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High-School Students' Knowledge of and Attitudes toward Biotechnology

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Abstract: *Perceptions regarding biotechnologies among high-school students have been too little researched compared to those of adults. In this paper, we present the results of an empirical research on high school students' knowledge and attitudes towards biotechnology. The objectives of the paper are: (1) Exploring the knowledge of Romanian high school students about biotechnologies; (2) Exploration of differences regarding perceptions related to biotechnologies based on gender, age, and profile variables; (3) Identifying the correlation between knowledge and attitudes regarding biotechnologies. The study participants were 111 high school students from the last two grades. The method used in our research was the questionnaire. The built tool was based on BKQ (Biotechnology Knowledge Questionnaire) (Prokop et al., 2007) and BAQ (Biotechnology Attitudes Questionnaire) (Erdogan et al., 2009). From the analysis of the results, the following conclusions emerged: (1). More than 50% of students have misconceptions about genetically modified organisms, and approximately 60% of students do not agree with the commercialization of products that use genetically modified materials. (2) There are differences regarding knowledge and attitudes related to biotechnologies, depending on gender, age, profile, specialization; (3). There is a positive correlation between high school students' knowledge and attitudes towards biotechnology.*

Keywords: *biotechnologies, knowledge, attitudes, high-school students.*

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Introduction

The application of science and technology to living animals and their components, products, or models to alter their structure in order to generate knowledge, goods, and services is known as biotechnology (OECD Policy Report, 2006). Some traditional biotechnological processes, such as the manufacture of wine, vinegar, bread, and yogurt, have existed for a long time. Biotechnology is becoming the primary technology of the twenty-first century, thanks to recent breakthroughs in proteomics and genomes (Arber & Brauchbar, 1998).

Biotechnology is a continuously developing field that requires responsible citizens who can face economic as well as social changes, and therefore, schools play a major role in their formation. In reviewing what the curriculum means in teaching for scientific literacy, Solomon (2002) notes that students need to be prepared to make democratic decisions on issues involving biotechnologies. As Lock et al. (1995) state, "we expect adults to play a full and responsible role in society, which involves applying the knowledge, understanding, and attitudes acquired through the study of science in everyday life." (p. 49)

Official curricular documents attest the role of education in the field of biotechnology. The national curriculum in England includes concepts of biotechnology ethics (Solomon, 2002), and in New Zealand, the national curriculum recognizes the importance of biotechnology, highlighting the social consequences of the implications that biotechnology presents (Conner, 2000). Thus, a new approach to teaching bioethics content has been introduced in the majority of state education programs (Dawson, 2001). Although education has begun to integrate biotechnologies into teaching, there are still shortcomings regarding the way these fields are taught, as biotechnologies involve numerous ethical, social, and moral aspects (Conner, 2000).

Research on the perceptions and understanding of biotechnology among school-aged children has been less extensive than studies on adults. However, this research is essential as it could highlight gaps in curricula or science textbooks, which are key sources of information on this subject (Martínez-Gracia et al., 2003). Miller (1998) suggests that formal education is the most effective way for individuals to acquire scientific knowledge and improve their understanding of science and technology. Moreover, both pre-university and university education are considered essential for the development of scientific literacy among the public (Miller, 1998).

In Romania the distribution and commercialization of genetically modified foods are prohibited by law. From a curricular perspective, Romanian students have the opportunity to learn about biotechnologies in a scientific way, sometimes in biology and possibly chemistry, but without a specific focus, somewhat coincidentally. At technological high schools there are a few specialized subjects, but they are not part of the common core of all students. However, we consider that these curricular practices are insufficient, which leads to many misconceptions and prejudices in relation to the field of biotechnologies. The transition from empirical to scientific knowledge about biotechnologies can be achieved with great difficulty for Romanian students - if not at all - which is deeply unfair for the future roles they will have to play in society. Our research aims to investigate the level of minimal knowledge of high school students regarding biotechnologies, in parallel with the exploration of attitudes regarding biotechnologies. There is no previous research investigating the knowledge and attitudes of students in Romania towards genetically modified organisms. We appreciate this to be a first step towards the curricular design of scientific literacy in the area of biotechnologies. With this research, we align ourselves with the international efforts to improve the level of scientific knowledge of today's students.

Previous research

Several opinion polls have been conducted among high school students regarding their attitudes towards biotechnology. Prokop et al. (2007) have concluded that students encounter obstacles in understanding this field and are only familiar with aspects related to microorganisms used in biotechnology, biotechnological methods used in medicine, and that biotechnology is associated with DNA modifications. The least understood topics in biotechnology refer to genetically modified organisms and the uses of this science in food. Additionally, students have difficulty defining genetic engineering and cloning (Dawson, 2007; Prokop et al., 2007).

Multiple research (DiEnno & Hilton, 2005; Weaver, 2002) have found a notable connection between knowledge and attitudes. Overall, it is commonly accepted that there is a relationship between the two. However, there are differing conclusions about whether an increased understanding of biotechnology actually changes students' attitudes toward its use (Dawson & Schibeci, 2003b). For instance, Lock et al. (1995) discovered that after learning about biotechnology, 16-year-old students showed a significant increase in knowledge and developed more positive attitudes towards biotechnology. Similarly, Chen & Raffan (1999) found that students who took biology as an A-level subject obtained more favorable attitudes towards

biotechnologies compared to those who did not take biology as a subject. Dawson & Schibeci (2003b) also demonstrated that the more knowledge about biotechnology, the more positive students' attitudes. Although these findings appear compelling, it is important to note that students' attitudes toward biotechnology prior to studying biology remain unclear.

Dawson & Schibeci (2003a) surveyed 1,116 Australian secondary school students to assess their knowledge of recent advances in modern biotechnology. The study involved a questionnaire designed to assess students' understanding and attitudes towards a range of known biotechnological innovations in the fields of cloning, genetically modified foods (GM foods, abbreviated) and genetic engineering. In this research, attitudes were measured by how students found these biotechnologies. Students were asked to express whether they consider certain biotechnological processes acceptable and to explain their reasons. The survey consisted of six questions. About a third of the students showed limited knowledge of biotechnology, while another third could not provide an example of an application of biotechnology.

A multi-year study by Dawson & Schibeci (2003b) showed that students have a wide variety of beliefs about the applications of biotechnology. In another study, Verdurme & Viaene (2003) explored public beliefs about genetically modified foods, focusing on perceptions of their risks and benefits, which were influenced by knowledge and attitudes toward genetically modified foods. In the survey with 400 GM foods users, they were asked about the dangers, advantages and their conceptions of genetically modified food, attitudes towards science, trust in the government and their intentions to buy genetically modified. The findings indicated that higher levels of knowledge did not lead to greater acceptance of GM foods.

The largest global study of consumer attitudes towards biotechnology was undertaken by Environics International (2000). More than 35,000 people from 35 countries around the world were surveyed to determine whether they believed the benefits of biotechnology outweighed the risks. Participants were also asked whether they were for or against the use of biotechnology in various fields. The results show that almost all participants (85%) supported the use of biotechnology to develop new medicines. Almost 75% were in favor of using biotechnology to protect the environment, 55% supported genetically modified animal feed and 42% supported the use of biotechnology for the purpose of medical cloning.

Study objectives

In this study we aimed to explore Romanian high school students' knowledge and attitudes towards biotechnology. The objectives of the paper are: (1). Exploring the knowledge of Romanian high school students about biotechnologies; (2). Exploration of differences regarding perceptions related to biotechnologies based on gender, age, and profile variables; (3). Identifying the correlation between knowledge and attitudes regarding biotechnologies.

The research questions were: 1. What is the level of Romanian high school students' knowledge about biotechnology? 2. Are there differences in perceptions of biotechnology according to the variables of gender, age, profile? 3. Can we identify a correlation between knowledge and attitudes?

Methodology

Participants

This study involved the participation of 111 students from two high schools in the north-eastern part of Romania. The participants are students in grades eleven and twelve. Their ages range from 15 to 18 years (n=98) and 18-21 years (n=13). In terms of gender, 63.1% belong to the female gender and 36.9% to the male gender.

Instrument and procedure

In this research we used the questionnaire method. The instrument used was built starting from two other tools identified in the specialized literature: *Biotechnology Knowledge Questionnaire (BKQ)* developed by Prokop et al. (2007) and *Biotechnology Attitudes Questionnaire* (BAQ) developed by Erdogan et al. (2009) in Turkey. We will describe each of them below.

Biotechnology Knowledge Questionnaire (BKQ) was included in a large study called "Slovakian Students' Knowledge of and Attitudes toward Biotechnology" (Prokop et al., 2007). This questionnaire consists of 16 Likert - type items, but in this study, we used only eight Likert-type items. Two of these questions were negatively worded and the scores were reversed before statistical analysis.

Biotechnology Attitudes Questionnaire (BAQ) was described in a study entitled "Development and Validation of an Instrument to Measure University Students' Biotechnology Attitude" (Erdogan et al., 2009). It contains 28 Likert-type items and 7 factors (consumption of genetically modified products, genetically modified products in agriculture, public awareness of genetically modified organisms, commercialization of

genetically modified products, ethics of genetic modification, ecological impact of genetic engineering and use of genetic engineering in human medicine). In this study we used only 13 of these items.

The questionnaire contains two sections, the first one consisting of five items about students' age, gender, stream, profile and specialization, and the second section contains 21 items, each with five response options, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire items were translated from English and then adapted to be understood by high school students. Their validity was also checked by a professor from the Faculty of Biology, University Alexandru Ioan Cuza Iasi.

The students completed the questionnaires in printed format and those with missing information were excluded from the statistical processing. The participants did not disclose personal information and gave their consent for the use of their responses for research purposes. Estimated time to complete the survey was 15 minutes.

Data Analysis

To process the answers to the questionnaires, we used the SPSS program, with a series of descriptive statistics such as averages, frequencies, percentages. Participants' answers to the knowledge questions were reported as correct or incorrect. Thus, students who gave answers as "strongly agree" and "agree" were considered as having correct answers, while those who gave answers "disagree" and "strongly disagree" were considered as ignorant. Participants' middle choices were perceived as uninformed responses.

Based on the results, we believe that participants' attitudes towards biotechnology and its applications should be correlated with their level of knowledge. Therefore, we calculated Pearson correlation coefficients on knowledge and attitudes. We used the Independent samples T-test to verify both the students' level of knowledge and their attitudes towards biotechnology uses by gender, age and high school stream. We also used the ANOVA test, for analysing the differences between the groups tested.

Results and discussions

Following the responses received, the data were entered into the SPSS statistical program and we performed a preliminary analysis, in which we measured the internal consistency of the scales and the Cronbach's Alpha index which is .789, and then we calculated different coefficients to verify the defined objectives (Table1).

Table 1. Items, mean and standard deviation

Items from BKQ and BAQ (Prokop et al. 2007; Erdogan et al., 2009)	Mean	Std. Deviation
1. Genetically modifying fruits to improve their taste is not acceptable to me.	3.08	1.415
2. I am against genetically modifying fruits and vegetables to make them stay fresh longer.	3.26	1.536
3. Eating genetically modified food is risky.	3.54	1.438
4. I would not give GM foods to children.	3.81	1.411
5. Eating GM foods can destroy human genes.	2.50	1.320
6. I support the use of genetic engineering if it helps to treat genetic diseases.	4.13	1.153
7. I agree with the use of food biotechnology to modify the genetic structure of plants to make them more resistant to insect damage, thus reducing the application of pesticides.	3.77	1.279
8. I agree with the use of plants into which genes have been inserted that increase quality and productivity.	3.50	1.271
9. I want to learn more about genetically engineered foods.	3.89	1.155
10. Applying genetic modification methods to animals can increase their resistance to disease.	3.69	1.212
11. The use of genetically modified varieties can increase plant productivity and disease resistance.	3.71	1.115
12. Genetic modification of plants can increase fruit flavor.	3.50	1.348
13. Genetically modified organisms contain many dangerous chemicals.	2.54	1.271
14. It is possible to transfer genetic material between different organisms, such as animals and plants, because DNA is chemically identical.	2.70	1.359
15. I trust that the food industry will take the necessary steps to provide safe GM food.	3.50	1.327
16. GM food does not influence human health.	3.01	1.443
17. I would eat GM tomatoes.	2.71	1.404
18. I think GM products taste better.	3.02	1.427
19. If I find out the product is made from genetically modified materials, I will buy it.	2.41	1.297
20. Inserting genes from human cells into fertilized sheep eggs is acceptable to me.	2.20	1.413
21. I support the use of genetic engineering for non-food purposes, such as drug production.	3.67	1.364

As we can see in Table 1, the three highest means had the items "I support the use of genetic engineering if it helps to treat genetic diseases ", "I want to learn more about genetically engineered foods" and "I would not give GM foods to children". Two of these items have a very strong social impact, referring to the value of health in the family.

Students' knowledge of biotechnology

The high school students questionnaire contains eight items testing knowledge about biotechnology and applications in this vast field. Two of these items (numbers 5 and 13) were wrongly worded to test the level of knowledge of high school students about the existence of risks associated with genetically modified organisms and products.

Table 2. Students' knowledge of biotechnology

Items from BKQ (Prokop et al. 2007)	Right answers (%)	Wrong answers (%)	"I don`t know" (%)
3. Eating genetically modified food is risky. (A)	57.6	27.9	14.4
5. Eating GM foods can destroy human genes. (F)	22.5	54	23.4
10.Applying genetic modification methods to animals can increase their resistance to disease. (A)	57.6	14.4	27.9
11. The use of genetically modified varieties can increase plant productivity and disease resistance. (A)	63	13.5	23.4
12. Genetic modification of plants can increase fruit flavor. (A)	54.9	22.5	22.5
13.Genetically modified organisms contain many dangerous chemicals. (F)	21.6	51.3	27
14. It is possible to transfer genetic material between different organisms, such as animals and plants, because DNA is chemically identical. (A)	26.1	41.4	32.4
16. GM food does not influence human health. (A)	37.8	38.7	23.4

A – right items
F – items were falsely worded; the score was reversed

According to the table above, for four out of the eight items, students answered correctly, with percentages above 50%. On the other hand, for the wrongly formulated items, the correct answers are not so numerous, with 22.5% and 21.6% of pupils respectively answering these questions wrongly. This is due to public fear of the risks posed by genetically modified products and organisms. Surprisingly, according to the results, high school students are aware of the implications of biotechnology in agriculture, answering correctly the items about the importance of using genetically modified varieties or plant species to resist diseases or to increase the flavor of fruit, with 57.6% and 54.9% of students respectively answering correctly.

However, it is noticeable that the answers associated with the conclusion "Don't know" are numerous for all questions. This reveals students' uncertainty about the uses of biotechnology.

To check whether there is a difference between 15-18- and 19–21-year-olds in their knowledge of biotechnology, we performed a statistical analysis using the independent samples t-test: $T = 2.205$, $sig = 0.030 < 0.05$ - there is a difference between 15-18 and 19-21 year olds in that 15-18 year olds ($M = 16.41$) have more knowledge of biotechnology than 19-21 year olds ($M = 14.07$).

In terms of gender differences between females and males, the T-test result suggests that there is a difference between girls and boys, in the sense that boys ($M = 17.17$) have more knowledge about biotechnology than girls ($M = 15.54$) ($T = 2.305$, $sig = 0.023 < 0.05$).

However, in terms of differences between students' streams (theoretical or technological), the statistical analysis suggests that there is no difference between theoretical and technological students, $T = 1.693$, $sig = 0.093 > 0.05$.

One of the questions in the first section was related to the high school profile attended by the students. Based on the answers received, we identified three profiles (human, real and technical) and analyzed the differences between them in terms of knowledge about biotechnology and applications in this field. For this purpose, we used the ANOVA test, which determined that there were significant differences between the groups tested in terms of the level of knowledge about biotechnology ($F = 12.40$, $p = 0.001 < 0.05$). The same approach was also used to determine whether there are differences between the specializations attended by students in the high school cycle (social sciences, natural sciences, mathematics-computing, philology, mathematics-computing intensive English, mathematics-computing bilingual English, veterinary technician, cook, confectioner). Thus, according to the obtained results ($F = 7.17$, $p = 0.001 < 0.05$), there

are significant differences between the students of the mentioned specializations in terms of their level of knowledge about biotechnology.

Student attitudes towards biotechnology

After centralizing the answers, we can appreciate that students do not agree with the consumption or commercialization of genetically modified products. However, they support the use of biotechnology in agriculture to improve the qualities of plant species, but also in medicine to create treatments for certain genetic diseases (Table 3).

Table 3. Student attitudes towards biotechnology

Items from BKQ and BAQ (Prokop et al. 2007; Erdogan et al., 2009)	Agreement (%)	Disagreement (%)	Whatever (%)
1. Altering the genes in fruits to improve their taste is not acceptable to me.	39.6	35.1	25.2
2. I am against altering genes in fruits and vegetables to make them stay fresh longer.	48.6	37.8	13.5
4. I would not give GM foods to children.	65.7	21.6	12.6
6. I support the use of genetic engineering if it helps to treat genetic diseases.	73.9	9	17.1
7. I agree with the use of food biotechnology to modify the genetic structure of plants to make them more resistant to insect damage, thus reducing the application of pesticides.	63	17.1	19.8
8. I agree with the use of plants into which genes have been inserted that increase quality and productivity.	50.4	20.7	28.8
9. I want to learn more about genetically engineered foods.	70.2	11.7	18
15. I trust that the food industry will take the necessary steps to provide safe GM food.	53.1	21.6	25.2
17. I would eat GM tomatoes.	31.5	45	23.4
18. I think GM products taste better.	40.5	42.3	17.1
19. If I find out the product is made from genetically modified materials, I will buy it.	20.7	58.5	20.7
20. Inserting genes from human cells into fertilized sheep eggs is acceptable to me.	19.8	63.9	16.2
21. I support the use of genetic engineering for non-food purposes, such as drug production.	57.6	19.8	22.5

According to the table above, more than 70% of high school students agree with the use of biotechnology in medicine for the treatment of some genetic diseases (M=4.13, SD=1.153). Nearly 60% of students disagree with commercialization of products made from genetically modified materials (M=2.41, SD=1.297), and over 65% would not give genetically modified food to children (M=3.81, SD=1.411). However, over 70% of surveyed high school students would like to know more about genetically engineered foods (M=3.89, SD=1.155).

To analyze whether there are differences between students aged 15-18 and 19-21, we used independent samples t-test. From the results, we found that there were no significant differences between the two groups (M = 52.30, M = 49.53) in terms of attitudes towards biotechnology (T = 0.979, sig = 0.330 > 0.05).

We also analyzed whether there are differences between girls (M = 51.40) and boys (M = 52.97) in attitudes towards biotechnology, and the results are similar to the above in that there are no significant differences between these two groups (T = 0.836, sig = 0.405 > 0.05).

In terms of the high school stream that the students follow, we analyzed whether there are differences between students in the theoretical and technological streams. Following the results of the T-test, we can state that there are significant differences between these two groups in terms of attitude towards biotechnology (T = 2.527, sig = 0.013 < 0.05), in the sense that students from the theoretical stream have a positive attitude towards biotechnology (M = 53.03) than students from the technological stream (M = 47.20).

Using the ANOVA test, we analyzed the existence of differences in attitudes towards biotechnology between the profiles in which high school students are enrolled (humanities, real and technical). The results obtained (F = 6.310, p = 0.003 < 0.05) suggest that there are significant differences between these three groups.

Using the same statistical method, we analyzed whether there are differences between the students of the majors they follow (social sciences, natural sciences, mathematics-computing, philology, mathematics-computing intensive English, mathematics-computing bilingual English, veterinary technician, cook, confectioner-baker). Thus, according to the obtained results (F = 3.199, p = 0.003 < 0.05) we can state that there are differences between these groups in terms of attitude towards biotechnologies.

Relationship between knowledge and attitudes towards biotechnology

In order to identify a correlation between the participants' knowledge about biotechnology and their attitudes towards the uses of this science in different fields, we calculated correlation coefficients. Following the results obtained, $r = 0.653$, $p = 0.001 < 0.05$, we can state that there is a statistically significant positive correlation between knowledge and attitudes, in the sense that participants who have knowledge about biotechnology also have positive attitudes towards this field and its applications, and reciprocally, students who have no knowledge about biotechnology topics have a worrying attitude towards applications in this field. This can also be seen in the graphical representation showing the relationship between knowledge and attitudes towards biotechnology (Figure 1).

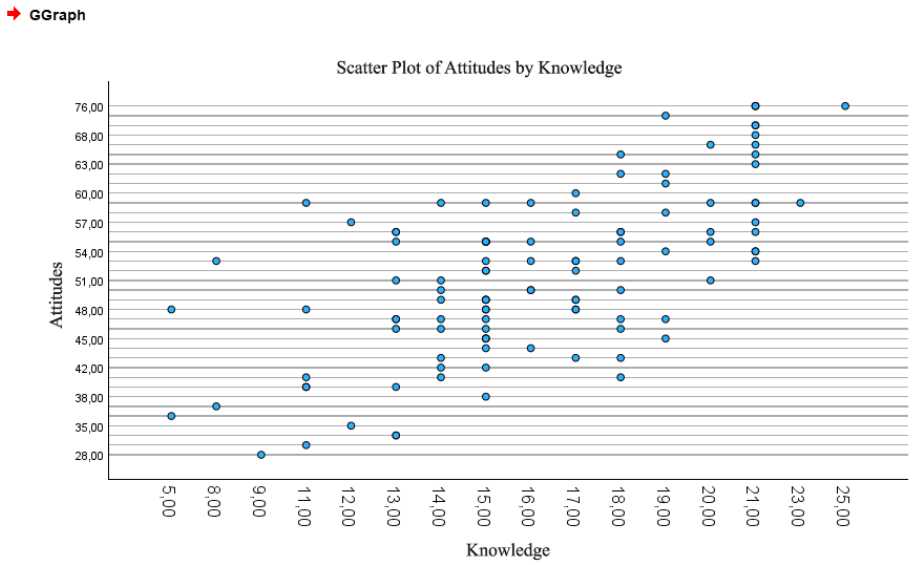

Figure 1. Correlation between knowledge and attitudes towards biotechnology

Conclusions and recommendations

In this paper, we studied the knowledge and attitudes of Romanian high school students regarding biotechnology and its applications. Thus, we designed and conducted a research study on the correlation between knowledge and attitudes regarding biotechnology among high school students, in which we used the questionnaire method. Following the centralization and processing of the responses, the obtained results suggest

that over 50% of students have misconceptions about genetically modified organisms, and approximately 60% of students do not agree with the commercialization of products that use genetically modified materials. However, over 50% of students are aware of the implications of biotechnology in agriculture, and over 70% support the use of biotechnology in medicine. Regarding the gender variable, boys have more knowledge about biotechnology than girls, but concerning their attitudes towards biotechnology, there are no significant differences between girls and boys. Thus, it has been proven that there is a positive correlation between knowledge and attitudes, in the sense that students with more knowledge about biotechnology have positive attitudes towards the implications and uses of this field in various domains.

We can conclude that due to the complexity of the subject related to biotechnologies, the content about this field must be approached in an organized manner by teachers, so that students are aware of both the positive aspects of biotechnologies and the risks. In this regard, a revision of the curriculum is necessary, which must include concrete and up-to-date information. In addition, it is recommended to organize discussions on these biotechnology-related topics so that students can acquire information to be able to support their arguments in various discussions. This contributes to the formation of responsible adults who are capable of making decisions.

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