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. Microorganisms 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

Ključne besede: gensko 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 (χ²) 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.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Correct answer</th>
<th>YES</th>
<th>%</th>
<th>NO</th>
<th>%</th>
<th>Do not know/empty</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge about classical genetics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1  Bacteria have the ability to mutually exchange genes.</td>
<td>Yes</td>
<td>52</td>
<td>15.2</td>
<td>46</td>
<td>13.5</td>
<td>243</td>
<td>71.3</td>
</tr>
<tr>
<td>3  Deoxyribonucleic acid (DNA) occurs only in genetically modified organisms.</td>
<td>No</td>
<td>13</td>
<td>3.8</td>
<td>215</td>
<td>62.9</td>
<td>114</td>
<td>33.3</td>
</tr>
<tr>
<td>4  Bacteria genes from yogurt that can be consumed can be incorporated into cells in the human organism.</td>
<td>No</td>
<td>45</td>
<td>13.2</td>
<td>119</td>
<td>34.8</td>
<td>178</td>
<td>52.0</td>
</tr>
<tr>
<td>5  Genes are sequences (of nucleotides) on chromosomes.</td>
<td>Yes</td>
<td>183</td>
<td>53.5</td>
<td>42</td>
<td>12.3</td>
<td>117</td>
<td>34.2</td>
</tr>
<tr>
<td>6  Genes are not normally transmitted from species to species in nature.</td>
<td>Yes</td>
<td>87</td>
<td>25.4</td>
<td>166</td>
<td>48.5</td>
<td>88</td>
<td>25.8</td>
</tr>
<tr>
<td>10 A cat can fertilize a female rabbit; the resulting young rabbits have shorter ears.</td>
<td>No</td>
<td>10</td>
<td>2.9</td>
<td>227</td>
<td>66.4</td>
<td>105</td>
<td>30.7</td>
</tr>
<tr>
<td>11 Mutations are the result of cloning.</td>
<td>No</td>
<td>105</td>
<td>30.7</td>
<td>58</td>
<td>46.2</td>
<td>79</td>
<td>23.1</td>
</tr>
<tr>
<td>12 Mutations are always inherited.</td>
<td>No</td>
<td>60</td>
<td>17.5</td>
<td>185</td>
<td>54.1</td>
<td>97</td>
<td>28.4</td>
</tr>
<tr>
<td>13 Deoxyribonucleic acid (DNA) is a source of information for the synthesis of proteins.</td>
<td>Yes</td>
<td>190</td>
<td>55.4</td>
<td>15</td>
<td>4.5</td>
<td>132</td>
<td>39.2</td>
</tr>
<tr>
<td>16 Propagation of plants by cuttings is cloning.</td>
<td>Yes</td>
<td>56</td>
<td>16.5</td>
<td>220</td>
<td>64.7</td>
<td>64</td>
<td>18.8</td>
</tr>
<tr>
<td>17 Recessive genes are never expressed.</td>
<td>No</td>
<td>18</td>
<td>5.3</td>
<td>85</td>
<td>25.1</td>
<td>236</td>
<td>69.6</td>
</tr>
<tr>
<td>18 The sex of the child depends on male sex cells.</td>
<td>Yes</td>
<td>223</td>
<td>65.2</td>
<td>79</td>
<td>23.1</td>
<td>40</td>
<td>11.7</td>
</tr>
<tr>
<td>19 All mutations are harmful.</td>
<td>No</td>
<td>36</td>
<td>10.6</td>
<td>225</td>
<td>66.0</td>
<td>80</td>
<td>23.5</td>
</tr>
<tr>
<td>20 Bread rising is a biotechnological process.</td>
<td>Yes</td>
<td>102</td>
<td>30.3</td>
<td>87</td>
<td>25.8</td>
<td>148</td>
<td>43.9</td>
</tr>
<tr>
<td>Knowledge about current applications of modern biotechnology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2  The vaccine against hepatitis B used to vaccinate all school children was produced with genetically modified yeast.</td>
<td>Yes</td>
<td>33</td>
<td>9.6</td>
<td>36</td>
<td>10.5</td>
<td>273</td>
<td>79.8</td>
</tr>
<tr>
<td>7  GM crops are cultivated in Slovenia.</td>
<td>No</td>
<td>200</td>
<td>58.7</td>
<td>17</td>
<td>5.0</td>
<td>124</td>
<td>36.4</td>
</tr>
<tr>
<td>8  Insulin for treating human diabetes is produced from GM (genetically modified) pig and cow pancreata.</td>
<td>No</td>
<td>25</td>
<td>7.3</td>
<td>39</td>
<td>11.4</td>
<td>278</td>
<td>81.3</td>
</tr>
<tr>
<td>9  Products from GMO (genetically modified organisms) must be labeled as containing GM components.</td>
<td>Yes</td>
<td>239</td>
<td>70.3</td>
<td>18</td>
<td>5.3</td>
<td>83</td>
<td>24.4</td>
</tr>
<tr>
<td>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.</td>
<td>Yes</td>
<td>229</td>
<td>67.0</td>
<td>11</td>
<td>3.2</td>
<td>102</td>
<td>29.8</td>
</tr>
<tr>
<td>15 Reproductive cloning from cells harvested from an adult produces an embryo from which develops a child genetically identical to this adult.</td>
<td>No</td>
<td>183</td>
<td>53.5</td>
<td>22</td>
<td>6.4</td>
<td>137</td>
<td>40.1</td>
</tr>
</tbody>
</table>
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°). 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


Acknowledgements

We would like to thank Dr. Darja Skribe Dimec (University of Ljubljana), Claudio Battelli M.Sc. (University of Primorska), Dr. Alenka Lipovec, and Martina Rajšp (University of Maribor) for their help in collecting the data.

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Literature


INSTRUCTIONS FOR AUTHORS

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SCIENTIFIC ARTICLES are comprehensive descriptions of original research and include a theoretical survey of the topic, a detailed presentation of results with discussion and conclusion, and a bibliography according to the IMRAD outline (Introduction, Methods, Results, and Discussion). In this category ABS also publishes methodological articles, in so far as they present an original method, which was not previously published elsewhere, or they present a new and original usage of an established method. The originality is judged by the editorial board if necessary after a consultation with the referees. The recommended length of an article including tables, graphs, and illustrations is up to fifteen (15) pages; lines must be double-spaced. Scientific articles shall be subject to peer review by two experts in the field.

REVIEW ARTICLES will be published in the journal after consultation between the editorial board and the author. Review articles may be longer than fifteen (15) pages.

BRIEF NOTES are original articles from various biological fields (systematics, biochemistry, genetics, physiology, microbiology, ecology, etc.) that do not include a detailed theoretical discussion. Their aim is to acquaint readers with preliminary or partial results of research. They should not be longer than five (5) pages. Brief note articles shall be subject to peer review by one expert in the field.

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ASSOCIATION NEWS reports on the work of Slovene biology associations.

2. Originality of Articles
Manuscripts submitted for publication in Acta Biologica Slovenica should not contain previously published material and should not be under consideration for publication elsewhere.

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Articles and notes should be submitted in English, or as an exception in Slovene if the topic is very local. As a rule, congress and association news will appear in Slovene.

4. Titles of Articles
Title must be short, informative, and understandable. It must be written in English and in Slovene language. The title should be followed by the name and full address of the authors (and if possible, fax number and/or e-mail address). The affiliation and address of each author should be clearly marked as well as who is the corresponding author.

5. Abstract
The abstract must give concise information about the objective, the methods used, the results obtained, and the conclusions. The suitable length for scientific articles is up to 250 words, and for brief note articles, 100 words. Article must have an abstract in both English and Slovene.

6. Keywords
There should be no more than ten (10) keywords; they must reflect the field of research covered in the article. Authors must add keywords in English to articles written in Slovene.

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This is a shorter version of the title that should contain no more than 60 characters with spaces.
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The introduction must refer only to topics presented in the article or brief note.

9. Illustrations and Tables
Articles should not contain more than ten (10) illustrations (graphs, dendrograms, pictures, photos etc.) and tables, and their positions in the article should be clearly indicated. All illustrative material should be provided in electronic form. Tables should be submitted on separate pages (only horizontal lines should be used in tables). Titles of tables and illustrations and their legends should be in both Slovene and English. Tables and illustrations should be cited shortly in the text (Tab. 1 or Tabs. 1-2, Fig. 1 or Figs. 1-2; Tab. 1 and Sl. 1). A full name is used in the legend title (e.g. Figure 1, Table 2 etc.), written bold, followed by a short title of the figure or table, also in bold. Subpanels of a figure have to be unambiguously indicated with capital letters (A, B, …). Explanations associated with subpanels are given alphabetically, each starting with bold capital letter (A), a hyphen and followed by the text.

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Articles shall end with a summary of the main findings which may be written in point form.

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Articles written in Slovene must contain a more extensive English summary. The reverse also applies.

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References shall be cited in the text. If a reference work by one author is cited, we write Allan (1995) or (Allan 1995); if a work by two authors is cited, (Trinajstić and Franjić 1994); if a work by three or more authors is cited, (Pullin et al. 1995); and if the reference appears in several works, (Honsig-Erlenburg et al. 1992, Ward 1994a, Allan 1995, Pullin et al. 1995). If several works by the same author
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The manuscripts should be sent exclusively in electronic form. The format should be Microsoft Word (*.doc) or Rich text format (*.rtf) using Times New Roman 12 font with double spacing, align left only and margins of 3 cm on all sides on A4 pages. Paragraphs should be separated by an empty line. The title and chapters should be written bold in font size 14, also Times New Roman. Possible sub-chapter titles should be written in italic. All scientific names must be properly italicized. Used nomenclature source should be cited in the Methods section. The text and graphic material should be sent to the editor-in-chief as an e-mail attachment. For the purpose of review the main *.doc or *.rtf file should contain figures and tables included (each on its own page). However, when submitting the manuscript the figures also have to be sent as separate attached files in the form described under paragraph 10. All the pages (including tables and figures) have to be numbered. All articles must be proofread for professional and language errors before submission.

A manuscript element checklist (For a manuscript in Slovene language the same checklist is appropriately applied with a mirroring sequence of Slovene and English parts):
English title – (Times New Roman 14, bold)
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Names of authors with clearly indicated addresses, affiliations and the name of the corresponding author – (Times New Roman 12)
Author(s) address(es) / institutional addresses – (Times New Roman 12)
Fax and/or e-mail of the corresponding author – (Times New Roman 12)
Keywords in English – (Times New Roman 12)
Keywords in Slovene – (Times New Roman 12)
Running title – (Times New Roman 12)
Abstract in English (Times New Roman 12, title – Times New Roman 14 bold)
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All Scientific Articles shall be subject to peer review by two experts in the field (one Slovene and one foreign) and Brief Note articles by one Slovene expert in the field. With articles written in Slovene and dealing with a very local topic, both reviewers will be Slovene. In the compulsory accompanying letter to the editor the authors must nominate one foreign and one Slovene reviewer. However, the final choice of referees is at the discretion of the Editorial Board. The referees will remain anonymous to the author. The possible outcomes of the review are: 1. Fully acceptable in its present form, 2. Basically acceptable, but requires minor revision, 3. Basically acceptable, but requires important revision, 4. May be acceptable, but only after major revision, 5. Unacceptable in anything like its present form. In the case of marks 3 and 4 the reviewers that have requested revisions have to accept the suitability of the corrections made. In case of rejection the corresponding author will receive a written negative decision of the editor-in-chief. The original material will be erased from the ABS archives and can be returned to the submitting author on special request. After publication the corresponding author will receive the *.pdf version of the paper.