



HAL
open science

Slovakian students' knowledge of and attitudes toward biotechnology

Pavol Prokop, Andrea Lešková, Milan Kubiátko, Carla Diran

► **To cite this version:**

Pavol Prokop, Andrea Lešková, Milan Kubiátko, Carla Diran. Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education*, 2007, 29 (07), pp.895-907. 10.1080/09500690600969830 . hal-00513326

HAL Id: hal-00513326

<https://hal.science/hal-00513326>

Submitted on 1 Sep 2010

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Slovakian students' knowledge of and attitudes toward biotechnology

Journal:	<i>International Journal of Science Education</i>
Manuscript ID:	TSED-2006-0089.R2
Manuscript Type:	Research Paper
Keywords:	university, biotechnology education
Keywords (user):	attitudes, biotechnology, Slovakia



Introduction

The importance of science and technology education continues to increase its impact on peoples' everyday life (Lappan, 2000). Public perception of some controversial technologies indicates their association with technological risk (Fischhoff, Slovic, & Lichtenstein, 1978). Biotechnology includes genetic modification that can be briefly defined as follows: 'Genetic modification concerns the transportation of genetic material from a living organism to another. These living organisms can be animals, plants or micro-organisms. In food production, the use of genetic technology could enable the transfer of desirable characteristics from one living thing to another, leading to disease resistance in plants, etc.' (Saba & Vassalo, 2002, p. 14). Biotechnology can be viewed as a typical example of high perception of risk (Slovic, 1987). DNA technologies were perceived to be very similar to hazards such as nuclear energy, radioactive waste, electromagnetic fields, and other technologies that use rays or chemical substances (Savadori et al., 2004). Although several studies deny the possibility of serious health hazards from the use of genetically modified (GM) foods (Jones, Clarke-Hill, Hillier & Shears, 2000; Lopez & Carrau, 2002), GM foods and crops claim to offer a range of benefits to a variety of beneficiaries, including higher productivity and lower pesticide costs for consumers; less environmental pollution from pesticides and herbicides, and new crop varieties to ameliorate hunger in developing countries (Welser, 1991).

Even though the public perception of GM products is the centre of controversy (Busch, 1991; Aerni 2002), the majority of experts judge that the benefits outweigh possible risks-if indeed there is any risk at all. Therefore, the role of science curriculum is to prepare students to be citizens with basic knowledge about genetic engineering.

1
2
3 Research into people's understanding of and attitude toward biotechnology showed that
4
5 women are generally less accepting of genetically modified products than men (Mangusson &
6
7 Hursti, 2002; Moerbeek & Casimir, 2005). Age and educational differences are also presumed
8
9 to play an important role, although findings are very often contradictory (Baker & Burnhum,
10
11 2002; Dawson & Schibeci, 2004; Hamstra & Smink, 1996). Other important factors are
12
13 differences in policy and GMO legislation among countries. For example, while GM crops in
14
15 the European Union have not been commercially applied yet (Moerbeek & Casimir, 2005),
16
17 the USA is the home of an estimated 63 % of global GM crops (James, 2003). This results in
18
19 relatively more favourable attitudes of US consumers toward GM products in comparison
20
21 with people from the UK (Moon & Balasubramanian, 2004).

22
23 Attitudes and knowledge toward biotechnology in school age students have been relatively
24
25 less investigated in comparison with adult consumers. This is, however, a crucial stage of
26
27 research in this area because this may reveal insufficiency of science curricula or school
28
29 textbooks that are an important source of information on this topic (Martínez-Gracia, Gil-
30
31 Quílez, & Osada, 2003). Briefly, approximately 20-50 % of the 15 – 19 year old students
32
33 from the UK, Australia, and Taiwan have little understanding of biotechnology (Chen &
34
35 Raffan, 1999; Dawson & Schibeci, 2003; Gunter, Kinderlerer, & Beyleveld, 1998; Lock &
36
37 Miles, 1993). For example, 47 % of Lock and Miles's 16 year-old students failed to provide
38
39 any example of biotechnology. A similar proportion of students (52 %) could not give an
40
41 example of genetic engineering. About one-third of Taiwanese and UK students aged 16 – 18
42
43 could not define genetic engineering even about half of them were studying A level biology
44
45 (Chen & Raffan, 1999). Comparable results have been currently reported from large sample
46
47 (1116 students) of students surveyed in the Australia. About 20 – 30 % of students could not
48
49 provide an example of genetic engineering, biotechnology, cloning or genetically modified
50
51 foods (Dawson & Schibeci, 2003).
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6 To date, no study was focused on the investigation of students' knowledge of and attitude
7
8 toward GMO in Slovakia. In addition, Slovakia is a relatively conservative country where
9
10 distribution of GM foods is banned by law. Thus, Slovak people are not constrained by
11
12 everyday decisions to buy or not to buy GM foods labelled as "*This products is produced*
13
14 *from genetically modified organisms*" (Pew Initiative on Food and Biotechnology, 2003).

15
16
17 However, media that seem to be an important source of students' knowledge of biotechnology
18
19 (Dimopoulos & Koulaidis, 2003; Gunter et al., 1998) often reports discussions about genetic
20
21 engineering and biotechnology is a significant part of biology courses taught at Slovak
22
23 universities. Therefore, Slovakia is currently in a somewhat interesting situation which can be
24
25 changed totally after potential policy changes which will be less averse toward the use of GM
26
27 products.
28
29
30
31
32
33

34 **The link between knowledge and attitudes toward biotechnology**

35
36 Allport (1935, p. 820) defined attitude as 'mental and neural state of readiness to respond,
37
38 organised through experience, exerting a directive and/or dynamic influence on behaviour'.

39
40 Many psychologist (Bagozzi & Burnkrant, 1979; Eagly & Chaigen, 1993) have proposed that
41
42 attitudes have three components. The cognitive component refers to knowledge about the
43
44 objects, the beliefs. The affective component includes feeling about object and its assessment
45
46 is performed using psychological indices (heart rate). The behavioural component pertains to
47
48 the ways people act toward the object.
49
50
51

52
53 Overall, it has been established that attitudes tend to be consistent and stable with time.

54
55 Nonetheless, despite this stability, they are open to some change and development, although
56
57 deeply held attitudes are highly internalised and are resistant to change (Reid, 2006).
58
59
60

1
2
3 A significant relationship between knowledge and attitudes has been found in several studies
4
5 (DiEnno & Hilton, 2005; Tikka, Kuitunen, & Tynys, 2000; Weaver, 2002). It is generally
6
7 appreciated that links between knowledge and attitudes exist. However, there are conflicting
8
9 findings on whether an increasing understanding of biotechnology results in a change of
10
11 students' attitudes about the use of biotechnology (Dawson & Schibeci, 2004). For example,
12
13 Lock, Miles and Hughes (1995) found that after teaching about biotechnology, knowledge of
14
15 16 year old students significantly increased and their attitudes toward biotechnology were
16
17 more positive. Chen and Raffan (1999) found that students studying A-level biology had more
18
19 positive attitudes toward biotechnology than those not studying biology. Dawson and Schibeci
20
21 (2004) also found that greater awareness of biotechnology resulted in more positive attitudes
22
23 toward them. Although these data seem to be convincing, it should be noted that it is unclear
24
25 what attitudes toward biotechnology had biology students *before* they attended to study
26
27 biology (Dawson & Schibeci, 2004). In another research, Dawson and Taylor (1999)
28
29 examined the effect of a 10 week transplantation course that introduced students to issues
30
31 associated with transplantation and bioethical principles. Using both a pretest/posttest and a
32
33 control group, they failed to find any significant differences between groups. Hill, Stanisstreet,
34
35 Boyes, and O'Sullivan (1998) compared differences in attitudes and knowledge among 16 –
36
37 19 year old students with and without 'A' level biology. They found that students with 'A'
38
39 level biology students had more knowledge about genetic engineering than those without
40
41 biology and tended to more likely affirm statements about possible advantages of genetically
42
43 modified foodstuffs. However, these authors conclude that these differences in students'
44
45 attitudes about genetic engineering were not concerned in general, because some questions
46
47 did not show differences in distribution of students' responses. In sum, there are few works
48
49 that examined differences in attitudes toward biotechnology between more and less aware
50
51 students empirically and very limited number of works that followed link between knowledge
52
53
54
55
56
57
58
59
60

1
2
3 and attitude experimentally. In addition, none of them have been conducted in Slovakia where
4
5 students' attitudes toward biotechnology remain to be studied.
6
7
8
9

10 11 **Purpose**

12
13 Slovakian university students who have been studying to become primary and secondary
14
15 teachers toward biotechnology were the subjects of this research. This paper explores the
16
17 following questions: What is the extent of Slovak university students' knowledge of and
18
19 attitudes toward biotechnology? Is there any relationship between students' knowledge of and
20
21 their attitudes toward biotechnology? Are there any gender differences in knowledge of and
22
23 attitudes toward biotechnology?
24
25
26
27

28 29 **Methods**

30
31 The study was conducted between October and December 2005. A total of 378 students (302
32
33 females, 72 males and four failed to provide some of their personal data) attending three
34
35 different universities in Slovakia participated in the study. Because our research was
36
37 conducted in educational faculties where strong female-bias in Slovakia historically exists, it
38
39 was impossible to adjust female to male ratio more accurately. The age of students ranged
40
41 from 18 to 25 (mean age was 20.7, SD = 1.68); only one student was 33 years old. Students
42
43 have been studying to become primary or secondary school teachers. They study various
44
45 disciplines while a significant part of them (217 of 378) enrolled in biology courses at various
46
47 levels. First year students (103 out of 195) just started to study university biology, so they
48
49 were experienced mostly in general biology course which include DNA replication, mutation,
50
51 proteosynthesis, but no topics are directly related to biotechnology. In contrast, secondary pre-
52
53 service teachers (114 out of 183) were experienced with genetics which includes genetic
54
55 engineering in general. Although they did not study biotechnology explicitly, they can be
56
57
58
59
60

1
2
3 expected to be better informed about biotechnology compared to students who do not study
4
5 any biology. The remaining 159 students enrolled mostly in humanities disciplines, and two
6
7 failed to provide this information. Because the sample contained more and less students
8
9 potentially aware about biotechnology, it allows us to compare more (enrolling biology
10
11 course) and less (students enrolling humanities) educated students in terms of their attitude
12
13 and knowledge of biotechnology.
14
15

16 17 18 19 20 *Instrument*

21
22 A 17 Likert-type Biotechnology Attitude Questionnaire (BAQ) items and 16 Likert-type
23
24 Biotechnology Knowledge Questionnaire (BKQ) was used to examine students' knowledge
25
26 and attitudes toward biotechnologies. Items were scored from 1 (strongly disagree) to 5
27
28 (strongly agree). As for statements representing a negative attitude, the score was reversed.
29
30 Items of each research tool were modified following several studies focusing similar topic
31
32 (namely, Arvanitoyannis and Krystallis, 2005; Lock and Miles, 1993; Olsher and Dreyfus,
33
34 1999; Priest, Bonfadelli and Rusanen, 2003; Subrahmanyam and Cheng, 2000; Wie, Strohhahn
35
36 and Hsu, 1998).
37
38

39
40 The translation of the questionnaire from English to Slovak proceeds as follows: A bilingual
41
42 speaker translated the English questionnaire into Slovak. A second bilingual speaker who was
43
44 also expert in this field translated the English version independently from the first one. Then
45
46 the two bilingual speakers consensually resolved the few resulting discrepancies between the
47
48 original English questionnaire and translated Slovak version.
49
50

51
52 The validity of the translated and adapted version of the questionnaire was established
53
54 through review by three experts in the field of genetics and biology education. All were asked
55
56 if the items in each dimension were relevant to the goal of the questionnaire. Revisions were
57
58
59
60

1
2
3 based on their comments and suggestions. The full version of the questionnaire is available
4
5 from the authors upon request.
6
7
8
9

10 *Reliability of the questionnaire*

11
12 Both BKQ (biotechnology knowledge questionnaire) and BAQ (biotechnology attitude
13 questionnaire) showed appropriate reliability (Cronbach's alpha = 0.69 and 0.76,
14
15 respectively). To examine relationship between BKQ and BAQ, split - half reliability and
16
17 correlation calculation between these two research tools, was applied. Guttman's split – half
18
19 correlation calculation between these two research tools, was applied. Guttman's split – half
20
21 reliability coefficient (0.68) and correlation between BKQ and BAQ was high (0.56) which
22
23 suggests significant relationship between knowledge and attitude toward biotechnology. In
24
25 addition, Cronbach's alpha calculated for BKQ and BAQ together also shows high internal
26
27 consistency between items ($\alpha = 0.82$). A graphical presentation of the relationship between
28
29 knowledge and attitudes toward biotechnologies is shown in Figure 1.
30
31
32
33
34
35

36 Insert Figure 1 somewhere here
37

38 Attitude items comprise from three dimensions; "Public awareness of genetically engineered
39 products" (4 items, $\alpha = 0.46$), "Control of genetic engineering" (8 items, $\alpha = 0.75$) and
40
41 "Shopping of genetically engineered products" (5 items, $\alpha = 0.72$). The Cronbach's alpha of
42
43 the first dimension is relatively lower, and some caution must be made when interpreting
44
45 these data.
46
47
48
49
50
51
52

53 *Analysis of students' knowledge of biotechnology*

54
55
56
57 Of the 16 biotechnology knowledge items only five were answered correctly by more than 50
58
59 % of participants (Table 1). Note that true items are marked 'T' and false items are marked
60

1
2
3 'F' in the table and were scored in the reverse order in further statistical comparisons (see
4
5 below). The same is valid for Table 2. The remaining 11 items were correct for 14 – 49 % of
6
7 students.
8
9

10 In general, the majority of students know that biotechnologies are associated with changes of
11
12 DNA that can result in productivity increase and organisms' resistance against diseases (Table
13
14 1).
15
16

17
18
19
20 *Insert Table 1 somewhere here*
21
22

23
24 Items with least frequent scores are shown in Table 2. About one third of students think that
25
26 GM organisms contain dangerous chemicals or do not know that genetic modification can
27
28 increase nutritional quality and/or taste of products (Table 2). Surprisingly, two-thirds of
29
30 students think, or do not know, if GM food can destroy human genes. A similar proportion of
31
32 students believes that GM organisms are always bigger than normal. Concrete substances
33
34 used in genetic modifications such as somatotropin were virtually unknown.
35
36
37
38
39

40
41 *Insert Table 2 somewhere here*
42
43
44

45
46 In order to examine what factors influence students' knowledge of biotechnology, analysis of
47
48 covariance (ANCOVA) with gender and enrolment in biology courses (factors), age
49
50 (covariate) and BKQ score (dependent variable) was used. A homogeneity-of-slopes GLM
51
52 analysis did not reveal significant interaction between factors (gender or enrolment in biology
53
54 courses) and age (covariate) which suggests that their age-related differences showed similar
55
56 trends among boys and girls and among more or less educated students. The effect sizes
57
58 analysis revealed medium power statistical test (Cohen's d for gender differences and for
59
60

1
2
3 enrolling biology course = 0.38 and 0.53, respectively) which suggest medium, but still
4
5 satisfactory power of the test. Males have statistically significantly better knowledge of
6
7 biotechnology than females (ANCOVA, $F_{1,366} = 10.6, p < 0.001$). Moreover, the students who
8
9 graduated from biology courses scored statistically significantly better than those that do not
10
11 (ANCOVA, $F_{1,366} = 23.9, p < 0.001$). Thus, both gender and biology course enrol
12
13 significantly affect students' knowledge of biotechnology, although an interaction between
14
15 these factors was only marginally significant ($F_{1,366} = 3.5, p = 0.06$). Detailed inspection of
16
17 marginally significant interaction between gender and biology course showed that males have
18
19 better knowledge only within a group that graduated from a biology course (Tukey HSD post-
20
21 hoc test, $p < 0.001$). No gender differences in group of students that did not graduate from
22
23 biology courses were found ($p > 0.76$).
24
25
26
27
28
29
30
31

32 *Analysis of students' attitude toward biotechnology*

33
34 Multivariate analysis of covariance (MANCOVA) was used to examine students' attitudes
35
36 toward biotechnology (N = 378 students entered analysis). Because biotechnology knowledge
37
38 among students greatly varied with respect to gender and biology course graduation, the score
39
40 from the BKQ was used as a covariate. Age was defined as a second covariate in order to
41
42 control for potential differences caused by age. Homogeneity-of-slopes GLM analysis did not
43
44 reveal any significant effects of covariates on factors which indicate that their effects across
45
46 subgroups was similar. Results indicate that males have a more positive attitude toward
47
48 biotechnology than females, regardless of whether they were enrolled in a biology course
49
50 (MANCOVA, $F_{3,364} = 3.3, p = 0.021$, see Fig. 2). The effect of knowledge was supported by
51
52 calculation of Pearson correlation coefficients between BKQ and each dimension of BAQ
53
54 score. We found that correlation coefficients ranged from 0.42 - 0.55, all were positive and
55
56 significant at least at 0.01 level. This means that better knowledge of biotechnology resulted
57
58
59
60

1
2
3 in more positive attitudes toward biotechnology. Because of the significant effect of BKQ on
4
5 BAQ score in all univariate tests presented below was found, we do not refer to it in further
6
7 text.
8
9

10 *Insert Figure 2 somewhere here*
11
12
13

14 *Students' attitudes toward public awareness of genetically engineered products*

15
16 To determine whether there was a statistically significant effect of gender, enrolment in
17
18 biology course, knowledge, or age, a univariate ANCOVA was used. None of these factors
19
20 statistically influenced students' awareness toward GM products. Analysis of means per
21
22 dimension (3.4 for females and 3.5 for males) suggest that attitudes were rather more neutral
23
24 than positive. Almost all (93 %) of students want to know more about GM products and,
25
26 consequently, only 3 % of all students agreed that the public is sufficiently informed about
27
28 risks associated with genetically engineered foods. About half of the students (49 %) imply
29
30 that the food industry takes necessary actions to provide safe genetically engineered foods.
31
32 Only 16 % of students thought that current governmental regulations are sufficient to protect
33
34 the public from risks associated with genetically engineered foods.
35
36
37
38
39
40
41
42

43 *Students' attitudes toward control of genetic engineering*

44
45 A univariate ANCOVA showed that females were statistically significantly more negative
46
47 responses toward genetic engineering than did males ($F_{1,366} = 7.27, p = 0.007$). About 50 % of
48
49 students are opposed to transfer of genetic material between animals and plants and similar
50
51 proportion (43 %) suggest that manipulations with DNA are unethical. The majority of
52
53 students (79 %) imply that advantages for biotechnologies in future are uncertain. Little more
54
55 than half of students were against altering genes in fruit to improve their taste (58 %) or to
56
57
58
59
60

1
2
3 make them stay fresh longer (54 %). A total of 39 % of students disagreed with production of
4
5 genetically modified plants.
6
7
8
9

10 *Students' attitudes toward shopping of genetically modified products*

11
12 A univariate ANCOVA showed that males were more accepting of shopping for genetically
13
14 modified products than females ($F_{1,366} = 9.4, p = 0.002$). Other effects remained not
15
16 statistically significant. Mean scores of most items were lower than 3 which suggest that
17
18 students' attitudes toward shopping of GM products are rather more neutral than positive.
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Slovakian students are generally not willing to buy GM food; only 13 % of students were
willing to buy genetically modified food; 42 % of students propose that consumption of GM
food is risky; and 21 % would like to consume genetically modified tomato. The majority of
students (89 %) focused on universally labelling GM products.

36 **Discussion**

37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Our results indicate that Slovakian university students have a poor knowledge of what
biotechnology processes mean. Students who enrol a biology course have a significantly
better knowledge of biotechnology and the level of knowledge positively correlates with
attitudes. However, as a result, Slovakian students (especially females) show less positive
attitudes toward biotechnology regardless of their knowledge about genetic engineering.
In general, the most negative attitudes were found in items related to control of genetic
engineering which probably resulted in reluctance against shopping of GM products. Both of
these seem to be in close relationship with knowledge of biotechnology. About half of the
students thought that genetic modification is painful for animals and another 41 % thought
that consumption of GM foods can destroy human genes. A high proportion of students who

1
2
3 incorrectly perceived the presence of dangerous chemicals in GM organisms (over half of
4 participants) clearly documents poor knowledge, probably resulting in negative attitudes
5
6 within these two dimensions.
7
8
9

10
11
12 These results are in strong contrast with those reported from the USA, where more familiar
13 attitudes toward GM products had been found (Wie et al., 1998). However, other research
14 reports from the European Union are more similar those found in our study, perhaps due to
15 the more conservative policy of the European Union toward biotechnologies (Herrick, 2005).
16
17
18
19

20
21
22 Few effects of educational level on attitudes toward biotechnology corroborate with Dawson
23 and Schibeci's (2004) finding from Australia and Chen and Raffan's (1999) report from UK
24 and Taiwan. They found that pupils studying biology were more knowledgeable than those
25 that were not studying biology. A similar trend was found by Hill et al. (1998) in 16 – 19
26 year old students from UK. Considering the significant correlation between attitudes and
27 knowledge found in our study, higher level of knowledge about biotechnology may result in
28 more positive attitudes (Chen & Raffan, 1999; Lock et al., 1995). However, students studying
29 biology expressed similar neutral/negative attitudes than those who did not study biology,
30 despite the fact that their scores from the biotechnology knowledge questionnaire were higher.
31 Because of similar findings that were also reported by Dawson and Schibeci (2004), we
32 suggest that lack of experiences with GM products in Slovakia could have a greater impact on
33 students' attitudes rather than the level of knowledge of biotechnology.
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52

53
54
55 Females' lower acceptance of biotechnology supports recent evidence that females have
56 different views on science (Jones et al., 2000, Miller, Blessing, & Schwartz, 2006),
57
58 technology and technological innovations (Cockburn & Ormrod, 1995). Gender differences
59
60

1
2
3 can be explained by the 'gender paradox' hypothesis (Moerbeek & Casimir, 2005) which
4
5 proposes that females have more tentative attitudes towards new products than males because
6
7 they buy food for children. Similar explanation for gender differences have been proposed by
8
9 Hill et al. (1998). Less knowledge about biotechnology identified in females might be an
10
11 additional co-factor of the gender differences in this study. However, some caution about
12
13 comparison of males/females is needed given the large disparity in numbers.
14
15
16
17
18
19

20 Slovakia is one of the youngest members of the European Union (since 2005). Following its
21
22 current policy, legalization of genetically engineered products in the near future can be
23
24 expected. Thus, the public needs to be aware of this subject. The current Slovak science
25
26 curriculum with respect to the presentation of genetic engineering should be therefore re-
27
28 evaluated, and students' scientific literacy in this area must be greatly improved. We suggest
29
30 that more biotechnology information sources, such as *Biotechnology Online*
31
32 (www.biotechnology.gov.au) in Australia (Dawson & Schibeci, 2004) may help teaching
33
34 about genetic engineering to be more effective. Science teachers' views of genetic
35
36 engineering should not be neglected but further investigation in this topic is needed.
37
38
39
40
41
42

43 **Acknowledgement**

44
45 We would like to thank Professor David Treagust and two anonymous referees for their
46
47 helpful comments on earlier draft of the manuscript.
48
49
50
51
52
53

54 **References**

55
56
57
58
59
60

- 1
2
3 Aerni, P. (2002). Stakeholder attitudes toward the risks and benefits of agricultural
4 biotechnology in developing countries: a comparison between Mexico and the Philippines.
5 *Risk Analysis*, 22(6), 1123–1137.
6
7
8
9
10 Allport, G. W. (1935). Attitudes. In C. M. Murchison (Ed.), *Handbook of social psychology*
11 (pp. 798 – 844). London, OUP.
12
13
14 Arvanitoyannis, I. S., & Krystallis, A. (2005). Consumers' beliefs, attitudes and intentions
15 towards genetically modified foods, based on the 'perceived safety vs. benefits' perspective.
16 *International Journal of Food Science and Technology*, 40(4), 343–360
17
18
19
20
21 Bagozzi, R. P., & Burnkrant, R. E. (1979). Attitude organisation and the attitude-behaviour
22 relationship. *Journal of Personality and Social Psychology*, 37, 913–929.
23
24
25
26
27 Baker, G. A., & Burnhum, T. A. (2002). The market for genetically modified foods: consumer
28 characteristics and policy implications. *International Food and Agribusiness Management*
29 *Review*, 4, 351–360.
30
31
32
33
34 Busch L. (1991). Biotechnology: consumer concerns about risks and values. *Food*
35 *Technology*, 45(4): 96, 98, 100–101.
36
37
38
39 Chen, S. Y., & Raffan, J. (1999). Biotechnology: student's knowledge and attitudes in the UK
40 and Taiwan. *Journal of Biological Education*, 34(1), 17–23.
41
42
43
44 Cockburn, C., & Ormrod, S. (1995). *Gender and Technology in the Making*. Sage
45 Publications, London.
46
47
48
49 Dawson, W., & Schibeci, R. (2003). Western Australian school students' understanding
50 of biotechnology. *International Journal of Science Education*, 25(1), 57–69.
51
52
53
54 Dawson, W., & Schibeci, R. (2004). Western Australian high school students' attitudes
55 toward biotechnology processes. *Journal of Biological Education*, 38(1), 7–12.
56
57
58
59 Dawson, W., & Taylor, P. C. (1999). Teaching bioethics in science: Does it make
60 a difference? *Australian Science Teachers' Journal*, 45, 59–64.

1
2
3 DiEnno, C. M., & Hilton, S. C. (2005). High school students' knowledge, attitudes, and levels
4 of enjoyment of an environmental education unit on nonnative plants. *Journal of*
5
6 *Environmental Education* 37, 13–25.

7
8
9
10 Dimopoulos, K., & Koulaidis, V. (2003). Science and technology education for citizenship:
11
12 the potential role of the press. *Science Education*, 87(2), 241–256.

13
14
15 Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Brace Jovanovich.

Fischhoff, B., Slovic, P., & Lichtenstein, S. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sciences*, 9, 127–152.

Gunter, B., Kinderlerer, J., & Beyleveld, D. (1998). Teenagers and biotechnology: a survey of understanding and opinion in Britain. *Studies in Science Education*, 32, 81–112.

Hallman, W. K. (1996). Public perceptions of biotechnology: another look. *BIO/TECHNOLOGY*, 14, 35–38.

Hamstra, A. M., & Smink, C. (1996). Consumer and biotechnology in the Netherlands. *British Food Journal*, 98, 34–38.

Herrick, C. B. (2005). 'Cultures of GM': discourses of risk and labelling of GMOs in the UK and EU. *Area*, 37(3), 286–294.

Hill, R., Stanisstreet, M., Boyes, E., & O'Sullivan, H. (1998). 'Reactions to the new technology: students' ideas about genetically engineered foodstuffs'. *Research in Science & Technological Education*, 16(2), 203–16.

James, C. (2003). Executive summary: global status of commercialized transgenic crops 2003 *Report of the International Service for the Acquisition of Agri-Biotech Applications* (<http://www.isaaa.org>) Accessed 2 October 2003

Jones, P., Clarke-Hill, P., Hillier, D., & Shears, P. (2000). Food retailers' response to GM controversy within the UK. *British Food Journal*, 102, 441–448.

1
2
3 Jones, M. G., Howe, A. & Rua, M. J. (2000). Gender differences in students' experiences,
4 interests, and attitudes toward science and scientists. *Science Education*, 84(2), 180–192.
5

6
7 Lappan, G. (2000). A vision of learning to teach for the 21st century. *School Science and*
8
9
10
11 *Mathematics 100*, 319–325.

12
13 Lock, R., & Miles, C. (1993). Biotechnology and genetic engineering: students' knowledge
14 and attitudes. *Journal of Biological Education*, 27(4), 267–273.
15

16
17 Lock, R., Miles, C., & Hughes, S. (1995). The influence of teaching on knowledge and
18 attitudes in biotechnology and genetic engineering contexts: implications for teaching
19 controversial issues and the public understanding of science. *School Science Review*,
20
21
22
23
24
25
26 76, 47–59.

27
28 Lopez, R. C., & Carrau, J. G. (2002). The GMO regulation in the EU and the commercial
29 conflict with the U.S. Paper presented in the Xth EAAE Congress. *Exploring diversity in the*
30
31
32
33 *European Agri-Food system*. 28-31 August, Zaragoza.

34
35 Mangusson, M. K., & Hursti, U. K. (2002). Consumer attitudes towards genetically modified
36 foods. *Appetite*, 39, 9–24.
37

38
39 Martínez-Gracia, M. V., Gil-Quílez, J., & Osada, M. J. (2003). Genetic engineering: a matter
40 that requires further refinement in Spanish secondary school textbooks. *International Journal*
41
42
43
44
45 *of Science Education*, 25(9), 1147–1168.

46
47 Miller, P. H., Blessing, J. S. & Schwartz, S. (2006). Gender differences in high-school
48 students' views about science *International Journal of Science Education*, 28(4), 363–381.
49

50
51 Moerbeek, H., & Casimir, G. (2005). Gender differences in consumers' acceptance of
52 genetically modified foods. *International Journal of Consumer Studies*, 29(4), 308–318.
53

54
55 Moon, W., & Balasubramanian, S. K. (2004). Public attitudes toward biotechnology: the
56 mediating role of risk perceptions on the impact of trust, awareness, and outrage. *Review of*
57
58
59
60 *Agricultural Economics*, 26(2), 186–208.

- 1
2
3 Olsher, G., & Dreyfus, A. (1999). The 'ostension-teaching' approach as a means to develop
4 junior-high student attitudes towards biotechnologies. *Journal of Biological Education*, 34(1),
5 25–31.
6
7
8
9
10 Pew Initiative on Food and Biotechnology (2003) *U.S. vs. EU: An Examination of the Trade*
11 *Issues Surrounding Genetically Modified Food*. Pew Initiative on Food and Biotechnology,
12
13
14
15 Priest, S. H., Bonfadelli, H., & Rusanen, M. (2003). The "trust gap" hypothesis: predicting
16 support for biotechnology across national cultures as a function of trust in actors. *Risk*
17 *Analysis*, 23(4), 751–766.
18
19
20
21
22 Reid, N. (2006). Thoughts on attitude measurement. *Research in Science & Technological*
23 *Education*, 24(1), 3–27.
24
25
26
27 Richmond. [WWW document]. URL [http://pewagbiotech.org/resources/issuebriefs/](http://pewagbiotech.org/resources/issuebriefs/europe.pdf)
28 [europe.pdf](http://pewagbiotech.org/resources/issuebriefs/europe.pdf).
29
30
31
32 Saba, A., & Vassalo, M. (2002). Consumer attitudes towards the use of gene technology in
33 tomato production. *Food Quality and Preference*, 13(1), 13–21.
34
35
36
37 Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert
38 and public perception of risk from biotechnology. *Risk Analysis*, 24(5), 1289–1299.
39
40
41
42 Slovic, P. 1987. Perception of risk. *Science*, 236(4799), 280–285.
43
44
45 Subrahmanyam, S., & Cheng, P. S. (2000). Perceptions and attitudes of Singaporeans toward
46 genetically modified foods. *Journal of Consumer Affairs*, 34(2), 269–290.
47
48
49 Tikka, P. M., Kuitunen, M. T., & Tynys, S. M. (2000). Effects of educational background on
50 students' attitudes, activity levels, and knowledge concerning the environment. *Journal of*
51 *Environmental Education*, 31(3), 12–19.
52
53
54
55 Weaver, A. A. (2002). Determinants of environmental attitudes. *International Journal of*
56 *Sociology*, 32(1), 77–108.
57
58
59
60

1
2
3 Welsch, J. R. (1991). An industrial perspective on biotechnology issues. *Food Technology*,
4
5 45(4), 102, 104, 107, 109.
6

7
8 Wie, S. H., Strohbehn, C. H., & Hsu, C. H. C. (1998). Iowa dietitians' attitudes toward and
9
10 knowledge of genetically engineered and irradiated foods. *Journal of the American Dietetic*
11
12 *Association*, 98(11), 1331–1333.
13
14

15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For Peer Review Only

Figure 1. A correlation between the knowledge and attitudes toward biotechnology found in Slovakian students (Pearson $r = 0.57$, $y = 3.095 + 0.897x$, $p < 0.001$, $N = 378$).

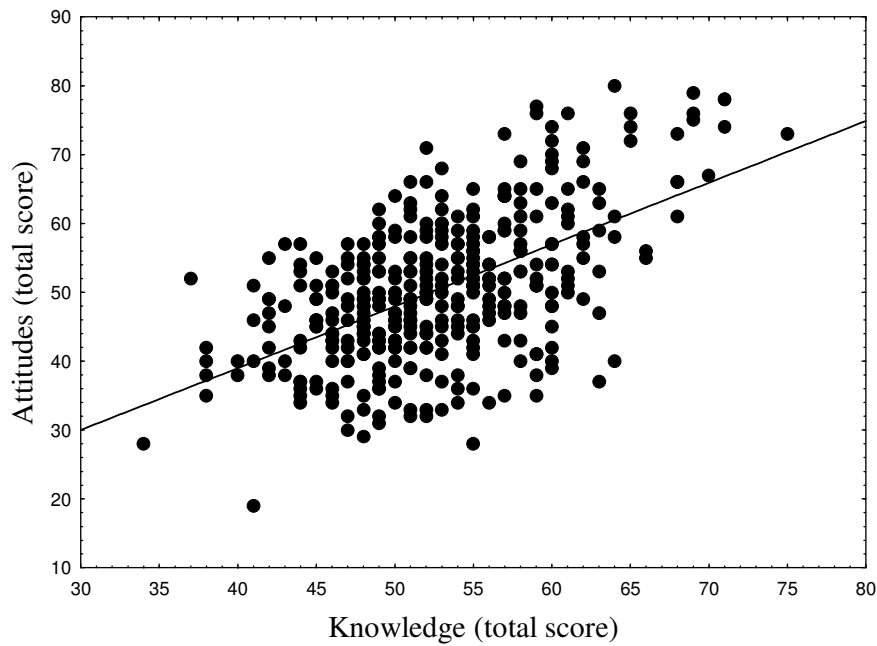


Figure 2. Differences between females (grey bars) and males (white bars) in attitudes toward biotechnology. Asterisks (**) denote statistically significant difference ($p < 0.01$).

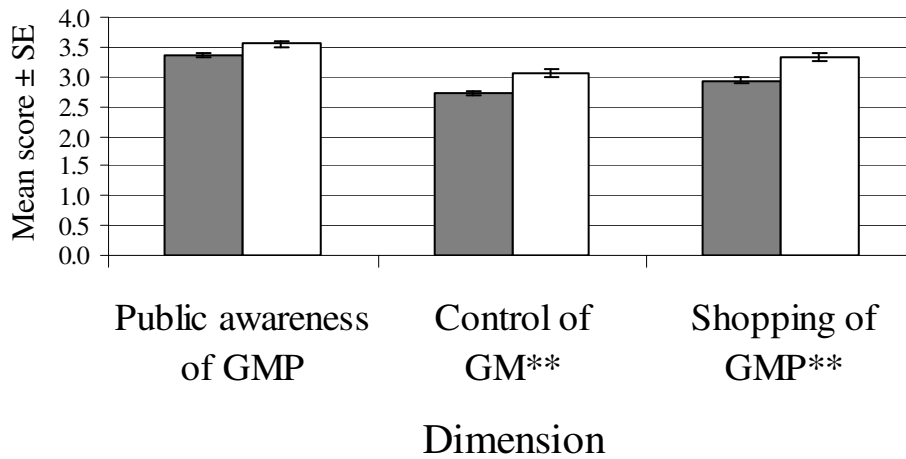


Table 1. Students' knowledge of biotechnology (N=378) .

	% Responded	% Disagree	
Items with most frequent correct responses	correctly		% Don't know
Practical application of GM plants may increase productivity and resistance of plants against diseases. (T)	77	14	9
Manipulation with DNA changes genes of GM organisms. (T)	77	9	14
Application of GM methods on animals can increase animal resistance against diseases. (T)	65	15	20
GM organisms are used in medicine (e.g. insulin production with GM microorganisms). (T)	65	8	27
Genetical modification is painful for animals. (F) [•]	51	12	37

• Negatively worded item; reverse scoring procedure used.

Items with least frequent correct responses are shown.

Table 2. Students' knowledge of biotechnology (N = 378).

	% Responded correctly	% Disagree	% Don't know
GM organisms contain many dangerous chemicals. (F) [•]	49	35	16
Genetical modification to plants can increase nutritional quality and flavour of fruits and develops traits to withstand shipping process. (T)	48	35	17
Foods with increasing nutritional value and vitamins can be created through genetic modification. (T)	48	27	25
Microbes should be genetically engineered to make them more efficient at decomposing human sewage. (T)	43	16	41
Consumption of GM food can destroy human genes. (F) [•]	38	41	21
GM crops are sterile. (F) [•]	38	21	41
GM organisms are always bigger than normal. (F) [•]	37	33	30
It is possible to transfer genetic material between dissimilar organisms, such as animals and plants, because DNA is chemically identical. (T)	33	41	26
GM modification of poultry results in greater	32	18	50

1
2
3 proportion of lean. (T)
4

5
6 Porcine somatotropin is a hormone active in
7
8 hogs that directs dietary energy away from fat
9
10 disposition toward production of lean muscle.
11

12
13 (T) 22 15 63
14

15 Recombinant bovine somatotropin is an animal
16
17 drug that increases milk produced by dairy
18
19 cows. (T) 14 8 78
20
21

22
23 • Negatively worded item; reverse scoring procedure used.
24

25 Items with least frequent correct responses are shown.
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60