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The importance of education of future elementary teachers about modern biotechnology issues

Pomen izobraževanja bodočih učiteljev razrednega pouka o biotehnologiji

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Abstract: The tremendous development of science and technology has influenced many aspects of our everyday lives, society and environment. A good example of such technology is biotechnology. However, besides its promise, this technology has also raised several controversial issues to which answers are not easily available. With increasing knowledge and applications on one side and controversy on the other the teaching of science is, anything but easy. Development of competencies for these issues, and questions like why, when, and how to integrate modern biotechnology into science education are becoming prominent in the near future. Nowadays, when we are confronted with issues of varying degrees of complexity and importance, it is necessary that teachers at all levels of education have the basic tools to cope with these issues. This is one of reason why we have attempted to establish what kind of knowledge, values and opinions about genetic engineering and genetically modified organisms (GMOs) are characteristic for the students, future Elementary Teachers, at three Slovene Faculties of Education. We collected answers of 360 questionnaires from pre-service elementary school teachers and analysed their statements from the field of general and classical genetics, modern biotechnology, legislation and the acceptance of different kind of GMOs. Prospective teachers have some knowledge of general and classical genetics and less knowledge about the use of modern biotechnology. They have concerns and fears about different kind of GMOs, mostly negative attitudes towards different kinds of GMOs, or they hold no strong opinions about them. Micro-organisms and plants are generally more acceptable than GM animal. Furthermore, more knowledge does not mean that individual GMOs are more acceptable.

Keywords: genetically modified organisms, GMO, students of elementary education

Abbreviations: GMO – genetically modified organism; GM – genetically modified

Izvleček: Izjemen razvoj znanosti in tehnologije vpliva na številne vidike vsakdanjega življenja posameznika, družbe in okolja. Dober primer tovrstne tehnologije

je biotehnologija. Poleg številnih obetov so s to tehnologijo povezana nekatera sporna vprašanja, na katera ni enostavnih odgovorov. Povečevanje znanj in uporabe na eni in polemik, na drugi strani, je razlog, da je poučevanje biotehnologije vse prej kot lahko. Kako usposobiti bodoče učitelje za obravnavo takih in podobnih tem in zakaj, kdaj in kako vključiti sodobno biotehnologijo v izobraževanje postaja pomembno za bližnjo prihodnost. Zato je nujno, da bi bili učitelji na vseh ravneh izobraževanja usposobljeni za obravnavo takih in podobnih tem. To je bil tudi eden od razlogov, zakaj smo želeli ugotoviti, kakšno je znanje, kakšne so vrednote in mnenja o genskem inženiringu in gensko spremenjenih organizmih (GSO) študentov, bodočih osnovnošolskih učiteljev treh slovenskih pedagoških fakultet (Univerze v Mariboru, Univerze v Ljubljani, Univerze na Primorskem). Zbrali smo odgovore anketnih vprašalnikov 360 bodočih učiteljev razrednega pouka, v katerih so se bodoči osnovnošolski učitelji opredelili do trditev s področja splošne in klasične genetike, moderne biotehnologije, zakonodaje ter sprejemanja različnih GSO. Bodoči učitelji razrednega pouka imajo nekaj znanja o splošni in klasični genetiki in manj znanja o uporabi moderne biotehnologije, velikokrat slabo sprejemajo različne GSO ali nimajo jasno izraženega mnenja o njih, pri čemer so mikroorganizmi in rastline v splošnem bolj sprejemljivi kot GS živali. Več znanja nikakor ne pomeni, da so posamezni GSO bolj sprejemljivi.

Ključne besede: genetsko spremenjeni organizmi, GSO, študenti razrednega pouka

Okrajšave: GSO – genetsko spremenjen organizem; GS – genetsko spremenjen

Introduction

The tremendous development of science and technology has influenced many aspects of our everyday lives, society and environment. A good example of such technology is biotechnology. It is not a recent invention, and humans have used it for centuries. The making of wine, beer, yogurt, cheese and bread, for example, involve ancient biotechnology techniques that have enabled the progress of civilization. Increasing advances in this discipline, such as recombinant DNA technology and the manipulation of genes, as well as the introduction of genes into more or less related organism, the same or different plant and animal species or other organism, to obtain genetically modified organisms (GMOs), have produced many powerful applications and have great potential for future discoveries. However, besides its promise, this technology has also raised several controversial issues (food from GMOs, therapeutic and reproductive cloning, surrogate maternity, potential cloning of people, and the potentially harmful influence of GMOs on the health of people, animals, other organisms and the environment) to which answers are not easily available. The consequence of such issues, called socio-scientific issue (Sadler 2004, Sadler and Zeidler 2005a, Sadler and Zeidler 2005b), is that the transfer of biotechnology discoveries to crop production, industry or medicine is not restricted only by the technological limitations, underdeveloped scientific methods, or modes of scientific reasoning, but also by ethics, morals, faith, the economy, environmental responsibility, risks, politics, etc. (Christoph et al. 2008, Flores and Tobin 2002, Steward and McLean 2005, Yunta et al. 2005). With increasing knowledge and applications on one side and controversy on the other the teaching of science is, anything but easy (Harms 2002). Questions like why, when and how to integrate biotechnology into science education will become prominent in the near future.

The development of opinions and values is a lifelong process originated in early childhood and influenced by school practice; it is not immune to the values, opinions and knowledge of teachers. The formation of values in the case of socio-scientific issues is not at the center of teacher education, and future teachers often construct their

value system about these issues without relevant professional foundations (Ambrožič-Dolinšek and Šorgo 2009). Nowadays, when we are confronted with issues of varying degrees of complexity and importance, it is necessary that teachers at all levels of education should have the basic tools to cope with them (Ambrozic-Dolinsek and Šorgo 2009, 2010).This is one of reason why we have attempted to establish what kind of knowledge, values and opinions about genetic engineering and genetically modified organisms (GMOs) are characteristic of students, future elementary teachers at three Slovene Faculties of Education: University of Maribor (PeFMb), University of Ljubljana (PeFLj) and University of Primorska (PeFKp). Our results could potentially be included in the undergraduate curriculum for the education of future and current elementary teachers.

Material and methods

We collected 360 questionnaires from students, future elementary teachers at three Slovene Faculties of Education (University of Maribor (PeFMb), University of Ljubljana (PeFLj) and University of Primorska (PeFKp)) in the academic year 2007/2008.

To find out student teachers' knowledge and opinion about GMOs, a questionnaire was assembled. The questionnaire was divided into two parts: (1) knowledge, and (2) acceptance about GMO and was completed anonymously. Knowledge concerning genetics, biotechnology and GMO was evaluated through a questionnaire consisting of 30 true–false statements (Table 1). Teachers had to choose among three options: yes; do not know; no.The correct answer on 17 statements was 'yes' and on 13 statements 'no', a device which prevented guessing. The statements could be assigned to general and classical genetics, modern biotechnology and legislation. The reliability of the questionnaire, expressed as Cronbach's alpha, was 0.827, which can be recognized as good. In Table 1 frequencies and percentages of correct, incorrect, and do not know answers are reported.

Furthermore we tried to establish the degree of acceptance of different kinds of GMO uses in possible real life situations, so we provided statements about various GMOs – microorganisms, plants and animals (Table 2). Acceptance of GMOs was evaluated with a closed questionnaire, where teachers were asked to choose among 17-items consisting of existing or potentially-existent GMOs and in such way to express their opinion about these. We provided three answers: 1- acceptable; 2 – don't know, do not have an opinion; 3 – not acceptable. The reliability of the questionnaire, expressed as Cronbach's alpha, was 0.869, which can be recognized as good.

Analysis of the results followed three tracks and the statistical package SPSS® 18.0 was used for data analysis. Chi-square (χ^2) statistics were used to identify differences in frequencies of answers from two general fields: first from the statements from general genetics and the statements from classic and modern biotechnology and legislation and the second from statements about acceptance of different kind of GMOs. To correlate their answers, the Pearson correlation coefficient was used. Symbols used in the figures are: ns denote statistically insignificant difference.

Results and discussion

Future elementary school teachers from three Slovenian universities (University of Maribor, University of Ljubljana, and University of Primorska) do have some basic knowledge of genetics (Table 1). They possess at least some knowledge about classical genetics and know something about genes, their structure, replication, expression and mutations. The majority of them correctly determined 9 among 14 (64.3%) statements, incorrectly determined 2 among 14 (14.3%) statements and do not know 3 among 14 (21.4%) statements. However, we should not be satisfied with observed knowledge. For example, some of them believe that a cat can fertilize a female rabbit, and they do not know that the broad use of vegetative propagation in plants is a kind of cloning.

The picture changed when they had to choose the correct statements in the areas of modern biotechnology and legislation. We observed deficiencies in their knowledge about current applications of modern biotechnology, such as transmission of genes between organisms,

Table 1: Knowledge of future elementary teachers from three Slovene Faculties of Education about genetically modified organisms. The highest frequencies of answers for individual statement are in bold.
Tabela 1: Znanje bodočih učiteljev razrednega pouka s treh Slovenskih pedagoških fakultet. Najvišje frekvence so označene s pisavo krepko.

	Statement	Correct answer	YES		NO		Do not know/ empty	
			N	%	N	%	N	%
	Knowledge about classical genetics							
1	Bacteria have the ability to mutually exchange genes.	Yes	52	15.2	46	13.5	243	71.3
3	Deoxyribonucleic acid (DNA) occurs only in genetically modified organisms.	No	13	3.8	**215**	**62.9**	114	33.3
4	Bacteria genes from yogurt that can be consumed can be incorporated into cells in the human organism.	No	45	13.2	119	34.8	**178**	**52.0**
5	Genes are sequences (of nucleotides) on chromosomes.	Yes	**183**	**53.5**	42	12.3	117	34.2
6	Genes are not normally transmitted from species to species in nature.	Yes	87	25.4	**166**	**48.5**	88	25.8
10	A cat can fertilize a female rabbit; the resulting young rabbits have shorter ears.	No	10	2.9	**227**	**66.4**	105	30.7
11	Mutations are the result of cloning.	No	105	30.7	**58**	**46.2**	79	23.1
12	Mutations are always inherited.	No	60	17.5	**185**	**54.1**	97	28.4
13	Deoxyribonucleic acid (DNA) is a source of information for the synthesis of proteins.	Yes	**190**	**55.4**	15	4.5	132	39.2
18	Propagation of plants by cuttings is cloning.	Yes	56	16.5	**220**	64.7	64	18.8
19	Recessive genes are never expressed.	No	18	5.3	85	25.1	**236**	**69.6**
22	The sex of the child depends on male sex cells.	Yes	**223**	**65.2**	79	23.1	40	11.7
25	All mutations are harmful.	No	36	10.6	**225**	**66.0**	80	23.5
26	Bread rising is a biotechnological process.	Yes	**102**	**30.3**	87	25.8	148	43.9
	Knowledge about current applications of modern biotechnology							
2	The vaccine against hepatitis B used to vaccinate all school children was produced with genetically modified yeast.	Yes	33	9.6	36	10.5	**273**	**79.8**
7	GM crops are cultivated in Slovenia.	No	**200**	**58.7**	17	5.0	124	36.4
8	Insulin for treating human diabetes is produced from GM (genetically modified) pig and cow pancreata.	No	25	7.3	39	11.4	**278**	**81.3**
9	Products from GMO (genetically modified organisms) must be labeled as containing GM components.	Yes	**239**	**70.3**	18	5.3	83	24.4
14	Before application of GM (genetically modified) plants, it is obligatory to perform a risk assessment about possible harmful influences of GM plants on the health of people, animals (other organisms) and the environment.	Yes	**229**	**67.0**	11	3.2	102	29.8
15	Reproductive cloning from cells harvested from an adult produces an embryo from which develops a child genetically identical to this adult.	No	**183**	**53.5**	22	6.4	137	40.1

	Statement	Correct answer	YES		NO		Do not know/ empty	
			N	%	N	%	N	%
17	Therapeutic cloning from stem cells harvested from an adult produces several types of cells used for treating diseases or harmful tissues of the same person.	Yes	98	28.7	20	5.8	**224**	**65.5**
20	Ribonucleic acid (RNA) is a genetically modified form of deoxyribonucleic acid (DNA).	No	29	8.5	147	43.0	166	48.5
21	Slovenia has passed a law dealing with GMOs.	Yes	51	8.5	31	43.0	**258**	**48.5**
23	Biogas methane from biogas reactors is produced by bacteria.	Yes	39	11.5	20	5.9	280	82.6
24	In Slovenia only GM corn is produced and marked as MON 810.	No	17	5.0	41	12.0	**283**	**83.0**
27	The cloning of genes and the cloning of organisms require the same methods of work.	No	41	12.0	67	19.6	**234**	**68.4**
28	Stem cells occur in adult humans.	Yes	**156**	**45.7**	19	5.6	166	48.7
29	Cloning of human embryos is already possible.	Yes	**192**	**56.3**	52	15.2	97	28.4
30	The transfer of animal genes to plants is possible.	Yes	44	12.9	87	25.4	**211**	**61.7**

production of medicines with GMOs, cloning of organisms and about GMO legislation, and the cultivating of GM crops in Slovenia. The majority of them correctly determined 5 among 16 (31.0%) statements, incorrectly determined 2 among 16 (12.0%) statements and do not know 9 among 16 (56.2%) statements.

Comparison of »do not know« with »yes« and »no« statements showed statistically significant higher number of »do not know« statements ($\chi^2 = 188.283$, $h = 4$, $p > 0.001$) about current applications of modern biotechnology, then about classical genetics. The high percentages of »do not know« answers indicate that they are aware of their insufficient knowledge about modern biotechnology. This could mean that future elementary teachers need additional more biotechnology topics in their education.

School practice is not completely impervious to the knowledge, values, opinions and attitudes of teachers. In other words, teacher's values, opinions and attitudes can play a certain role in the acceptance of biotechnology issues by school pupils by the whole vertical of compulsory education. Attitudes toward genetic modified organisms among students, future elementary teachers at three Slovene Faculties of Education were already evaluated and analysis of their answers reveals uncertainty, distrust and rejection (Ambrožič-Dolinšek and Šorgo 2009). The same is true for acceptance of different kind of GMOs. Among 17 different kinds of GMOs, only 5 are acceptable to more than 50% of students; students either find others not acceptable or have no opinion (Table 2). This low level of acceptance again indicates that in most cases, the attitudes of future elementary school teachers from three Slovenian universities toward GMOs are not positive or they hold no strong opinions about them.

In dealing with acceptance, we were able to recognize two patterns. The first one is that GM microorganisms and plants are generally more acceptable than GM animals, which are actually unacceptable. Our results confirm that acceptance of one type of GMO does not mean that some other GMO will also be acceptable (Steward and McLean 2005). The second pattern is that GMOs not used for food consumption are generally more acceptable if they or their parts cannot be used directly or indirectly for consumption and if they produce something recognized as useful for purposes such as medicine, bio-fuel, or organic substances, and have the capacity to clean something, or to improve resistance to stress conditions. A drop in the level of acceptance in pairs was observed, where plants tolerant to stress are acceptable to more than half the teachers, while plants manipulated to be tolerant to pests in food production are ac-

ceptable to only one-third of respondents. Among plants, the lowest scores were given to ornamental plants, a result which can be connected with the level of perceived utility and benefit. Genetically manipulated animals, always in the lower ranks of acceptability, are especially unacceptable if they have been manipulated for food consumption. The lowest scores in acceptability were given to genetically modified viruses. We can speculate that the answers somehow correlate with knowledge of and attitudes towards viruses as the cause of disease, which is never recognized as useful. In the uncertainty group (do not know; do not have an opinion), there occurred only microorganisms and viruses, which crossed the fifty percentages border. Students cannot decide whether or not manipulated viruses and microorganisms modified for production of substances for the food industry and synthesis of organic substances are acceptable. An interesting issue is their relation to health. It seems that, in the case of health, GMO plants and microorganisms could become more acceptable. When human health is at issue, the acceptance level of GMOs appears higher, as has also been shown by other studies (Cavanagh et al. 2005).

The correlation among knowledge and acceptance level was calculated. There was no correlation between knowledge and acceptance ($r = 0{,}052^{ns}$). It seems that GMOs acceptance is not connected with more knowledge or more knowledge about genetics does not automatically mean that GMOs would be more accepted.

Biotechnology is in broader sense the use of living organisms to solve problems and make useful products and applications (Thieman and Palladino 2009) and intended to improve the quality of human life. Currently we are witness of public resistance and skepticism to science, especially to modern biotechnology. Some assign it to the low levels of knowledge of science or »scientifically illiterate« public (Allum et al. 2008) and the importance of introduction of biotechnology in the education at the whole vertical of undergraduate curriculum. Education should starts with introduction of the science behind simply everyday biotechnology practices as making of food stuff like cheese and bread and continues with other more sophisticated agronomy, food and drink producing practices later continuing with some modern biotechnology practices.

Our study shows that there is no correlation between knowledge and acceptance of GMOs, and the former studies (Šorgo and Ambrožič 2009, 2010) that there it is strong correlation between acceptance and attitudes against GMOs, meaning that attitudes and not knowledge shaped the acceptance. So simple introduction of biotechnology, and science behind, by addition of new facts or teacher-provided explanations about ancient and current biotechnological processes does not influence the acceptance.

Public resistance and skepticism to science mean that modern biotechnology is not recognized only as something beneficial. Especially popular media sometimes present it as a threat, or controversial issue, causing concerns in society (Šorgo et al. 2011). Schools and teachers, as a part of society, must be prepared also for dealing with such socio-scientific issues and should be trained to developed competences based on active work of pupils such as critical thinking or scientific reasoning of pros and contra.

Emotions are especially important part of elementary education (Čagran et al. 2008) and could be important factor in shaping attitudes toward different GMOs ant their acceptability (Šorgo et al. 2011). Emotions related to GMOs are usually negative and hidden in concerns, risk, uncertainty, worry, anger and fear (Šorgo et al. 2011), and the same pattern was observed in emotions expressed by our future teachers. Negative emotions of future teacher against modern biotechnology, no matter of their origins, would not supported and lead to higher acceptance of this technology. This also supported the need for early introducing of biotechnology in education, development of positive experiences with biotechnology and also the importance of education of competent future and current elementary teachers.

Conclusions

The students included in our study have concerns and fears about different kind of GMOs and mostly negative attitudes towards different kinds of GMOs, or they hold no strong opinions about them. Only a few of GMOs are accepted by more than half the students. We also observed some knowledge (often severely flawed) about

classical genetics and little or no knowledge about current applications of modern biotechnology and the last is not differing from other publics (Allum et al. 2008). The early positive experiences with biotechnology are recommended. Schools and teachers, as a part of society, must be prepared also for dealing with socio-scientific issues.

Povzetek

Izjemen razvoj znanosti in tehnologije vpliva na številne vidike vsakdanjega življenja posameznika, družbe in okolja. Dober primer tovrstne tehnologije je biotehnologija. Poleg številnih obetov so s to tehnologijo povezana nekatera sporna vprašanja, na katera ni enostavnih odgovorov. Povečevanje znanja in uporabe na eni ter polemik, na drugi, dela poučevanje biotehnologije vse prej kot lahko. Kako usposobiti bodoče učitelje za obravnavo takih tem in zakaj, kako in kdaj vključiti sodobno biotehnologijo v izobraževanje bo postalo pomembno v bližnji prihodnosti. Pomembno je, da bi bili učitelji vseh ravni izobraževanja usposobljeni za obravnavo takih in podobnih tem. To je bil tudi eden od razlogov, zakaj smo želeli ugotoviti, kakšno je znanje, kakšne so vrednote in mnenja o genskem inženiringu in gensko spremenjenih organizmih (GSO) študentov, bodočih osnovnošolskih učiteljev treh slovenskih pedagoških fakultet (Univerze v Mariboru, Univerze v Ljubljani, Univerze na Primorskem). Zbrali smo odgovore anketnih vprašalnikov 360 bodočih učiteljev razrednega pouka, v katerih so se bodoči osnovnošolski učitelji opredelili do trditev s področja splošne in klasične genetike, moderne biotehnologije, zakonodaje ter sprejemanja različnih vrst GSO. Bodoči učitelji razrednega pouka imajo kar nekaj znanja o splošni in klasični genetiki, čeprav z doseženim ne moremo biti povsem zadovoljni. Zelo šibko je njihovo znanje o uporabi moderne biotehnologije in z njo povezano zakonodajo. Bodoči učitelji zelo slabo sprejemajo različne GSO ali nimajo svojega mnenja o njih. GS mikroorganizmi in rastline so v splošnem bolj sprejemljivi kot GS živali. Pri tem so še posebej nesprejemljive GS živali za hrano. Ko gre za zdravje so GS mikroorganizmi in rastline bolj sprejemljive. Med znanjem in sprejemanjem GSO ni korelacije, kar pomeni, da več znanja nikakor ne pomeni, da bodo posamezni GSO bolj sprejemljivi.

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