Electronic Journal of Biotechnology ISSN: 0717-3458
http://www.ejbiotechnology.info
DOI: 10.2225/vol14-issue4-fulltext-5 *RESEARCH ARTICLE*

Knowledge about and acceptance of genetically modified organisms among pre-service teachers: a comparative study of Turkey and Slovenia

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Received November 28, 2010 / Accepted April 26, 2011
Published online: July 15, 2011

Abstract Genetically modified organisms cannot be regarded as merely a topic for academic debate, since these have serious implications as a research field and for production based on genetic engineering. Public debates rarely base their arguments on elements rooted in scientific arguments and knowledge but are heavily loaded with emotions, opinions and informal reasoning. This study aimed to investigate the knowledge and acceptance of genetically modified organisms among prospective teachers in Slovenia and Turkey. Knowledge of genetic modification was measured with a two-tier instrument. The level of acceptance of genetic modification was measured with a 17-item instrument. Findings revealed that knowledge of genetics and biotechnology barely influenced the acceptability of genetic modification, and correlations are low. The relationship between knowledge and acceptance was not significant among Slovenian students and while significant for the Turkish or combined groups, the r values were only 0.179 and 0.244. It was found that differences in the acceptability of clusters of different kinds of genetically modified organisms do exist between the two countries. In both countries, participants recognized microorganisms and plants that produce something useful as the most acceptable organisms, while at the other end were animals used for consumption or as donors of organs. Practical implications for teaching are discussed and implications for further studies are drawn.

Keywords: biotechnology, genetic engineering, genetic modifications, teaching

INTRODUCTION

Since the 1990s, genetic modification has been the focus of debate, owing to its increased use and effect on our lives. There is evidence that genetic modification, including genetic engineering and biotechnology, has appeared in a number of areas, ranging from agriculture, chemical engineering, industry and the food industry, to medicine, molecular biology, environmental protection and human health. However, this increasing appearance of genetic modification in various areas has resulted in growing interest, concerns, ethical and social issues not only in scientific communities but in public ones as well; so, genetic modification is recognized as a socioscientific issue (Sadler, 2009).

Teaching about socioscientific issues, as in the case of genetic modification, gives rise to the need for science teachers to develop strategies not accompanied by traditional science teaching (Dawson and Venville, 2009; Dawson and Venville, 2010). Researchers have pointed out that the problem with the teaching of these issues is not only to find strategies and active methods to enhance understanding and raise knowledge but also to find and transform alternative conceptions, and to include attitudes and emotions, as well as moral and informal reasoning in the process of decision making (Sadler and Zeidler, 2005a; Sadler and Zeidler, 2005b; Sadler and Fowler, 2006; Dawson and Venville, 2010). The main aim of such teaching is not to persuade students to have more positive attitudes (Chen and

Raffan, 1999) but to help them develop their competence in evaluating risks and making decisions based on testable premises and scientifically sound reasoning. The practical implications are that public acceptance will play a major role in determining whether biotechnology development continues to expand (Cavanagh et al. 2005), and consequently will affect the transfer of new findings from laboratories into the open field, food production, industry, medicine, etc. (Šorgo and Ambrožič-Dolinšek, 2009).

In particular, if the main aim of science education is to cultivate scientifically literate citizens, then in fulfilling this task, a society needs teachers with a better understanding of new emerging technologies such as genetic modification to successfully adopt appropriate strategies in the teaching of these issues. Over the past two decades, research studies have focused on the individuals' knowledge and acceptance of genetic modifications in various application areas. In general, the results of these studies have shown that views on genetic modification have consisted of negative and concerned opinions but they often vary overall according to the type of application. For example, applications involving genetically modified plants tend to be viewed as more acceptable than the use of genetically modified animals (*e.g.*, Pardo et al. 2002). The use of genetic engineering for medical purposes has been found to be more acceptable than its use for food production purposes (*e.g.*, Gaskell et al. 1999). Medical applications are perceived to be more beneficial, less risky and more ethical compared to food applications (Frewer and Shepherd, 1995). Several researchers have investigated whether knowledge plays the crucial role in the acceptance of applications of genetic modification. For example, Prokop et al. (2007) reported that knowledge influence attitudes and level of acceptance of an application of genetic modification. Hoban (1997) and Ganiere et al. (2006) reported that low acceptance levels for genetically modified products are a result of the lack of knowledge about biotechnology. On the other hand, another part of the research found that knowledge is not a predictor of attitudes and acceptability (Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010). Furthermore, Scholderer and Frewer (2003) suggested that additional information decreases the level of acceptance, and Onyango et al. (2004) suggested that good technological knowledge is likely to produce the opponents of biotechnology.

Studies that have investigated knowledge of and attitudes towards genetically modified products have also revealed that public perception can be shaped by a variety of factors, including age, gender, level of education, culture, usefulness of the application, and type of organism involved (Črne Hladnik et al. 2009). The best known surveys in Europe – Eurobarometer – have been conducted at various times in order to determine public perception of genetic modification, as a contribution to the informed public and policy debate (Gaskell et al. 2006). However, these surveys measured public perceptions in a general manner, and they specifically lacked an analysis of the prospective teacher's knowledge and attitudes towards genetic modification. Although perceptions of genetic modification have been receiving increasing attention, only a few studies about pre-service teachers' knowledge and attitudes on this issue have been conducted. In one of the research studies, Prokop et al. (2007) found that PSTs in Slovakia have poor knowledge about biotechnology, and their attitudes were mostly negative towards the technology of genetic engineering, while they had neutral attitudes towards genetically engineered products and the marketing of such products. They indicated that the level of knowledge correlated positively with attitudes. Türkmen and Darçın (2007) reported that Turkish elementary and science PSTs had inadequate knowledge about agricultural biotechnology, environmental biotechnology and food production, while they had an appropriate level of knowledge regarding the description of biotechnology and human health and pharmacy. In another study, Bal et al. (2007) reported that prospective teachers in Turkey lacked sufficient knowledge about the basic principles of genetic engineering, and prospective teachers seemed reluctant to agree about genetically modified animals, while they seemed positive about plants. Correlations between knowledge and acceptance of genetically modified organisms among teachers and PSTs teachers were investigated by Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010 in Slovenia. Their findings revealed that knowledge of the facts and procedures of genetic modification had only a low impact on acceptance of genetically modified organisms. Similar low correlations between knowledge and attitudes were also reported by Allum et al. (2008).

Although the existing studies give insights into students' views of genetically modified organisms, it is difficult to derive an international overview of the prospective teachers' knowledge and attitudes towards genetic modification. Since genetic modification affects cross-national boundaries, it is very important to compare knowledge and attitudes towards biotechnology across the countries in which the industrialization of new technologies is occurring across the globe (Kidman, 2009; Lü, 2009; Kidman, 2010; Šorgo et al. 2011a). Therefore, there is a need to carry out a comprehensive international study to be able not only to determine the importance of knowledge in predicting the acceptability of modern biotechnology but also to answer the question of whether we can use universal teaching strategies, or if each country or region must develop such strategies for themselves. By examining the prospective teachers' knowledge of and attitudes regarding genetic modification, we can enhance our knowledge about what works best in different contexts and deepen our understanding of the educational contexts in different countries (Guo, 2007; Kidman, 2009; Ozel et. al 2009; Ketpichainarong et al. 2010; Surmeli and Sahin, 2010; Šorgo et al. 2011a). Besides, an investigation of similarities and differences between participating countries can help us to choose appropriate teaching strategies and actions not only for genetic engineering, but as a model for teaching science and seeking better understanding between teachers from different cultures (Šorgo et al. 2011b). It would be grandiose to say that a comparative study based on two countries can give globally valid answers. With this in mind, we have attempted to make a first step in establishing differences in acceptance and knowledge of pre-service teachers towards genetic modification in the context of two distinct countries, Slovenia and Turkey. Turkey and Slovenia were chosen because of the shared interest on the part of the authors in improving the teaching of socioscientific issues in their countries through teacher education. The differences between Slovenia and Turkey are enormous in almost all respects that can be regarded as important for education. To take one example: Slovenia has 2 million inhabitants and Turkey close to 75 million. The recent study can be regarded as a pilot study with all the flaws that accompany such studies in the global context. To test validity and reliability, a greater number of countries should be involved. The results and instruments developed in this comparative study of two countries will be used in teacher training with a possible transfer of findings from biotechnology to other socioscientific issues. Thus, the research questions that guided this study were as follows: How well do the PSTs accept various kinds of genetic modification, and what are the differences, if any, between the two countries? What is the PST's level of knowledge about genetic modification, and what are the differences, if any, between the two countries? What is the correlation between knowledge and acceptance in each country? What is the correlation between knowledge about, attitudes towards and acceptance of GMOs in both countries, and what are the differences, if any, between the two countries? Another question was whether people with a better understanding of the biotechnology and genetics could more easily accept/reject GMOs than people with a basic knowledge of the facts. With this in mind, we rejected the knowledge questionnaire used in previous Slovenian studies (Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010; Šorgo et al. 2011a). In these questionnaires, respondents had to choose among three options -true; do not know; false- and in this way show their knowledge at the recognition level. With the questionnaire tested in the recent study, we tried to produce an instrument measuring higher order thinking, following a path recommended by Treagust (1988). The list of GMOs used to measure acceptability remains for the most part the same as in previous studies. The sample in the recent study did not allow us to answer this question in detail, so one could regard this question as a pilot study in testing the suitability of the improved instruments.

MATERIALS AND METHODS

Participants

The study was carried out in the autumn term of the 2009-2010 school year. A total of 281 pre-service teachers (PSTs) participated in the study; 122 PSTs (20 males, 101 females, 1 unidentified) were from Slovenia, and 159 PSTs (89 males, 70 females) were from Turkey. Participants were between 18 and 25 years old. The participants were all studying to become primary and secondary school teachers. Students came from various departments, including both science and non-science majors, but none of them had studied biotechnology explicitly.

The instruments

The knowledge questionnaire. As part of the choice for measuring knowledge at the higher cognitive levels (interview, cognitive mapping, essays, etc.) we compiled a 13-item test. There were four open-ended items in the questionnaire. The task of two open-ended items (**Appendix**, items 2.1 and 4.1) was to list genetically modified organisms and biotechnological processes. Additionally, two complex items performed the function of checking their knowledge at the application level by requiring that they apply knowledge in two hypothetical situations (**Appendix**, items 12 and 13). The main part of the test consisted of nine two-tier items, where in the first part students in two cases had to write a definition and in seven items had to circle an answer, and were finally required to explain in open ended format their choice or definition. In constructing two-tier instruments, we loosely followed the procedure proposed by Treagust (1988) and used on many later occasions (*e.g*., Tsui and Treagust, 2010). By constructing the two-tier instrument, we had two intentions: a) to prepare an instrument above the recognition or recall level for estimating or understanding the purposes of the present study; b) to identify misconceptions concerning genetic biotechnology (not presented or discussed in the recent study).

In the processes of developing the questions and tasks, some specific steps were followed. First, researchers reviewed a wide range of articles and conference papers relevant to genetic modification, as well as genetic engineering and biotechnology. In the second step, we made up a question pool in light of the literature review. In parallel to this, we also tried to produce new questions about genetic modification. The validity of the knowledge questionnaire was examined by two professors from science education, and one professor from the field of biotechnology. The professors were asked to review the questions and each item within the questions. They were also asked whether the questions were relevant to the goal of the questionnaire. Revisions were made based on their comments and suggestions. At the next step, we invited prospective teachers to answer the questions in order to conduct this study.

The questionnaire delivered to the students in both countries was initially prepared in English as being the language of communication between the authors. Ultimately it was translated into Slovenian and Turkish. The initial set of questions and tasks was broader than the number of items later used in our analysis. The tasks "List as many biotechnological processes as possible" and "List as many existing cases of successfully implemented genetically modified organisms as possible", were left blank by most students, and organisms were listed without explanation, as was the expected answer from the authors. Besides lack of knowledge, one possible reason for not answering such questions is that respondents are susceptible to respondent fatigue, and many respondents may not have had an interest in answering these questions. Additionally, two complex tasks (**Appendix**, 12 and 13), where our intention was to explore the application of some genetics and biotechnology processes, stayed unanswered by most students as well.

Two of the two- tier items scored four points, and seven of them scored three points. One or two points were delivered to the correct answer in the first part. Guessing was prevented in most cases by the option "not sure". In open-ended parts of the questions, incorrect and missing answers were scored zero; partially correct answers were marked as one point and mostly correct answers gained two points. In such scoring, the minimum was 0 points and the maximum 29 points for the whole instrument.

The acceptability questionnaire. To determine the students' views about different kinds of genetically modified organisms, the questionnaire developed by Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010 was used. The questionnaire consisted of 17 five-scale Likert-type items, including actual genetically modified organisms (GMOs). Reliability and Cronbach's alpha of the questionnaire were calculated at 0.847, which was reliable. More detailed information about the development of the questionnaire can be found in Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010. Researchers asked students to circle Likert-type items as:

1 = acceptable without any exception;

2 = acceptable with some exceptions;

3 = do not have an opinion/ do not know;

4 = unacceptable with some exceptions;

5 = unacceptable without any exception.

In this way someone for whom all GMOs are acceptable without any exceptions will gain 17 points, and someone who rejects all GMOs will gain 85 points. The initial list was prepared in Slovenian and for the purpose of the study translated into Turkish. The third part of the questionnaire included questions about participants' personal information (*e.g*., name of the faculty, study programme, year of study and gender).

Data analysis

The data analysis was carried out with the statistical software SPSS 17.0. Owing to the distribution of data, which was not normally distributed in some variables and was tested by the Kolmogorov-Smirnoff test, the Mann-Whitney non-parametric test was used to identify the differences in the frequencies of answers between different groups of respondents. In order to show relative values of the responses, means and standard deviations were reported. Correlations were calculated as Spearman's correlation coefficient. To compare means, one way ANOVA and Cohen's d was used to calculate effect size.

RESULTS

In our sample, acceptance of different kinds of genetically modified organisms is independent of the gender of PSTs, a finding which differs from other studies (Qin and Brown, 2007), but dependent on knowledge and on the country of PSTs, as calculated by multiple regression of the whole sample of PSTs (Table 1).

Table 1. Results of multiple regression. The dependent variable was the acceptability expressed as the sum of answers; the predictors were Gender, Country and Knowledge expressed as the sum of correct answers.

Coefficients[a]					
Model	**Unstandardised Coefficients**		**Standardised Coefficients**	**t-value**	**Significance**
	B	Standard Error	Beta		
(Constant)	64.955	2.964		21.913	0.000
Gender	-0.489	1.508	-0.021	-0.324	0.746
Country	-4.737	1.585	-0.203	-2.989	0.003
Knowledge[b]	0.301	0.109	0.172	2.756	0.006

[a] Dependent Variable: acceptability expressed as the sum of answers. [b] Knowledge expressed as the sum of correct answers.

The relationship between knowledge and the acceptance of the genetic modification in the two countries is presented in tabular and graphic form. We analyzed these and did cluster analysis showing the existence of correlation among them.

Knowledge

As can be seen in Table 2, the average knowledge of both groups PSTs did not exceed half the maximum possible scores. These findings show that knowledge is significantly better among prospective Turkish teachers than among prospective Slovenian teachers, as the Turkish average lies at 40.9% and the Slovenian average at 24.9% of the available maximum. The recognition that differences in knowledge between two countries are large is supported by the value of the effect size (Cohens' d = 0.77).

The distribution of frequencies of obtained scores (Figure 1) between the Slovenian and Turkish PSTs is not uniform and shows a different course. Turkish PSTs reached two peaks, the first between 3 and 11 points and the second between 15 and 23 points, while the Slovenian PSTs reached only one peak between 3 to 11 points. The Turkish data was most probably sampled from two populations with different properties (K-S test), but from the available data the differences in the Turkish data cannot be explained.

In further analysis, we divided the results for knowledge into two groups. The first group of results consisted of those pertaining to answers in which students had to circle the answer "yes", "no" or "not sure" or give a definition (Figure 2), and the second group consisted of the results for answers in which students had to explain in open-ended format (Figure 3) why they had chosen those simple answers. When we grouped the results of knowledge in this way, we obtained a different distribution of frequencies. The results of the scores from the first group were distributed equally with one peak, with the exception that the maximum of Slovene PSTs lay between 3 and 5 points (M = 4.08; SD = 2.06), and the maximum of Turkish PSTs between 6 and 8 points (M = 5.35; SD = 2.30). These differences are statistically significant with $F(1, 278) = 22.9$, $p = .000$) and Cohen's d = 0.58, which can be regarded as a medium-range difference.

Table 2. Differences in knowledge measured by the two-tier instrument between countries (maximum available points = 29).

	Sample size	Mean	Standard Deviation	Standard Error	F-value	Significance
Turkey	159	11.86	6.989	0.554	38.472	0.000
Slovenia	119	7.22	4.854	0.445		
Total	278	9.87	6.571	0.394		

The results of the scores from the second, open-ended group of answers, showed better knowledge among the Turkish students (M = 6.50, SD = 5.34) when compared with the Slovenian results (M = 3.14; SD = 3.27). Cohen's d = 0.79 can be regarded as the large effect size. One can recognize a different distribution of frequencies of obtained scores between the Slovenian and Turkish populations of PSTs (Figure 3). We obtained two peaks in the distribution for the Turkish PSTs and one peak in the distribution of frequencies of obtained points for the Slovenian PSTs. The first peak was the same for the Slovenian and Turkish PSTs and lay between 0 and 2 points. The second extra peak, much higher than the first one, was present only among the Turkish students, and lay between 12 and 14 points, again showing that the Turkish data had been sampled from two populations with different properties (K-S test); but from the available data the differences in Turkish data cannot be explained.

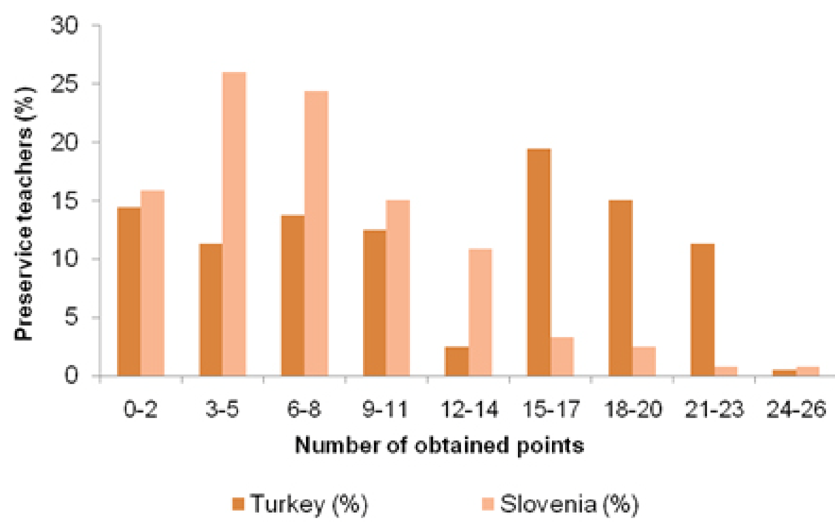

Fig. 1 The frequency dispersal of scores between Turkish and Slovenian PSTs. The maximum available points were 29. In both groups of PSTs a score of 26 points were the highest obtained results.

Acceptability

Overall, it can be concluded that PSTs from both countries had positive views about the acceptability of most genetically modified organisms (Table 3). Regarding the differences between the countries, the Turkish PSTs showed higher scores for acceptance (M = 38.91; SD = 11.26) of genetically modified organisms than the Slovene PSTs (M = 45.18; 10.86), but individual differences within the sample can be enormous in both countries, ranging from total acceptance (N = 3) to total rejection (N = 1). Differences between countries are statistically significant at the p = 0.001, level with Cohen's d at 0.57. The Turkish PSTs had significantly more positive views on 8 of 17 kinds of GMOs than the Slovenian PSTs (Table 3), and their acceptance level was not significantly different in the case of 9 of 17 kinds of GMOs. In this group, two genetically modified (GM) plants ('Plants for animal food that are resistant to pests and pathogens', and 'Plants used for producing biofuel') are more readily accepted by Slovenian PSTs, yet the differences are small. The difference between countries is large (Cohen's d above 0.8), in three cases and the other differences are in the small to medium range. The differences within a group of organisms can be bigger than those between groups. For example, three of the most readily accepted GMOs among Turkish pre-service teachers are 'Plants with the ability to synthesize medicinal substances' (M = 1.36: SD =0.507); 'Microorganisms with the ability to synthesize applicable organic substances' (M = 1.55; SD =0.653), and 'Domesticated animals with new properties' (M = 1.72; 0.974). Sometimes differences based on usage are hard to interpret. The PSTs in both countries showed, for example, high level of acceptance regarding the use of microorganisms and plants with the ability to synthesize medicinal substances. In the case of microorganisms, the difference is not statistically significant, but in the case of the GM plants, Turkish PSTs showed significantly more support than the Slovenian PSTs (Cohen's d = 0.63). (Table 3).The PSTs in both countries showed the lowest acceptance regarding the use of genetically modified animals (Table 3), depending on the modification. For the Turkish PSTs, it was especially unacceptable to use such animals for food consumption, while the Slovenian PSTs showed the lowest level of acceptance in the case of animals as donors for genetically modified organs. Interestingly, the Turkish PSTs also showed lower acceptance levels regarding the use of plants for human food than for animals as donors.

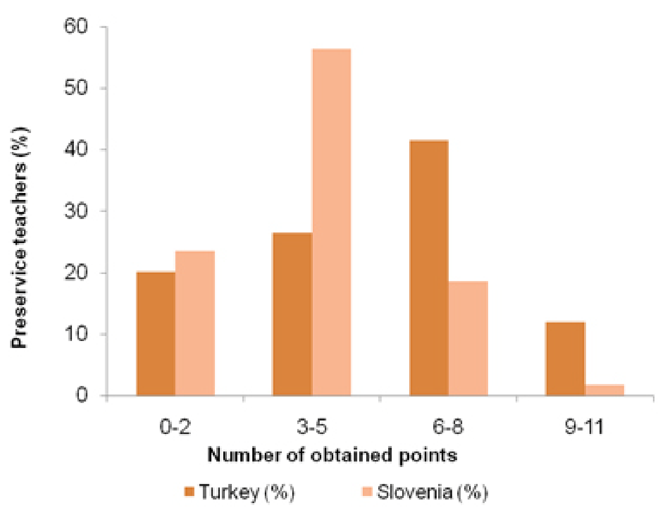

Fig. 2 Frequency dispersal of scores between Turkish and Slovenian PSTs for answers from the first part of the two-tier instrument. The maximum of points available was 11. In both groups of PSTs, 11 points also marked the highest result obtained.

We gained additional insight into the acceptance of genetically modified organisms with cluster analysis (Figure 4) for each country, where we could recognize a different arrangement of clusters for Slovenian and Turkish PSTs. For the Slovenian PSTs, we recognized four clusters of organisms. In the first cluster were the GMOs acceptable to the majority of respondents. This group consisted of plants and microorganisms that were very useful but not used for food consumption (medicinal substances for stress tolerance or the decrease of something harmful). The second group consisted of plants and microorganisms not directly used for human food (used in the food industry for a variety of synthesis of organic substances or animal food). In the third cluster were those animals and plants that were also not for food (animals producing medicinal substances or with new properties, ornamental garden or house plants and plants with improved quality characteristics). In the fourth cluster animals and viruses were grouped together which can be put into the human body (animals as donors of organs and for food and viruses for the transfer of genes). For the Turkish PSTs, we also recognized four clusters of organisms. In the first cluster there were again genetically modified organisms acceptable to the majority of responders. The first group consisted of all three organisms: animals, plants and microorganisms (animals with new properties, producing medical substances, microorganisms for organic synthesis and medical substances, and plant producers of medicinal substances). In the second cluster were the plants and microorganisms not directly used for food (plants for animal food, producing biofuel, tolerance to stress, ornamental garden plants with new properties and microorganisms for organic synthesis in the food industry). The third and fourth clusters were mutually connected and consisted of less acceptable organisms. In the third cluster were the viruses, plants and animals, potentially there for putting into the body or as a part of the homes of the responders (viruses for transfer of genes, plants for food with improved cultivation characteristics and ornamental house plants with new characteristics, animals for food with improved characteristics), and in the fourth cluster were animals and plants both for putting into the body (donors of organs and plants for food with improved characteristics).

Correlation between knowledge and acceptance

The correlation between knowledge about and acceptance of genetically modified organisms for the whole sample (N = 278) of PSTs was r = 0.244; p = 0.01. The correlation for Slovenian prospective teachers (N = 119) was r = 0.143; p = n.s., and for Turkish prospective teachers (N = 159) r = 0.179; p = 0.05. A similar result was obtained when we calculated the correlation among the results of grouped knowledge (Figure 2, Figure 3) and acceptance (data not shown) (between groups), for the Slovenian and Turkish PSTs, based on acceptance level.

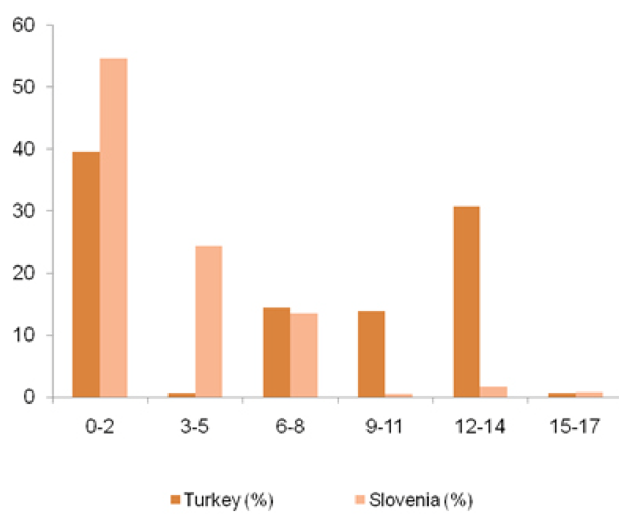

Fig. 3 Frequency dispersal of scores between Turkish and Slovenian PSTs of the second part of the two-tier instrument. The maximum available points were 18. In both groups of PSTs 16 points marked the highest result obtained.

DISCUSSION

From our findings, it can be concluded that student teachers' knowledge levels concerning genetics and genetic modifications are not satisfactory. This low level of knowledge about modern biotechnology among prospective and current teachers has already been noticed in Slovenia (Šorgo and Ambrožič-Dolinšek, 2009; Šorgo and Ambrožič-Dolinšek, 2010) and in Turkey (Özden et al. 2008). This lack of knowledge could be the reason that teachers are not interested in these topics in spite of their importance (Kidman, 2010). Regarding the student teachers' knowledge levels, there was a significant difference between Slovenia and Turkey. It is interesting and worth noting that the PSTs from Turkey had more knowledge than the Slovenian PSTs. The difference in knowledge is notable from the results of the answers (Figure 2), and is much more evident in Figure 3. Almost all the Slovenian and many of the Turkish PSTs did not know how to discuss biotechnology and issues associated with it and were, furthermore, not skilled in argumentation (Lewis and Leach, 2006; Dawson and Venville, 2010). While among Slovenian PSTs practically nobody or only a few possessed such skills, 31% of the Turkish prospective teachers were skilled in such types of discussion. From the unanswered open-ended questions, we can make an assumption those students, even if they have some basic knowledge of genetics and biotechnology cannot use it in novel situations or apply it in out-of-school situations. One possible reason in both countries lies in the teaching for high-stakes exams at the end of secondary education (Šorgo et al. 2011b). Additionally, it is likely that the difference for these kinds of results may stem from the content of the biology curricula in the two countries (Šorgo et al. 2011b), or the reason might be a lack of support from the educational and scientific authorities. A good example of such support has been set by Australia and their authorities (Kidman, 2010). With further improvement of the curriculum of prospective biology and science teachers, the problem of flawed knowledge can be eliminated by changes in university courses, and exchanges of best practices between countries should be encouraged. The question of, how to improve knowledge among the teachers of subjects such as Sociology or Philosophy remains unanswered. For them, courses on genetics or biotechnology are not provided, but they can participate in building opinion among students in the context of GMOs as a socioscientific issue.

Awareness concerning GMOs in Turkish and especially Slovene prospective teachers can be recognized as low and would have to be improved in such a way as to exceed the knowledge based on classical genetics and to contain examples of modern biotechnology and discussion of its impact on science and society (Lamanauskas and Makarskaite-Petkevičiene, 2008, Dawson and Venville, 2010), particularly because these discussions could contribute to its acceptance. From the results, we can conclude that one cannot treat all GMOs as general category, and even narrower categories such as GM plants or GM animals are unsuitable for detailed analysis; yet, some generalization can be made with caution. In general, the PSTs are much readier to accept GMOs producing medical substances, especially plants, the use of microorganisms for organic synthesis or production of organic substances, or viruses used to transfer genes and animals for medical purposes or possessed of other new properties. However, the PSTs did not accept genetically modified organisms produced for food consumption or animals as donors of organs. In summary, the findings also showed that the Turkish PSTs had the higher scores of acceptance for GM products than the Slovene PSTs.

If we connect acceptance with educational level, then better educated people have more favourable attitudes toward biotechnology (Pardo et al. 2002; Uşak et al. 2009). The same can be true with the higher level of acceptance among Turkish students. Better educated Turkish students were more agreeable towards modern biotechnology than the Slovenian PSTs. These findings are also confirmed by correlations. Although the correlation is weak, we can suspect from the results of the combined sample that it is more likely that students who possess a better understanding of genetic modification would more readily accept GMOs. As a result, we can draw the conclusion here that, if we want to promote decisions based on rational reasoning, we should promote classroom methods that result in a deeper understanding of biotechnology. Simply adding new facts or having a shallow broadening of the subject would not result in improved reasoning (Sadler and Zeidler, 2005a).

Calculations of correlations between knowledge and acceptance among potential consumers of GMOs showed either a pattern of three clusters, -opponents, supporters and a group of mostly indifferent individuals-; or a pattern of four clusters, two sharing different degrees of support, and two different degrees of refusal (Christoph et al. 2008). The same pattern was observed for the same group of organisms in a study conducted among Slovenian students (Šorgo and Ambrožič-Dolinšek, 2010) and in the present study. The Turkish clusters show the same pattern as the Slovenian clusters in the current and former study (Šorgo and Ambrožič-Dolinšek, 2010), but there is one surprising exception. The Turkish PSTs showed high tolerance for GM animals, but not for food nor for putting GM products into the body, which are grouped in the first cluster. In the Slovenian cluster analysis, these are both grouped in the third cluster. In other ways, these GM animals in the opinion of Turkish PSTs' fall into the first two supporting clusters, while for the Slovenian PSTs they belong in one of the last two refusal clusters. The final conclusion could be that Turkish society could be more tolerant towards genetic transformations of animals.

Table 3. Differences in the acceptability of different kinds of genetically modified organisms between Turkish and Slovenian prospective teachers. (1 = acceptable without any exception, 2 = acceptable with some exceptions, 3 = do not have an opinion/ do not know, 4 = unacceptable with some exceptions, 5 = unacceptable without any exception).

Genetically modified organisms	Turkey (N = 159)	Sloveni (N =19)		
Microorganisms	**Mean (± SD)**	**Mean (± SD)**	**Sign.**	**Effect size**
Microorganisms used for organic synthesis in the food industry (for example, bioethanol)	2.16 (1.321)	2.65 (1.094)	0.000	0.40
Microorganisms with the ability to synthesise medicinal substances (for example, insulin)	1.89 (1.131)	1.97 (1.061)	0.261	0.07
Microorganisms with the ability to synthesise applicable organic substances (for example, various organic acids)	1.55 (0.653)	2.59 (0.817)	0.000	1.40
Microorganisms that can degrade toxic or harmful substances previously biologically non-degradable	2.28 (1.317)	2.37 (1.061)	0.321	0.07
Genetically modified viruses designed for the transfer of genes between organisms	2.10 (1.313)	3.21 (1.096)	0.000	0.91
Plants				
Plants with the ability to synthesize medicinal substances	1.36 (0.507)	1.86 (0.995)	0.000	0.63
Plants for animal food that are resistant to pests and pathogens	2.82 (1.462)	2.48 (1.111)	0.090	0.26
Ornamental garden plants with new properties (for example, blue carnations)	2.21 (1.454)	2.39 (1.213)	0.033	0.13
Crop plants with increased tolerance to stress conditions (for example, drought, salinity, etc.)	2.02 (0.990)	2.10 (0.986)	0.517	0.08
Ornamental house plants with new properties (for example, ornamental plants that glow in the dark)	2.85 (1.603)	3.04 (1.311)	0.276	0.13
Plants used for producing biofuel	2.52 (1.440)	2.29 (1.163)	0.346	0.17
Plants for human food with improved quality characteristics of fruit (for example, prolonged cold storage, more intense coloration, etc.)	2.99 (1.463)	3.05 (1.185)	0.710	0.04
Plants for human food that are resistant to pests and pathogens	2.49 (1.427)	2.76 (1.164)	0.058	0.20
Animals				
Domesticated animals with new properties (for example, cats with non-allergenic fur or fish that glow in the dark)	1.72 (0.974)	2.87 (1.365)	0.000	0.97
Animals, for example goats that produce milk containing medicinal substances (for example, blood coagulation factor)	1.92 (1.043)	2.69 (1.184)	0.000	0.69
Animals for food consumption having meat with improved characteristics (for example, meat with low fat or with more intense color)	3.14 (1.553)	3.39 (1.250)	0.261	0.18
Animals reared as donors for GM organ transplants (replacing or repairing defective organs or tissue)	2.89 (1.682)	3.47 (1.294)	0.006	0.38

As science educators, we should consider why the participants possess a low level of knowledge regarding genetic modification, which is a controversial issue and also a popular topic. Among similarities, one was that in both countries teaching is predominately dominated by a teacher and direct instructions that follow a prevalent teaching method (Šorgo et al. 2011b). Since the knowledge of the prospective teacher is important and can influence further and future biotechnology education, investigation of knowledge and acceptance could provide a baseline for further improvement of scientific literacy. We suggest that promoting scientific literacy requires extra responsibilities for science educators to teach new scientific discoveries and to consider the consequences of new scientific and biotechnological applications in an active way so as to foster critical thinking.

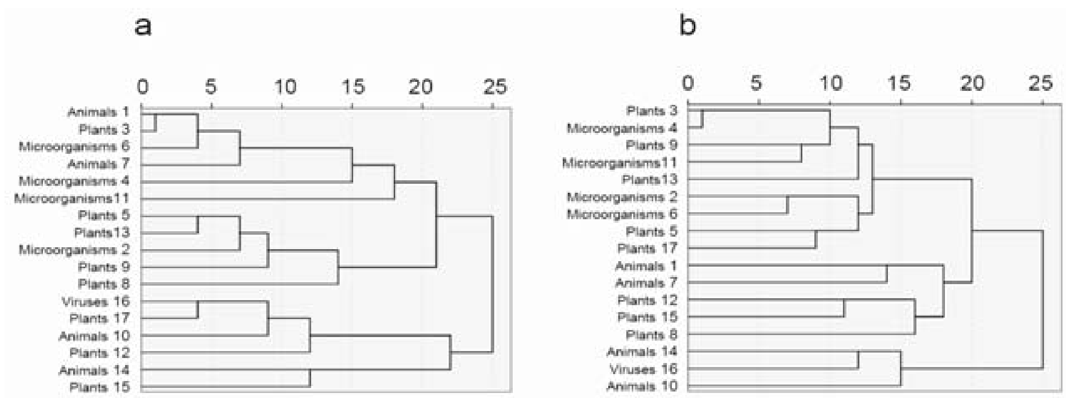

Fig. 4 Dendrograms of clusters of genetically modified organisms using average linkage distance (a = Slovenia; b = Turkey).

Legend:

1 Domesticated animals with new properties (for example, cats with non-allergenic fur or fish that glow in the dark).
2 Microorganisms used for organic synthesis in the food industry (for example, bioethanol).
3 Plants with the ability to synthesise medicinal substances.
4 Microorganisms with the ability to synthesize medicinal substances (for example, insulin).
5 Plants for animal food that are resistant to pests and pathogens.
6 Microorganisms with the ability to synthesize applicable organic substances (for example, various organic acids).
7 Animals, for example goats that produce milk containing medicinal substances (for example, blood coagulation factor).
8 Ornamental garden plants with new properties (for example, blue carnations).
9 Crop plants with increased tolerance to stress conditions (for example, drought, salinity, etc.).
10 Animals for food consumption having meat with improved characteristics (for example, meat with low fat or with more intense color).
11 Microorganisms that can degrade toxic or harmful substances previously biologically non-degradable.
12 Ornamental house plants with new properties (for example, ornamental plants that glow in the dark).
13 Plants used for producing biofue.
14 Animals reared as donors for GM organ transplants (replacing or repairing defective organs or tissue).
15 Plants for human food with improved quality characteristics of fruit (for example, prolonged cold storage, more intense coloration, etc.).
16 Genetically modified viruses designed for the transfer of genes between organisms.
17 Plants for human food that are resistant to pests and pathogens.

APPENDIX

Dear student,

Progress in Biology and its related disciplines allows us to understand the world around us in greater detail and provides humankind with technological solutions at the limits of imagination. Schools can barely follow the trends in providing students with correct and up- to-date information. If we want to improve education about vital innovations, we must establish what students already know and think about their previous experiences at high school–not to blame anyone but to set a baseline for improvement.

Authors of the Survey

1.1 Provide a short definition of biotechnology. (W*rite your answer in the box below*).

1.2 Explain your definition of biotechnology as briefly as possible (W*rite your explanation in the box below*).

2.1 List as many biotechnological processes as possible. (W*rite your answer in the box below*). * *omitted from analysis*

3.1 Provide a short definition of genetic engineering. (W*rite your answer in the box below*).

3.2 Explain your definition of genetic engineering as briefly as possible (W*rite your explanation in the box below*).

4.1 List as many existing cases of successfully implemented genetically modified organisms as possible. (W*rite your answer in the box below*). * *omitted from analysis*

5.1 For better cooking, meat should not be used until at least a week after slaughter. Biotechnologists have derived an enzyme called papain from the papaya plant which makes the meat ready for cooking right after slaughter if this enzyme is injected just before the animal is slaughtered. The meat changes because papain. *(Circle the letter before the answer)*:

a) Breaks down collagen proteins

b) Increases cell metabolism

c) Increases the nutritional value of meat

d) Makes the animal more muscular

e) Prevents infections.

5.2 Explain the reason for your choice. (*Write your explanation in the box below*).

6.1 A goat was genetically modified in such a way that its mammary glands produce additional protein, which works as factor of blood coating, and can be used as medication in patients with hemophilia. Is such modification painful for animals? *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

6.2 Explain the reason for your choice. (*Write your explanation in the box below*).

7.1 Can consumption of GM foods destroy human genes? *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

7.2 Explain the reason for your choice. (*Write your explanation in the box below*).

8.1 Is the brewing of beer a biotechnological process? *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

8.2 Explain the reason for your choice. (*Write your explanation in the box below*).

9.1 Is it possible to transfer genetic material between dissimilar organisms, such as animals to plants or humans to bacteria? *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

9.2 Explain the reason for your choice. (*Write your explanation in the box below*).

10.1 The sex of the child is determined by its mother. *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

10.2 Explain the reason for your choice. (*Write your explanation in the box below*).

11.1 If a male cat copulates with female rabbit, the result will be offspring with short ears. *(Circle the letter before the answer)*

a) Yes

b) No

c) Not Sure

11.2 Explain the reason for your choice. (*Write your explanation in the box below*).

12. Researchers have found that a substance produced by a rare tropical tree species can be used as a drug in cancer treatment. Unfortunately, this plant species is so rare and endangered that extracting the drug directly from the plant is out of question. You are a scientist who has received the task to transfer genes that code the substance into yeast. Organize your work into boxes connected with arrows. On the arrows write the names of the necessary procedures and into the boxes the necessary equipment, an explanation why the procedure is necessary, chemicals, etc. * *omitted from analysis*

13. You are a breeder of black hamsters. In a group of black animals an albino is born. You want to establish a line of white animals. Provide in steps all the necessary breedings and write down the genotypes and phenotypes if black (B) is dominant over white (b). * *omitted from analysis*.

Financial support: This research was supported by the Slovene Ministry of Higher Education, Science and Technology within the Biodiversity Research Programme (Grant No. P1-0078)

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How to reference this article:

ŠORGO, A.; AMBROŽIČ-DOLINŠEK, J.; ŲSAK, M. and ÖZEL, M. (2011). Knowledge about and acceptance of genetically modified organisms among pre-service teachers: A comparative study of Turkey and Slovenia. *Electronic Journal of Biotechnology*, vol. 14, no. 4. http://dx.doi.org/10.2225/vol14-issue4-fulltext-5