New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION

Misconceptions about Current Biotechnology in Society: What to Focus On in School and Lifelong Education?

Michaela Horniaková

Department of Biology, Faculty of Education, Palacký University Olomouc, Czech Republic

Abstract

The progress of biotechnology is unstoppable and its impact on society is unquestionable. Consequently, it is imperative to grasp the prevailing awareness not only among students but also in the larger societal framework. The study used interviews as the primary research method, employing a semi-structured format for flexibility beyond pre-defined questions. A total of 40 respondents participated in the research, and the collected data underwent both qualitative and quantitative analyses. For qualitative analysis, the Grounded Theory [1] was applied, categorizing coded segments from transcribed interviews into four key concepts: biotechnology, genetic engineering, genetically modified organisms (GMOs), and cloning. Across these concepts, many respondents expressed a negative connotation. Misconceptions were diverse with the prevalent idea being that biotechnology and genetic engineering produce or are akin to robots or machines, unrelated to living organisms. Additionally, respondents associated biotechnology, genetic engineering, and GMOs with breeding. Quantitative analyses revealed notable gaps in awareness. Almost 30 % of respondents had limited awareness of biotechnology, and nearly 33 % lacked information on genetic engineering. Regarding GMOs and cloning, respondents were unaware of their nature. The misconceptions that emerged from the research may help in the future to identify critical areas that need to be addressed in raising awareness of biotechnology in society. This is vital for both academic settings and lifelong education.

Keywords: *biology instruction, education, biotechnology awareness, lifelong learning*

1. Theoretical background

Nowadays, when the flow of information from every side is enormous, it is especially important to have valid information, especially when it comes to such a controversial phenomenon as biotechnology is. Correct concepts are the starting point for the constructive debate that today's society needs to have on the subject. It is necessary to engage in critical thinking in the face of the large amount of information that comes from various media outlets. Of course, the media are not always conducive to constructive debate. For instance, media extensively covered genetic engineering, often portraying scientists with stereotypical depictions as rigid, indifferent, and unsympathetic individuals [2]. Biotechnology is a rapidly advancing field with widespread onto whole society. When we think of society as a product of the education system, it is necessary to look at the state of society's knowledge of the phenomenon. Discussing benefits or drawbacks is becoming more and more common [2,3]. Biotechnology, exemplified by DNA technologies, is often perceived with a high level of risk akin to other technologies involving chemical substances, nuclear energy, radioactive waste, and electromagnetic fields [4]. For example, while numerous studies dismiss the likelihood of significant health risks associated with the consumption of genetically modified (GM) foods, the focal point of misconceptions lies in the public perception of GM products [5–7]. Therefore, there´s more of a shortage of enhancing critical thinking and recognizing their preconceptions, and especially misconceptions about the subject matter. Dawson & Schibeci [8, p. 66] ask a very important question: “If the science curriculum is to prepare students to be citizens, can we continue to pay insufficient attention to this area of science?“. This creates a space for finding out what citizens really know. In this research, our objective is to assess the public's knowledge of current biotechnology and identify the main preconceptions and misconceptions they may harbour. Misconceptions are strongly held in minds, different from accepted understanding [9]. Having correct concepts about any phenomenon is the most important ability for making the right decisions in everyday life [10].

2. Methodology

The aim of the research was to find out the preconceptions and misconceptions of laypeople in the field of current biotechnology. The main research instrument used in the study is a semi-structured interview with individual respondents [11]. Questions for the interview were designed based on the content analysis [12] of Framework Education Program for Basic Education (FEP BE; [13]) and school textbooks (20 textbooks and 7 workbooks) for lower and upper secondary schools, with a focus on the field of biotechnology. Questions for the interview were validated by 4 experts in the fields of biotechnology, genetics, and biology educational research. Altogether, the interviews consisted of 28 questions. The questions were divided into four concepts: biotechnology, genetic engineering, genetically modified organisms (GMO), and cloning. Interviews were administered by the author. The interviews were gathered from 40 respondents: “laypeople” in biotechnology or another similar field. All the interviews were recorded on a dictaphone and transcribed. The gathered data were analysed both qualitatively and quantitatively. For the qualitative analysis, the Grounded theory [1]; inductive coding was used. The data were analysed in MAXQDA 2022, a data analysis software. Furthermore, for the qualitative analysis the modified Certainty of Response Index (CRI) method [9; p. 296]; see Table 1. The quantitative analysis was based on the absolute and relative abundance of a particular category and subcategory obtained from the qualitative analysis and analysed in MS Excel.

Table 1 Modified 4 categories of Certainty of Response Index (CRI) [modified from 9; p. 296]

	High Confident Answer	Low Confident Answer
Correct Answer	Know they know (Scientific Concept; SC)	Don´t know they know (Low Confidence; LC)
Wrong Answer	Know they don´t know (Lack of Knowledge; LK)	Don´t know they don´t know (Misconception; M)

3. Research results

The results of the qualitative analysis showed that the answers of the respondents were divided into 4 main concepts and into subcategories according to the respondents' answers (see Table 2). Research results are divided into two parts. First is the relative abundance from MS Excel of subcategories from the qualitative analysis.

Biotechnology in general was the most problematic concept, with 68 % of respondents in the “Nothing to say” subcategory. Etymology played quite a large role when trying to determine what biotechnology does. Almost 23 % of respondents derived the concept of biotechnology from the combination of the words "bio" and "technology". In the concept of biotechnology and genetic engineering, respondents see their greatest potential for use in industry (73 %, 60 %) and medicine (55 %, 73 %), they also see further use in science and research (both 28 %). Within each of these 2 concepts, a subcategory emerged that indicated at least a partial negative relationship or negative association between the respondent and the concept. Most responses were related to exploitation for personal gain, utilitarianism, economic domination, and intent to exploit. The survey showed that in the biotechnology concept, most misconceptions (23 %) were related to mechanics, robotics, or the use of computers. Another very strong misconception (20 %) was that biotechnology products were considered to be bio products (organically grown vegetables, fruits, etc.). Around 15 % of respondents claimed that genetic engineering is superior to biotechnology. In the genetic engineering concept, 55 % of respondents considered only certain kingdoms (only plants or only animals) of organisms as those on which it is realistic to perform genetic modification. In addition, about 15 % of respondents associated genetic engineering with robotics and non-living things.

When focusing on the subcategories of positives and negatives of GMOs (for society and environment), 92 % of respondents are aware that GMOs bring benefits to humans. Respondents see the potential for the use of GMOs in the field of agriculture in order to improve the quality of life of people However, only 57 % of respondents are also aware of the benefits for the environment and 70 % of respondents see more environmental disadvantages. Almost everyone is also aware of the dichotomy in the sense that "there are two sides to every coin"; 83 % see the possibility of use only for the individual's own benefit. With GMOs, respondents were most concerned about the environment and misuse. They perceived the occurrence of GMOs in nature as something unnatural that could disrupt ecosystems and food chains. Regarding genetically modified organisms (GMOs), the most common misconception (23 %) was that it is the same process as breeding or crossbreeding organisms.

The use of cloning is perceived by the majority of respondents as very questionable. The question of ethics and law arose in the case of cloning. Although almost 93 % of respondents see cloning as realistic, 80 % of respondents see the negative side precisely in terms of law and ethics. Regarding cloning, a frequent response was that it would be misused in the military or to create perfect individuals. Cloning had the most frequent misconceptions concerning its origin.

The second part shows us the relative representation (Table 2) of categories from Table 1, based on the modified CRI method [9; p. 296].

The concept of biotechnology is very bipolar (see average in Table 2). This is because those respondents who had the correct concepts about biotechnology in general usually always knew both the application and at least one product. Those who had no awareness of what biotechnology involves incorrectly included both its uses and products. A minimum of responses fell into the category of Lack of Confidence. Respondents either knew or did not.

The concept of genetic engineering has an average of 51 % scientific concepts. Where the sub-category relationship between biotechnology and tribal engineering was the least valuable; only 13 % scientific concepts. Genetic engineering contained 20 % of responses falling into the LK category (Table 2). This is because 45 % of the respondents “Know they don´t know” (LK) what´s the relationship between biotechnology and genetic engineering. The other subcategories contained less representation in the LK category. Respondents admitted to having no knowledge of the relationship between biotechnology and genetic engineering. This subcategory had also 40 % in the Misconceptions category.

Table 2 The results represents the resulting relative category (SC, LC, LK, M) values for each subcategory from qualitative analysis. The table contains the average value for a main concept.

CONCEPT	SUBCATEGORY	Scientific Concept (SC)	Lack of Confidence (LC)	Lack of Knowledge (LK)	Misconception (M)
Biotechnology (BT)	Concept	38 %	0 %	10 %	53 %
	Use	48 %	8 %	15 %	30 %
	Product	40 %	3 %	18 %	40 %
	Average	42 %	3 %	14 %	41 %
Genetic engineering (GI)	Concept	65 %	0 %	10 %	25 %
	BT + GI	13 %	3 %	45 %	40 %
	Use	65 %	0 %	13 %	23 %
	Product	60 %	5 %	13 %	23 %
	Average	51 %	2 %	20 %	28 %
Genetically modified organisms (GMOs)	Concept	80 %	5 %	8 %	8 %
	Making	43 %	13 %	25 %	20 %
	Product	53 %	18 %	15 %	15 %
	Use	63 %	5 %	18 %	15 %
	Society - Positives	80 %	0 %	5 %	15 %
	Society - Negatives	75 %	15 %	8 %	3 %
	Environment - Positives	73 %	3 %	10 %	15 %
	Environment - Negatives	70 %	5 %	13 %	13 %
	GMO vs. Breeding	70 %	5 %	8 %	18 %
	Average	67 %	8 %	12 %	13 %
Cloning	Concept	85 %	5 %	5 %	5 %
	Making	20 %	5 %	55 %	20 %
	Purpose	75 %	10 %	10 %	5 %
	Product	50 %	0 %	40 %	10 %
	Law and Ethics	75 %	3 %	10 %	13 %
	Average	61 %	5 %	24 %	11 %

For the concept of GMOs, up to 80 % of respondents correctly identified what it represents. However, with GMOs, the biggest problem was their origin. When asked how they could be created, only 43 % answered correctly (SC) and 25 % said "Know they don't know" (LK) and 20% fall in the category “Don´t know they don´t know” (M). The other subcategories (positives, negatives, use, etc.)

contained higher scores in the Scientific Concepts category. This can be seen in the average score of 67 %, which is the highest among all 4 concepts.

When it comes to the subcategory of “what is a clone”, 85 % of respondents fall into the Scientific Concept category. The most interesting subcategory is "making". 20 % of respondents have the correct concept but the same number have a misconception in that subcategory. Up to 55 % of respondents admitted that they that they “Know they don´t know” (LK) how a clone is created. On average, the LK category has 24 %. This is because only 5 % of respondents said they did not know what a clone is but 40 % did not know any example of a clone. Of the 50 % who could identify the product, the majority answered Dolly.

The results show that the etymology of a term is the greatest help in defining what it entails. This implies that concepts such as GMOs and cloning were most correctly defined. Concepts such as biotechnology and genetic engineering are more abstract concepts and also cause more problems.

4. Discussion and conclusions

When we look at the research findings, we find that the more 'graspable' and practical the knowledge of the area was, the more respondents mentioned it and regarded it as positive. Respondents often reached for practical examples within all 4 main concepts. More abstract examples such as production of insulin or growth hormone are almost nonrepresented. But even though respondents cited examples such as food, they were still sceptical of them. This was also confirmed by the research of Usak et al. [14], that attitudes towards shopping for genetically modified products are therefore negative. In our research, the positives of GMOs for the society outweigh the negatives. This was confirmed by the research of Cavanagh et al. [15], which found that 11 % of respondents definitely see more positives than negatives and 42 % of respondents probably see more positives than negatives.

As mentioned, the etymology of a word brings an advantage in defining the phenomenon in answering question. However, it also has a significant disadvantage. If respondents reached for an explanation of a phenomenon through its etymology it happened that they ended up with considerable misconceptions such as robotics, mechanics, machines and the like (especially for biotechnology).

Misconceptions in other concepts were subsequently derived from this. For example, research results show, some students stated that preservatives and chemical processing of food were examples of genetic engineering [2, 14]. This misconception was confirmed in our research as well, as 7 % of respondents stated that biotechnology and thus genetic engineering is a chemical substance that is harmful to humans and the environment.

Medicine (60 %) and industry (73 %) were the most commonly considered uses of genetic engineering in our research. Other research has confirmed that respondents most commonly assigned its use to medicine, industry, or agriculture [2, 8, 15]. In our research, agriculture was a frequent response when asked about the use of GMOs. Regarding the subcategory “GMO products”, 15 % of respondents said that they “Know they don´t know” (LK) any example, but 18 % said that they don´t know any example of GMOs, yet in the interview they talked about an example without realizing that they were talking about GMOs (Lack of Confidence; LC). In the research of Dawson & Schibeci [8], 33 % of the respondents could not give an example of GM food. In our re14

search, it was food (in general) that formed the basis of the GMO example. As far as our research is concerned, quite a few respondents considered Dolly the sheep as an example of a GMO. However, when asked for an example of cloning, Dolly the sheep was the most well-known example of a cloned organism, and this has been confirmed by other research (e.g. [8]).

Looking at the results of the research, we can say that respondents have too little information about the given phenomena to be able to deal with sometimes controversial issues. Most of the respondents have not even been taught about biotechnology at schools at all. The most knowledgeable respondents are those who are either actively interested in the field and the topic is close to their heart. However, just because respondents have correct concepts about one concept (e.g. biotechnology) does not mean that they are thinking correctly about genetic engineering or cloning. Very often these concepts are strictly separated by respondents as unrelated to each other.

Therefore, it seems to be necessary to include at least some information about the phenomenon in the school curriculum or inform the society. There is compelling evidence that explicit teaching of these issues improves understanding and reduces uncertainty [8]. Respondents also reported feeling under-informed. Given the rapid evolution of this phenomenon, it is crucial to assess the current level of societal awareness, with a particular focus on identifying knowledge gaps in this area.

Acknowledgment

The research was carried out under a project called '*Biodiversity*'; Internal Fund of Faculty of Education UP (GFD_PdF_2023_06).

References

[1] Strauss, A. & Corbin, L. (1990). Grounded Theory Research: Procedures, Canons and Evaluative Criteria. *Zeitschrift für Soziologie*, *19*(*6*), 418–427
[2] Dawson, V., & Soames, C. (2006). The effect of biotechnology education on Australian high school students' understandings and attitudes about biotechnology processes. *Research in Science & Technological Education*, *24*(2), 183–198.
[3] Kooffreh, M.E., Ikpeme, E.V., & Mgbado, T.I. (2021). Knowledge, perception, and interest regarding biotechnology among secondary school students in Calabar. *Biochemistry and Molecular Biology Education, 49*(4), 664–668.
[4] Welser, J. R. (1991). An industrial perspective on biotechnology issues. *Food Technology*, *45*(4) 102–109.
[5] Prokop, P., Lešková, A., Kubiatko, M., & Diran, C. (2007). Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education*, *29*(7), 895–907.
[6] Jones, P., Clarke-Hill, P., Hillier, D. & Shears, P. (2000). Food retailers' response to GM controversy within the UK. *British Food Journal*, *102*(5/6), 441–448.
[7] López, R. C., & Carrau, J. G. (2002, August 28–31). The GMO Regulation in the EU and the Commercial Conflict with the United States [Conference presentation]. International Congress, Zaragoza, Spain. https://doi.org/10.22004/ag.econ.24924
[8] Dawson, W. and Schibeci, R. (2003). Western Australian school students' understanding of biotechnology. *International Journal of Science Education*, *25*(1), 57–69.
[9] Hasan, S., Bagayoko, D., & Kelley, E. L. (1999). Misconceptions and the certainty of response index (CRI). *Physics Education*, *34*(5), 294–299.
[10] Harms, U. (2002). Biotechnology Education in Schools. *Electronic Journal of Biotechnology, 5*(3), 5-6.
[11] Posner, G. J., & Gertzog, W. A. (1982). The clinical interview and the measurement of conceptual change. *Science Education, 66*(2), 195–209.
[12] Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution.* Klagenfurt, Austria. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-395173
[13] Jeřábek, J. & Tupý, J. (2007). The Framework Educational Programme for Basic Education. Ministry of Education Youth and Sport Czech Republic. https://edumedia-depot.gei.de/bitstream/handle/11163/1586/782826296_2007_A.pdf?sequence=2
[14] Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology: A Turkish experience. *Biochemistry and Molecular Biology Education*, *37*(2), 123–130.
[15] Cavanagh, H., Hood, J., & Wilkinson, J. (2005). Riverina high school students views of biotechnology. *Electronic Journal of Biotechnology*, *8*(2), 1–7.