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High School and University Students' Knowledge and Attitudes Regarding Biotechnology

A TURKISH EXPERIENCE

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Biotechnology has a considerable importance in Turkish biology curriculum. This study was designed to explore or indicate Turkish high school and university students' knowledge and attitudes toward biotechnology. A total number of 352 high school and 276 university students were invited to the study. The Biotechnology Knowledge Questionnaire (BKQ) with 16 items and Biotechnology Attitude Questionnaire (BAQ) with 37 items were used as data collection instruments. The statistically significant correlation was observed between the level of biotechnology knowledge and the subdimensions of attitudes toward biotechnology. We found no statistically significant difference between high school and university students' knowledge of biotechnology. In contrast, university students showed more positive attitudes toward biotechnology than did high school students. However, the effect of gender was equivocal; therefore, it did not support a "gender paradox" hypothesis. Our results suggest that although students' appreciation of (agricultural) biotechnology is relatively positive, the understanding of biotechnology processes is superficial and attitudes toward shopping genetically modified products are therefore negative. The possible impact of current science and biology curriculum, and also biotechnology news given in media on Turkish students' views of biotechnology is discussed.

Keywords: biotechnology, knowledge, attitudes, students' knowledge and attitudes toward biotechnology.

The field of science education started to change after biotechnology studies appeared in the scientific area. One of the most important scientific and technological developments of the 21st century is, without doubt, biotechnology [1]. As known, biotechnology involves biochemistry, immunology, genetics, chemical engineering, and molecular biology, including the economic, legal, and social aspects related to biotechnology. Over the last decade, the rapid developments in biotechnology have stood out with medical innovations and other successive breakthroughs such as genetically engineered products in food industry. Biotechnology raises various issues with regard to ethics, the level of acceptable risk, and usefulness of the new products [2, 3]. Therefore, to make better personal and social choices as members of the society, people would like to be informed about science and technology. In such an environment, the perceptions or opinions of students on the development of biotechnology are significant, because genetic engineering will have a profound impact on their future lives as adults in a number of areas [4]. Parallel to the recent developments in biotechnology, our students need to become more knowledgeable about the social, ethical, and economic implications that surround areas such as genetic engineering, cloning, genetically modified foods, and other aspects of biotechnology. One of the necessary components of science education is by all means the promotion of scientific literacy of young people. Dawson and Soame [5] emphasize scientific literacy as follows: "A high level of scientific literacy can help young people to question the claims of the scientific community, weigh up evidence about scientific issues, use critical thinking skills, and enable them to use their understanding of science to make well-informed and balanced decisions." However, Miller's findings show that, in 1992, 73% of Europeans and 63% of American respondents could not be classified as civic scientifically literate [6].

Current science and science education literature involves several studies to determine high school and university students' attitudes and/or knowledge toward biotechnology. Lock and Miles [7] investigated the views of 188 14- to 16-year-old students to determine their

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knowledge and attitude regarding biotechnology. They reported that one third of the sample claimed that they did not know what genetic engineering and biotechnology meant. About 47% of the students could not exemplify biotechnology, nor could 52% of them exemplify genetic engineering. When their attitudes were analyzed, it was found that there was a broad approval of biotechnology and genetic engineering applied to plants and microbes but not to animals. In another study, Chen and Raffan [4] surveyed 183 Taiwanese students and 153 16–18 year-old British students (56% of the students were studying A level biology) about their understanding of biotechnology. They found that 31% could not define genetic engineering and 33% were unable to give an example of genetic engineering. Gunter and Kinderlerer [8] examined the understanding and opinions of 48 teenagers toward biotechnology, with special reference to food production. The results showed that despite these young peoples' poor understanding of biological sciences, they seemed less reluctant toward GM-foods than did adult respondents. Overall, teenagers considered genetic engineering of plants to be more acceptable than genetic engineering of food crops and animals. Their reasons for opposing genetic engineering of animals was that it was "unnatural," "dangerous," "should not be done," and "unethical." Similar reasons were reported by Hill *et al*. [9], who examined the attitudes of 778 students aged between 11 and 18 about using genetically engineered animals in medical research. In their study, 42% of the sample felt it should not be allowed, because it was cruel (47%) or unnatural (53%). Dawson and Schibeci [10] have conducted a study among 1,116 secondary school students from Western Australian schools on the understanding of recent advances in modern biotechnology. Students' responses indicated that different procedures were acceptable. Approximately one-third of the students turned out to have little or no understanding of biotechnology, and one-third was unable to give a single example of biotechnology. In another study Dawson and Schibeci [11] reported 905 15- to 16-year-old high school students' attitudes toward biotechnology processes. Their results showed that the students hold a wide range of beliefs about what an acceptable use of biotechnology was. Students' attitudes ranged from those of the 55 (6.0%) students who did not agree with the use of any living organisms in biotechnology to the 125 (14%) students who approved of all the stated uses of biotechnology, with a wide spread in between. Acceptance of the use of organisms in biotechnology decreases up from micro-organisms ($>$90% approval), plants (71–82%), humans (42–45%), to animals (34–40%). Clarification of their statements for acceptance or rejection was rather negative. Arguments such as "the procedure is wrong," "unnatural," or "unethical" were given. Reasons for acceptance were that procedures will be beneficial for humanity or "if it can be done then it should be done." Dawson [12] carried out a study with 465 western Australian high school students whose ages ranged from 12 to 17 on the understanding and attitudes toward biotechnology processes. She reported that students' ability to provide a generally accepted definition and examples of biotechnology, cloning, and genetically modified foods was relatively poor amongst 12- to 13-year-old students but improved in students who were older. Most students approved of the use of biotechnology processes involving microorganisms, plants, and humans and disapproved of the use of animals. Overall, 12- to 13-year-old students' attitudes were less favorable than older students regardless of the context. Similarly, Cavanagh *et al*. [13] reported that at least two-thirds of students (from Riverina high school in the rural Australia) had a good knowledge of medical biotechnology issues; however, a significant proportion of the students did have concerns about the use and/or safety of biotechnology.

Prokop *et al*. [14] have conducted a study among 378 university students from three universities in Slovakia on students' knowledge and attitudes toward modern biotechnology. They stated that the Slovakian students had numerous misconceptions and poor knowledge about what genetic engineering meant in that there was a positive correlation between the knowledge-level and attitudes of the students toward biotechnology; and generally the most negative attitudes were found in items related to control of genetic engineering, which probably resulted in reluctance against shopping of genetic modification (GM) products. On the other hand, Eurobarometer polls conducted in the 25 Member States of the European Union by way of face to face interviews in peoples' homes in their national language between September 2 and October 6, 2005, indicated that more than 40% of people believed that their health could be damaged by the food they eat or by other consumer goods. However, the spontaneous association of food with health is only made by one person in five. There are as many Europeans who spontaneously cite GMOs and food additives as possible sources of risk since there are people who consider food to be safe [15].

As mentioned earlier, although a number of recent studies have examined the development of school students' understandings of knowledge and attitudes toward biotechnology, none of them investigated university and high school students simultaneously, and just few of them examined relationship between attitudes and knowledge explicitly. In addition, a majority of these research works were conducted in countries in which distribution of genetically engineered products is legalized. In contrast, Turkey still has not yet legalized the use of transgenic and GM products [16], but, on the other hand, Turkey will benefit from the advantages and forthcoming use of modern biotechnology and biotechnology will be a prioritized area in the near future in Turkey [16, 17]. This means that Turkish inhabitants do not have personal experiences with buying genetically engineered products, but they are partly influenced by science curriculum that contains basic biotechnology topics although teaching Mendelian genetics and other parts of classic genetics greatly exceeds modern trends in genetic engineering. Turkish citizens are in conflict between impact by media that introduce biotechnology research and discoveries to general public [17], and by unfamiliarity with genetically engineered products that greatly influences perception of them [18]. An intriguing

question, whether Turkish citizens are ready for the introduction of genetically engineered products to their country and what their perception of genetically engineered products is; therefore, arises.

Purpose of the Study

This article investigated Turkish high school and university students' knowledge and attitudes toward biotechnology. The following questions guided the overall aim of the study. 1) What is Turkish high school and university students' knowledge and attitude toward biotechnology? 2) Is there any significant relationship between students' knowledge and their attitudes toward biotechnology? 3) Is there any significant difference in knowledge and attitudes toward biotechnology in terms of gender and school level (*e.g*. high school and university)?

RESEARCH METHODOLOGY

This survey study was carried out with Turkish high school and university students in spring semester of 2007.

Sample

The study population constituted the students selected from two high schools and three universities in Turkey. A total number of 352 high school students (228 boys, 124 girls) between the ages of 14 and 18 (Mean = 16.17, SD = 0.85), and of 276 university students (161 boys, 115 girls) between the ages of 18 and 27 (Mean = 20.78, SD = 1.46) were invited to this study. Selected universities have accepted students from various parts of Turkey based upon their university entrance exam results. These universities are not nationally representative, but the students are coming from various social and cultural background. They are typical public universities in Turkey. Similarly, the high schools selected conveniently from the urban district of one of the largest cities in Turkey were typical public schools. This study does not aim to make any generalization from the selected students to all other students in Turkey, but establishes a base for further nation-wide and more representative research studies. The high school students were from all grades of high school. They at least took a course related to biology at various levels. The university students were studying in order to become a teacher in the area of elementary education. Similar to high school students, they took at least one course related to either biology or environmental sciences.

Data Collection Instrument

In this study, a five-point (1—strongly disagree and 5—strongly agree) Likert-type Biotechnology Attitude Questionnaire (BAQ) with 37 items and a five-point Likert-type Biotechnology Knowledge Questionnaire (BKQ) with 16 items both developed by Prokop *et al*. [14] were used to examine students' knowledge on and attitudes toward biotechnologies. Initial form of BAQ included 38 items. In the adaptation process of the instrument into Turkish, one of the items was excluded based upon experts' opinions. The Turkish form of this instrument consists of 37 items. The BAQ includes both positive and negative items. These negative items were reversed for calculating overall score. As indicated in original development process, BAQ includes eight subdimensions whereas BKQ does not include any subdimension.

The original form of the instruments were developed in English and later adapted to Slovakian by Prokop *et al*. [14] with the comprehensive literature review, and validated with Slovakian students. For the present study, these instruments were adapted into Turkish. First of all, BAQ and BKQ were independently translated by two researchers who were bilingual and knowledgeable on biotechnology. These translated instruments were reviewed by another researcher to investigate the gaps between the translations. Furthermore, the Turkish items were back translated and then mostly fit items were considered for the last version of the instrument given to the students.

Reliability of the Questionnaire

The initial internal consistency of BKQ and BAQ based on Slovakian students' scores demonstrated satisfactory results, Cronbach's $\alpha = 0.69$ and $\alpha = 0.75$, respectively [14]. The reliability analyses of these instruments were performed again with the data gathered from Turkish sample. Cronbach's α of BKQ was found 0.50 and of BAQ 0.75. Separate reliability analysis was run for eight subdimensions emerged from initial analysis done by Prokop *et al*. [14]. The following table (Table I) presents the reliability scores of the subdimensions, their abbreviations and number of items per each subscale. Abbreviation titles of each subscale are used further in the text.

Data Collection and Analysis

Two data collection instruments were together administered in classroom environment to both high school

TABLE I
Mean, standard deviation, number of the items, and reliability of subdimension of biotechnology attitude questionnaire (BAQ)

Subdimensions of BAQ	Mean	SD	Number of items	Cronbach's α
DNA manipulation (DNAM)	12.11	3.91	4	0.56
GMO production (GMOP)	15.92	5.12	6	0.64
Risks from genetic engineering (RGE)	18.48	4.28	6	0.76
Shopping of genetically modified products (SGMP)	16.78	3.69	6	0.54
Genetically modified animals (ANIMALS)	8.12	2.88	3	0.64
Genetically modified plants (PLANTS)	13.15	4.21	4	0.57
Ecological consequences from cultivating of genetically modified plants (ECCGMP)	8.31	2.77	3	0.60
Public awareness of genetically engineered foods (PAGEF)	14.77	3.62	5	0.55

and university students in the spring semester of 2007. Collected data were entered to SPSS program, and after cleaning process, data set was subjected to descriptive (particularly mean and frequency) and inferential (particularly correlation and MANCOVA) statistics.

RESULTS

Results on Analysis of High School and University Students' Knowledge of Biotechnology

As illustrated in the Table II, nine of the 16 biotechnology knowledge items were correctly answered by more than 50% whereas seven items were correct for 25–44% of high school students. On the other hand, these results are interestingly different for university students. Only six of the 16 biotechnology knowledge items were correctly answered by more than 50% whereas 10 items were correct for 9–46% of university students.

High school students seemed to have more knowledge than the ones from the universities in terms of nearly all items. Majority of both high school and university students knew that biotechnology was associated with changes of DNA that could result in productivity increase. Besides, especially half of the high school students suggested that GM organisms contain many dangerous chemicals. Also, most of the students knew that genetic modification could increase nutritional quality and/or taste of GM products.

Surprisingly, 25% of high school and 10% of university students thought or did not know if GM food can destroy human genes. Most of the university students did not virtually know the items related to genetic modifications like somatotropin.

Two-way ANCOVA with the covariate of age was performed to investigate the effect of gender (male and female) and school type (high school and university) on high school and university students' knowledge on biotechnology. The main effect of gender [F (1, 623) = 0.654, $p = 0.419$], school type [F (1, 623) = 0.754, $p = 0.386$], and also the interaction effect of these two factors [F (1, 623) = 0.409, $p = 0.523$] were found to be not significant. However, the male high school students seemed to have higher score on BKQ than did the female students and all university students.

Results on Analysis of High School and University Students' Attitude Toward Biotechnology

Multivariate correlation analysis performed among the variable of age and eight dimensions of BAQ indicated that age significantly contributed to dimensions of BAQ except the dimension of ANIMAL. Because of this significant contribution, 2 (Gender) × 2 (School Type) MANCOVA with the covariate of age was conducted to determine the main effects of gender and school type, and interaction effects of gender and school type on eight subdimensions of BAQ. Multivariate analysis indicated significant result for main effect of gender, Wilks' $\lambda = 0.948$, F (8, 616) = 4.228, $p < 0.001$, $\eta^2 = 0.052$, for main effect of school type Wilks' $\lambda = 0.880$, F (8, 616) = 10.487, $p < 0.001$, $\eta^2 = 0.12$, and for the interaction effect of gender and school type Wilks' $\lambda = 0.962$, F (8, 616) = 3.021, $p < 0.001$, $\eta^2 =$

TABLE II
Students' knowledge on biotechnology[a]

	Responded correctly (%)		Responded incorrectly (%)		Don't know (%)	
	HSS	US	HSS	US	HSS	US
Application of GM methods on animals can increase animal resistance against diseases. (T)	82	64	17	13	0.8	23
GM organisms are used in medicine (*e.g.* insulin production with GM microorganisms). (T)	82	56	0.2	34	8	23
Practical application of GM plants may increase productivity and resistance of plants against diseases. (T)	79	68	18	13	3	19
GM organisms are always bigger than normal. (F)[b]	68	46	26	18	6	36
Microbes should be genetically engineered to make them more efficient at decomposing human sewage. (T)	65	54	32	12	3	34
Genetical modification to plants can increase nutritional quality and flavor of fruits and develops traits to withstand shipping process. (T)	62	50	33	16	4	34
Porcine somatotropin is a hormone active in hogs that directs dietary energy away from fat disposition toward production of lean muscle. (T)	56	15	37	6	6	79
Foods with increasing nutritional value and vitamins can be created through genetic modification. (T)	54	44	41	24	5	31
GM organisms contain many dangerous chemicals. (F)[b]	51	30	37	22	12	48
Genetical modification is painful for animals. (F)[b]	44	37	45	32	11	31
It is possible to transfer genetic material between dissimilar organisms, such as animals and plants, because DNA is chemically identical. (T)	42	22	55	16	3	62
GM modification of poultry results in greater proportion of lean. (T)	40	23	54	34	5	43
Manipulation with DNA changes genes of GM organisms. (T)	39	54	54	15	7	31
Consumption of GM food can destroy human genes. (F)[b]	36	18	62	62	2	20
GM crops are sterile. (F)	13	81	52	10	35	10
Recombinant bovine somatotropin is an animal drug that increases milk produced by dairy cows. (T)	25	10	69	64	5	25

[a] Total high school students 352, University students 276.
[b] Negatively worded item; reverse scoring procedure used.

0.038. After these significant results, univariate analyses were run to see the effects of these factors on each subdimension of BQA. The results are illustrated in Table III.

Students' Attitudes Toward DNA Manipulation

University students showed significantly higher positive attitudes toward DNA manipulation (DNAM) subscale than did high school students [F (1, 623) = 8.398, $p < 0.005$], and university female students showed significantly higher score than did university male and high school students [F (1, 623) = 8.714, $p < 0.005$]. Both high school and university students indicated positive attitude toward the use of cloning for saving of endangered species and not transferring genetic materials between plants and animals. However, they indicated neutral attitudes on the items regarding as unethical concern in manipulation with DNA and having right of human being to intervene to DNA.

Students' Attitudes Toward GMO Production

Girls showed significantly higher positive attitudes toward GMO production (GMOP) than did males [F (1, 623) = 11.99, $p < 0.005$]. University students showed significantly higher positive attitude than did high school students [F (1, 623) = 12.497, $p < 0.005$]. The scores of all items for both high school and university students were higher than 3 referring to students' neutral attitudes toward GMOP (Table II). All of the students agreed that use of genetically modified organisms (regardless of whether they are animals or plants) should be regulated. They believed that consumption of GM food was risky and did agree with improving taste or freshness maintenance of GM products through genetic modification. Furthermore, the use of GM microbes in decomposing human sewage appeared to be more acceptable among students because there was not direct risk from GM food consumption.

Students' Attitudes Toward Risk from Genetic Engineering

University students showed significantly higher positive attitudes toward risk from genetic engineering (RGE) than did high school students [F (1, 623) = 36.455, $p < 0.005$]. However, the effect of gender, even though boys indicated more positive attitudes than did female, [F (1, 623) = 3.148, $p = 0.434$] was not significant. Both high school and university students agreed on not giving GM food to children. Moreover, about half of the high school students and one third of the university students thought that GM food could endanger human health. Only about 26% of high school students and about half of university students thought that GM food did not influence human health. However, most of the university students believed that advantages of biotechnologies in future are uncertain. About half of the high school students and more than one third of university students relatively agreed with the use of genetic engineering in human medicine.

Students' Attitudes Toward Shopping of Genetically Modified Products

University students showed significantly higher positive attitudes toward shopping of genetically modified products (SGMP) than did high school students [F (1, 623) = 33.776, $p < 0.005$]. However, females' attitudes toward SGMP was nearly the same as males' [F (1, 623) = 0.0004, $p = 0.934$]. Nearly all of the students in both groups accepted that GM foods included dangerous chemicals that possibly harm human body. They all reported that genetically engineered foods should be universally labeled. Many of the high school students and about half of the university students thought that taste of GM food could be worse than that of normal. Consequently, based upon their negative attitudes, nearly all of them were not willing to buy GM food.

Students' Attitudes Toward Genetically Modified Animals (ANIMALS)

Males' attitudes toward ANIMALS were more positive than females' [F (1, 623) = 12.453, $p < 0.005$]. However, there is no significant mean difference between high school and university students [F (1, 623) = 0.716, $p = 0.398$] with regard to ANIMALS. About 67% of high school and 70% of university students indicated that it was not acceptable to insert genes from people to animals. However, half of the students believed that genetically engineered animals (*e.g*. sheeps) could be used for producing medicine for human being.

Students' Attitudes Toward Genetically Modified Plants (PLANTS)

Male students' attitudes toward PLANTS were observed to be more positive than female ones' [F (1, 623) = 3.88,

TABLE III
The significant and nonsignificant effects of these factors on each dimenions of BQA

Subdimensions of BQA	Gender	School type	Gender and school type
DNA manipulation (DNAM)	*	*	*
GMO production (GMOP)	*	*	–
Risks from genetic engineering (RGE)	–	*	–
Shopping of genetically modified products (SGMP)	–	*	–
Genetically modified animals (ANIMALS)	*	–	–
Genetically modified plants (PLANTS)	*	*	–
Ecological consequences from cultivating of genetically modified plants (ECCGMP)	–	*	–
Public awareness of genetically engineered foods (PAGEF)	–	*	*

*, significant effects; –, nonsignificant effects.

$p < 0.05$]. University students showed more positive attitudes than did high school students [F (1, 623) = 11.393, $p < 0.05$]. In contrast to animals, attitude toward genetic modification on plants seemed to be more favorable. For both high school and university students, mean score per each item ranged from 3.12 to 3.60, suggesting that attitudes are rather neutral but not negative. To examine if difference between attitudes toward animals and plants was significant, *t*-test on means per each dimension was performed. Mean score per dimension "plant" was significantly greater than mean score per "animal" attitudes. Thus, attitude toward genetic engineering on plant seemed to be more positive than that of animals.

Students' Attitudes Toward Ecological Consequences of Cultivation of Genetically Modified Plants

There was no significant mean difference observed between male and female students with regard to attitude toward ecological consequences of cultivation of genetically modified plants (ECCGMP), [F (1, 623) = 0.004, $p = 0.947$]. University students indicated more positive attitudes toward ECCGMP than did high school students [F (1, 623) = 16.048, $p < 0.005$]. University students were not afraid of the impact of GM plants on wild plants in the natural habitats, whereas high school students were afraid of GM plants on wild plants in the natural habitats. So, high school students believed that GM plants may have greater competitive abilities in comparison with wild plants and that they could hybridize and endanger original genetic resources.

Public Awareness of Genetically Engineered Foods

University students showed more positive attitude toward public awareness of genetically engineered foods (PAGEF) than did high school students [F (1, 623) = 33,498, $p < 0.005$]. No significant mean difference was observed between male and female students [F (1, 623) = 0.122, $p = 0.727$] with regard to PAGEF. Most of both high school and university students reported that public was not sufficiently informed about risks associated with GM foods. About 76% of high school and 88% of university students would like to know more about GM foods. A governmental regulation that would protect public from potential danger associated with GM food was seen to be inappropriate. Most of the students reported that a ban should be put on the production and purchase of genetically engineered products.

Results on Correlation among Knowledge and Subdimensions of Attitudes

By holding the age variable constant, multivariate partial correlation was performed to investigate the correlation among biotechnology knowledge and subdimensions of attitude toward biotechnology. Given in Table IV, 30 correlations of all the 36 correlations were found to be statistically significant and greater than 0.039. Among all significant correlations, only one correlation was negative.

Three correlations associated with KNOWLEDGE were not significant. Significant correlations were found between knowledge and GMOP [r (625) = 0.125, $p < 0.05$], RGE [r (625) = 0.291, $p < 0.05$], SGMP [r (625) = 0.105, $p < 0.05$], PLANTS [r (625) = 0.204, $p < 0.05$], and ECCGMP [r (625) = 0.175, $p < 0.05$]. The correlation between KNOWLEDGE and RGE was moderate in magnitude, but the other correlations were relatively low. Overall, these results suggest that knowledge of biotechnology was linked with more positive attitudes toward biotechnology.

DISCUSSION AND CONCLUSION

The findings indicate that both high school and university students have similar knowledge of what biotechnology processes mean. More positive attitudes toward biotechnology found among university students support current notion that better educated peoples have more favorable attitudes toward modern biotechnology [1]. Significant correlation between knowledge and attitudes supports an idea that public awareness is positively linked with greater appreciation of genetically engineered products [1, 19].

Turkish Students' Knowledge of Biotechnology

Overall, about half of the knowledge questions were answered correctly by more than half of all the partici-

TABLE IV
Correlations among biotechnology knowledge and dimensions of attitudes toward biotechnology

Study variables	1	2	3	4	5	6	7	8
1. KNOWLEDGE	–							
2. DNA manipulation (DNAM)	−0.0315	–						
3. GMO production (GMOP)	0.125**	0.168**	–					
4. Risks from genetic engineering (RGE)	0.291**	0.132**	0.215**	–				
5. Shopping of genetically modified products (SGMP)	0.105**	−0.068	0.128**	0.281**	–			
6. Genetically modified animals (ANIMALS)	−0.012	0.097*	−0.116**	0.185**	0.206**	–		
7. Genetically modified plants (PLANTS)	0.204**	0.037	0.159**	0.337**	0.213**	−0.018	–	
8. Ecological consequences from cultivating of genetically modified plants (ECCGMP)	0.175**	0.135**	0.245**	0.345**	0.111**	0.106*	0.039**	–
9. Public awareness of genetically engineered foods (PAGEF)	0.022	0.125**	0.153**	0.271**	0.198**	0.086*	0.204**	0.190**

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

pants. Similarly, a study by Turkmen and Selcen-Darcin [20] on Turkish Elemantary and Science Educaton Students' knowledge levels toward biotechnology issues revealed that science and elementary teacher candidates had an approximate consistent knowledge of describing biotechnology and human health/pharmacy that almost all students had an inadequate knowledge about other biotechnological issues. In another study, Prokop *et al*. [14] found only five of 16 identical questions to be answered correctly by more than half of university students from Slovakia. This suggests that Turkish students' understanding of biotechnology is somewhat better than that of Slovakian students. Our results suggest that most correctly answered questions were related to practical applications of biotechnology. In contrast, least score were found for mechanisms of basic biotechnology processes such as transfer of DNA from one organism to another or the core of genetic engineering in general. We suggest that greater awareness of practical applications of biotechnology might be an indirect result of harmonization of Turkey with the EU legislation [21], and direct result of the news regarding agricultural biotechnology in Turkey through Turkish Biotechnology Society (TBS) and technology related magazines such as "Science and Technology" (*Cumhuriyet Bilim Teknik*). This magazine introduces the concept of biotechnological research and related ethical issues to its readers. The TBS, established in 1986, organizes various symposia and conferences focused on biotechnology [17].

Current biotechnology awareness in Turkish students favors practical applications of (agricultural) biotechnology, but somewhat exceeds students' understanding of the core of biotechnology processes. These trends are evident both in high school and university students suggesting that science curriculum probably might not provide enough place for teaching biotechnology. Teaching Mendelian genetics and other similar topics neither contains examples of modern biotechnology nor requires discussions of ethical impacts of applications of modern technologies. This is however of special importance, considering that these discussions greatly contribute to students' appreciation of biotechnology processes [4].

Turkish Students' Attitudes Toward Biotechnology

Overall mean score for each dimension seems to be around average. However, students' most favorable attitudes were found toward genetically modified plants. Most negative attitudes were found toward genetic manipulations on genetic modification production, shopping genetically modified products, animals at risk of ecological consequences of cultivating GM plants, and public awareness of genetically engineered foods. These results are in strong contrast with those findings reported from the USA, where more familiar attitudes toward GM products had been observed [22]. But, other research reports from the Europe are more similar to those found in the present study maybe due to the more conservative policy of the European Union toward biotechnologies [23]. For example, we found that attitudes toward GM plants or microorganisms are more liberal than those of animals which support findings of other studies [9, 11]. We propose that negative views of manipulations with animals are directly related to poor knowledge of how genetic manipulations take place, because about 40% of all students did not know that genetic modification is not painful to animals. In addition, most of high school and university students incorrectly thought that consumption of GM foods can destroy human genes. About 49% of high school students and the high proportion of (70%) university students incorrectly perceive the presence of dangerous chemicals in GM organisms. Similar reports can be found in Prokop *et al*. [14]. Lastly, we suggest that fear of the GMO can be regulated by increasing awareness following providing information and discussions from media such as television, journals, or internet.

Significance of Gender

The level of knowledge positively correlated with attitudes. Multivariate results indicated significant differences in attitudes toward biotechnology between male and female students. Turkish students, especially boys, show somewhat more positive attitude toward biotechnology comparing with females regardless of their educational level. However, Turkmen and Selcen-Darcin [20] reported that there was no significant mean difference between female and male Turkish primary teacher candidates' knowledge levels related to biotechnology. However, our results does not fit a "gender paradox" hypothesis [24] which states that females have more negative attitudes toward modern biotechnologies than males because they invest more in the next generation. We have at least three arguments that reject the gender paradox hypothesis. First, an effect sizes calculation of multivariate differences showed that gender differences explained only 5.2% of total variance ($\eta^2 = 0.052$) of dependent variables. Second, a detailed inspection of univariate results revealed that gender differences occurred only in four out of eight dimensions (Table III) and, out of them only three favored higher mean scores of males. Thus, four dimensions failed to show gender related differences in attitudes to biotechnology. Third, shopping of genetically modified products, one of the most sensitive dimension related to the gender paradox hypothesis [24] showed neither significant difference between males and females nor nonsignificant trends that could at least partly support this hypothesis.

One would expect that weak gender differences could be caused by the absence of students' first-hand experiences (*e.g*. shopping and selling) with genetically engineered products, because their needs are mostly covered by their parents who tend to buy such products by themselves. Whereas we cannot reject this possibility, an intriguing question why Prokop *et al*. [14] found significant gender differences in Slovakia, where the distribution of GM products is still banned by law, emerges. We hope that our further international comparisons of attitudes toward biotechnology will contribute deeply to understanding of this phenomenon [25, 26].

Little effects of educational level on attitudes toward biotechnology was also observed in the findings of similar studies carried out by Dawson and Schibeci [11] with Australian sample, and by Chen and Raffan's [4] with UK and Taiwan sample. The significant correlation between subdimensions of attitudes and knowledge found in our study indicated that higher level of knowledge about biotechnology would result in more positive attitudes [4, 27].

Turkey has been in the process of European Union (EU) membership since 1990s [28]. Following its current policy, legalization of genetically engineered products in near future can be expected. Thus, the public needs to be aware of this area, because better knowledge is related to more positive attitudes toward biotechnology [14]. Our results suggest that the news regarding biotechnology together with science curriculum may not prepare Turkish citizens for biotechnology sufficiently. Poor understanding of biotechnology processes is covered by superficial appreciation of (agricultural) biotechnology probably due to particular impact of Turkish media. Better understanding of what biotechnology really means can be improved by re-evaluation of science curriculum and public discussions with scientists perhaps through TV or magazines. Current attitudes to biotechnology in Turkey are not favorable toward shopping of genetically engineered products and this should be of interest for future food policy in Turkey. More biotechnology information sources, such as *Biotechnology Online* (www.biotechnology.gov.au) in Australia [11] or www.gmo.sk in Slovakia, may help researchers in their research and teachers in their teaching about genetic engineering more effectively. Science and biology teachers' preparedness for teaching biotechnology should not be neglected, but further investigation in this topic is needed.

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