total of 192 students for pilot testing. For the sake of diversity, the students were selected not only among the ones who took biology and biotechnology classes but also among the ones who did not take any biology-related classes. An answer sheet accompanied with the instrument was given to each student and then the students were asked to show their responses in this sheet. Student answer sheets were received from all departments and entered into excel document for scoring. The data was analyzed by researchers by making use of the STATISTICA (StatSoft Inc. 2001), one of the statistical software programs. The results of pilot testing showed that 16 of the 53 items were not clearly understood by most of 192 students. Based upon students' opinions and expert suggestions, these 16 items were excluded and the instrument was re-designed for real administration.

Step 7. Administration of the Instrument

Final draft of the instrument with 37 items was administered to 326 university students for calculating validity (particularly construct validity) and reliability of the instrument. Students' responses were entered an Excel file created for further analyses.

Step 8. Calculating Validity and Reliability

The data collected from 326 university students were analyzed by means of factor analysis and reliability analysis through the use of STATISTICA. Firstly, In order to examine the factor structure behind the instrument, the data were subjected to factor analysis with principle component method. The factor analysis was carried out using the procedure FACTOR in STATISTICA. Secondly, reliability analysis was performed for each of the emerged sub-scales.

Results

Factor Structures

The correlation matrix for the item 1 to 37 was computed. The Bartlett's test of sphericity produced a value of 2,512.702 with a significance level <0.001, indicating the suitability of the factor model for the data. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is an index for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. Large values for the KMO measure indicate that a factor analysis was appropriate. In our research, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.86. Another indicator of the strength of the relationship among variables is Bartlett's test of sphericity. Bartlett's test of sphericity is used to test the null hypothesis that the variables in the population correlation matrix are uncorrelated. The observed significance level was $p < 0.001$. It is concluded that the strength of the relationship among variables was strong (George and Mallery 2001). These indicators thus allowed us to use factor analysis for the data.

Factor analysis on BAQ derived 10 factors with eigenvalues exceeding 1.0. These factors altogether explained 57.6% of variance of results. Scree plot shows that seven factors were in sharp descent and then started to be level off. This was evidence that rotation was necessary for seven factors. Overall, seven of ten factors were represented just by one item per each factor with loading higher than 0.3. Thus remaining three factors were considered not interpretable. Nine items were deleted because their factor loadings were lower than 0.3 (Anastasi 1996).

In summary, nine out of 37 attitude items were deleted and the factor analysis for rotation was run again over the data set with 28 items. Varimax rotation was used. Thus, the factor analysis resulted in seven independent factors with factor loadings greater than 0.3. Table 1 presents factor loadings and factor structures of the items.

These seven factors explained 55.68% of total variance and were named according to the common characteristics

Table 1 Factor structures and loadings of the 28 items in BAQ

Items	F 1	F 2	F 3	F 4	F 5	F 6	F 7
Altering the genes in fruit to improve their taste is not acceptable to me	0.73						
I am against altering the genes of fruits and vegetables to make them stay fresh longer	0.74						
Consumption of genetically modified food is risky	0.71						
I would not give GM food to children	0.65						
I agree with the use of genetic engineering if it helps with therapy of genetically determined diseases		0.63					
I support the use of food biotechnology to modify plant's genetic structure to be more resistant to damage by insects, thereby reducing pesticide applications		0.64					
Altering the genes of plants so that they will grow better in salty soils is acceptable to me		0.61					
I agree with the use of plants in which genes increasing quality and productivity were inserted		0.67					
I want to know more about genetically engineered foods		0.32					
I trust the food industry to take necessary actions to provide safe genetically engineered foods			0.68				
I think current governmental regulations are sufficient to protect the public from risks associated with genetically engineered foods			0.77				
Public is sufficiently informed about risks associated with genetically engineered foods			0.67				
Genetically modified food does not influence human health				0.68			
I would eat genetically modified tomatoes				0.62			
I think that genetically modified products taste better				0.72			
If I find that the product is made from genetically modified stuff, I will buy it				0.73			
Inserting genes from human cells into the fertilized eggs of sheep is acceptable to me				0.48			
I support changing the genes in cattle to make their meat more nutritious to eat				0.51			
I am opposed to transfer of genetic material between plants and animals					0.54		
Manipulations with DNA are unethical					0.73		
Men do not have rights to intervene to DNA, it is against nature					0.69		
We should not alter the genes in plants to get them to make more oils useful in manufacturing						0.44	
Genetic manipulations disturb ecological relationships						0.63	
There is a threat of hybridization between genetically modified and normal plants which would endanger original genetic resources of wild plants						0.73	
I would support a ban on the production and purchase of genetically engineered products						0.59	
Use of GM microbes to decomposing human sewage is acceptable to me							0.67
I support the use of genetic engineering for non food purposes such as production of human medicines							0.69
I agree with production of insulin with using genetically modified microbes							0.74

of the items loaded on the same factor. This value is appropriate considering that other works focused on attitudes showed lower explained variance (e.g., Salta and Tzougraki 2004: 47%, Spinner and Fraser 2005: 42%). Eigenvalues of the factors are 5.927, 3.258, 1.559, 1.404, 1.228, 1.184 and 1.029, respectively. Table 2 gives the factors, eigenvalues and total variance explained. The proportion of explained variance by the prime factor in valid scales should be at least 20% (Reckase 1979). Because our Factor 1 explained 21.167% of total variance (Table 2), these results are considered satisfactory. This suggests the presence of one major factor and thus reinforce the prior evidence concerning the internal consistency of the BAQ.

Table 2 Factor names, eigenvalues and variance of factors

Factor names		Eigenvalues	% of Variance
Consumption of GM products	Factor 1 (CGMP)	5.927	21.167
GM in agro industry	Factor 2 (GMAI)	3.258	11.637
Public awareness of GMO	Factor 3 (PAGMO)	1.559	5.570
Shopping of GM products	Factor 4 (SGMP)	1.404	5.015
Ethics of genetic modifications	Factor 5 (EGM)	1.228	4.387
Ecological impact of genetic engineering	Factor 6 (EIGE)	1.184	4.229
Use of genetic engineering in human medicine	Factor 7 (UGEHM)	1.029	3.677

Description of BAQ Dimensions

Factor 1 included four items. These items explicitly measures people's attitudes toward consumption of GM products (2 items) and genetic modification of vegetables intended for consumption (2 items). This factor was therefore named as "Consumption of Genetically Modified Products (CGMP)." The mean score of CGMP dimension was 2.37 (SE = 0.05) which means that students showed negative attitudes toward consumption of genetically engineered products.

Factor 2 included five items. Four of these items measure people's attitudes toward application of genetic engineering in agro industry, especially in the elimination of plant diseases or on fitness of plants planted on salty soils. Remaining one item focuses on additional information about GM foods. Thus, this factor was named as "Genetic Modification in Agro Industry (GMAI)." The mean score of the GMAI was 3.74 (SE = 0.04) which suggest that students were supportive for the use of genetic engineering in agro industry.

Factor 3 included three items which focus on people's beliefs about the regulations associated with risks from genetic modification. This dimension was named as "Public Awareness of GMO (PAGMO)." The mean score of the PAGMO was 2.66 (SE = 0.04) which suggests that students were not satisfied with public awareness of GMO.

Factor 4 consisted of six items, one of which explicitly focuses on purchasing GM products and other five items more or less focus on people's willingness to eat GM products. Because direction of these items is more likely behavioral rather than affective or cognitive, we named this dimension as "Shopping of GM Products (SGMP)." The mean score of the SGMP was the lowest comparing with mean scores of other dimensions ($M = 2.32$, SE = 0.04) which means that students are most probably very conservative and unwilling to purchase GM products.

Factor 5 consisted of three items focus on the nature of genetic modification and human rights to perform them. This dimension was named as "Ethics of Genetic Modifications (EGM)." The mean score of the EGM dimension was 2.69 (SE = 0.05) which means that students were not convinced with human rights to perform genetic modifications.

Factor 6 consisted of four items, two of which are related to people's concerns from the disturbance of natural environment after applications of genetic engineering. The remaining two items focus on disagreement with genetic engineering in terms of application and purchasing GM products. This dimension was named as "Ecological Impact of Genetic Engineering (EIGE)." The mean score of the EIGE dimension was 2.54 (SE = 0.04) which suggests that students are concerned with the negative impact of genetically engineered plants on human environment.

Factor 7 consisted of three items, two of which focus on the use of genetic engineering in human medicine. The remaining item focuses on improving the human–environment relationships by the use of GM microorganisms. We named this dimension as "Use of Genetic Engineering in Human Medicine (UGEHM)." The mean score of the EIGE dimension was 3.56 (SE = 0.04) which means that students were relatively supportive with the use of genetic engineering in human medicine.

Reliability and Discriminant Validity of Emerged Factors

Series of reliability analyses were performed for each factor. Table 3 summarizes factor names, number of the items and reliability of each factor. The values of discriminant validity, or scale independence, the mean of correlation values of a sub-scale with other scales, ranged from 0.06 to 0.29. Fraser (1989) reported that alpha coefficients in the range 0.58–0.81 indicate that the instrument had satisfactory reliability for scales containing five items each. Francis and Greer (1999) reported alpha values for three science attitude dimensions from 0.64 to 0.72. Dhindsa and Chung (2003) reported alpha values for six science attitude dimensions from 0.59 to 0.75 and discriminant validity in their research ranged from 0.12 to 0.22. Jegede and Fraser (1989) reported sub-scale alpha reliability for Test of Science-Related Attitudes (TOSRA)

Table 3 Reliability of each factor in the BAQ

Factor names	Number of the items	Reliability (α)
Factor 1. Consumption of GM products	4	0.80
Factor 2. GM in agro industry	5	0.66
Factor 3. Public awareness of GMO	3	0.56
Factor 4. Shopping of GM products	6	0.79
Factor 5. Ethics of genetic modifications	3	0.61
Factor 6. Ecological impact of genetic engineering	4	0.61
Factor 7. Use of genetic engineering in human medicine	3	0.62
Whole instrument	28	0.82

ranged from 0.61 to 0.91 and discriminant validity coefficient ranged from 0.13 to 0.40. Spinner and Fraser (2005) reported alpha values for sub-scales of the Test of Mathematics Related Attitudes (TOMRA) ranged from 0.46 to 0.90 and mean correlations between scales between 0.34 and 0.40. The high values of the alpha coefficients suggest that the instrument displayed adequate internal consistency and low mean values of correlation coefficients between each scale provided the discriminant validity of the scales. These results support that the instrument is internally consistent and reliable for interpreting biotechnology attitudes among university students. Only Factor 3 (Public Awareness of GMO) showed relatively lower reliability, but this is most probably because low number of items were loaded in this dimension (DeVellis 1991).

Discussion

In this study, the BAQ was developed through the use of eight-step model proposed by the authors. Subsequent to an extensive review of literature, the authors validated the item pool across the experts and then constructed initial draft of the instrument. Later, this initial draft was reviewed by the experts (on biotechnology and science education). Upon which the pilot test conducted with 192 students, the revision was done over the test items and BAQ was administered to 326 university students in three different universities to provide validity and further reliability evidences. The 28 itemed BAQ was finalized to measure seven dimensions of biotechnology. The BAQ were also subjected to: (1) factor analysis for exploring factor structures and (2) series of reliability analyses for investigating reliability of each factors emerged.

The results of the factor analyses show that there are seven key factors for the attitudes toward biotechnology and its applications. With these aspects, this study differs from previous studies in terms of the development of the BAQ with seven clearly defined dimensions. It must be emphasized that a reliable and valid research instrument, which allows researchers to study the biotechnology attitudes of university students, was developed. Many of the researches conducted in the literature are limited with participants just from a single university, but this study was carefully designed with respect to diversity of participants from three different universities, of their subject area (biology majors and non-majors) and of gender (the number of males and females was balanced).

Factor analysis with principle component methods revealed seven dimensions behind BAQ which explain 55.68% of the variance together. The factors were named according the characteristics of the items loaded on that factor. Cronbach's alpha reliability of the factors ranged from 0.56 to 0.80 indicating acceptable reliability range (Fraser 1989), despite low level of reliability of Factor 3 (0.56). Simple analysis of means of seven attitude dimension suggests that Turkish university students have not favorable attitudes toward genetically engineered products. Greatest conservatism and concerns from genetic modification was found in potential consumption and purchasing genetically engineered products. In contrast, mean scores from two dimensions suggest that there are supportive attitudes in terms of the use of GM products in human medicine (factor 7, UGEHM) and agro industry (factor 2, GMAI). We hope that the data will be useful both for implementing biotechnologies into Turkish science curriculum and for Turkish policy which seems to be favorable toward legalization of GM products in the near future. Interventions and public presentation of biotechnologies should be utilized peoples' supportive attitudes toward GMO in agro industry and human medicine for building new views of humans on modern technologies.

Researchers now have an instrument of biotechnology attitude for university students in seven dimensions, containing all aspects of biotechnology for a better understanding. However, of course, we believe that it is necessary to apply this scale in different countries to see whether it works similarly like in our research. Moreover, further evaluation of the scale should be validated with different school students. It is believed that further validations would provide very fruitful information whether the scale can be used also for younger students. We suggest that usefulness of this scale is not restricted only to university students, but also responses of younger students can result in meaningful factor dimensions. In addition, some dimensions that loaded with low number of items (three or four) should be further evaluated and also related items can be added to the questionnaire.

Implications for Science Education

It is seen that the BAQ is promising tool for both instruction and research in science education to explore students' attitudes toward biotechnology. Instructors can use the instrument to measure attitudes of their students and more specific views of students' attitudes in seven dimensions. One practical implication of this instrument would allow instructors to modify their current instructions in scientific debates in science curriculum. For instance, instructions can provide classroom environment which students' engagements in socio-scientific issues are enhanced through student-centered instruction. If students have low scientific literacy, instructions may spend more time in students understanding applications of biotechnology. In this way, students will have more evidence about biotechnology and their ability of scientific literacy will be enhanced.

Despite the increasing importance of biotechnology, the findings of recent study by Steele and Aubusson (2004) indicated that most biology teachers perceived that parts of the biotechnology topic were too difficult for their students and had insufficient practical work compared to other biology topics. The results of similar study also indicated similar findings (Macer et al. 1996). We suggest that more biotechnology information sources, such as instructional materials, web sites like in Australia (www.biotechnology.gov.au), may help teaching about biotechnology and genetic engineering more effectively. Instructional materials that offer a wide range of resources including informational text, case studies, experiments, interactive activities, practical work, student worksheets and teacher notes should be provided for instructors and educators. Considering increasing necessity to teach (more) about biotechnology, because teaching just classic genetic is not enough for preparing scientifically literate citizens for the future, it would be very interesting to compare data obtained with this questionnaire with students from other countries. We do not claim that this scale is better than other biotechnology attitude scales, but we objectively evaluated its validity and reliability. We suggest that the use of a single scale among different countries would result in objective comparison of student attitudes toward biotechnologies.

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