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Knowledge and Attitudes Towards Biotechnology in High School Students in Córdoba, Argentina

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A R T I C L E I N F O

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A B S T R A C T

Biotechnological issues frequently raise debates before which society must make important informed decisions. This has been a driving force to promote the teaching of biotechnology contents in secondary education in several countries. After some years of this inclusion, several works have investigated the knowledge and attitudes of students towards biotechnological applications. However, few studies of this nature are recorded for Latin America and none for Argentina. Thus, the objectives of this work are to characterize students' knowledge and attitudes about biotechnology, its procedures and applications. To this end, we designed and applied a semi-structured questionnaire to 836 students of Year 3 (14 years old) and 471 students of Year 6 (17 years old) in the city of Córdoba (Argentina). Based on the results we found that students present conceptual difficulties in defining biotechnology and tend to associate it mainly with genetic engineering processes. On the other hand, they express positive attitudes towards the use of biotechnology for therapeutic purposes while presenting reserves for other biotechnological applications. On this basis, we present reflections and guidelines for biotechnology education.

1. Introduction

From an educational perspective focused on scientific and technological literacy, science education provides opportunities for responsible and democratic participation in society (Yacoubian 2018; Aikenhead 2003; Laugksch 2000). The aim is to promote the learning of scientific concepts and to encourage the development of capacities that allow the evaluation of information, critical reflection and the taking of positions linked to axiological questions (Zeidler et al. 2005). This process prepares people to manage their daily lives and become aware of the complex relationships between science, technology, society, and the environment (Pedretti and Nazir 2011). Specifically, biotechnology is characterized by presenting socio-scientific issues (SSI), such as the controversial debates on cloning, gene editing, the use of stem cells or the creation of genetically modified organism (GMO), among others (Sadler and Zeidler 2005). Democratic participation in these debates requires bringing into play a system of knowledge, skills and value judgments involving scientific, technological, economic, environmental, and ethical aspects, among others (Levinson 2006; Klosterman and Sadler 2010; Erduran and Kaya 2016; Jiménez-Aleixandre and Evagorou 2018). Therefore, to ensure that citizens can be involved in these discussions, it is essential to include biotechnology in citizen science education. For this reason, several countries have incorporated biotechnology into the secondary school curriculum (France 2007).

The inclusion of biotechnology in secondary schools raises the question of what knowledge and attitudes towards biotechnology young people have. Based on this, articles have been published on the study of knowledge and attitudes of high school students towards biotechnology in different countries (Dawson and Schibeci 2003a; Dawson and Schibeci 2003b; Klop and Severiens 2007; Pedrancini et al. 2008; Prokop et al. 2007; Sáez et al. 2007; Fonseca et al. 2012; van Lieshout and Dawson, 2016; López-Banet et al. 2020); this in turn has even encouraged the publication of specific reviews (Gardner and Troelstrup 2015; Nordqvist and Aronsson, 2019). However, as stated by Nordqvist and Aronsson (2019), there is a lack of studies of this nature for South America. In this work we focus our study in the city of Cordoba (Argentina) and we have two main objectives: 1) To characterize the knowledge that high school students have about biotechnology, its procedures and applications; 2) To identify their attitudes towards biotechnology and its applications.

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2. Theoretical Framework

In this paper, when referring to students' knowledge of biotechnology, we include a wide range of topics, from managing specific vocabulary to solving problems in context and building arguments to support a position on biotechnology SSI. On the other hand, in relation to attitudes, we use this term to indicate whether a person approves or disapproves a particular biotechnology application (van Lieshout & Dawson 2016).

One aspect that characterizes biotechnology is that it develops in a dynamic of controversies that are complex, open, often polemical dilemmas with no definitive answers (Sadler 2004). When these controversies link scientific issues, one speaks of SSI. These involve discussions in which a collective composed of different actors and social forces (expert groups, non-governmental organizations, companies, users, etc.) interact in conversation, either by disagreement, discussion or debate (Kolstø 2001).

Ratcliffe and Grace (2003) characterize SSI and indicate that they are based in areas that are on the frontiers of scientific knowledge, are linked to local and global problems, or are confronted with incomplete information from scientific evidence or records. They are usually publicized in the media, which highlight aspects of SSI according to certain interests. This media exposure requires the formation of opinions and the making of choices based on the evaluation of costs and benefits in which risks interact with values and ethics. In the field of biotechnology, we identified several examples of SSI that meet these characteristics such as gene therapies (Simonneaux and Chouchane 2011), the development of GMOs (Solli 2019) or vaccination (Lundström et al. 2012; Sadler et al. 2016), to name but a few.

The ability to engage in reasoned debate, argue, and make decisions related to SSI, depends, among other things, on people's ability to recognize the key issues in a SSI, and this requires a certain understanding of the scientific knowledge involved (Lewis and Leach 2006). Accordingly, the school is challenged to provide learning contexts with opportunities for students to explore conceptual connections to science, engage in debate, develop critical thinking, and make decisions in SSI (Klosterman and Sadler 2010). In response to this demand and focusing the analysis on SSI linked to biotechnology, it is observed that several countries have incorporated specific training for biotechnology issues (France 2007).

After some years of education in biotechnology, several authors have studied the knowledge and attitudes about biotechnology among high school students (Gunter et al. 1998; Dawson and Schibeci 2003a; Dawson and Schibeci 2003b; Klop and Severiens 2007; Pedrancini et al. 2008; Prokop et al. 2007; Sáez et al. 2007; Concannon et al. 2010; Fonseca et al. 2012; van Lieshout and Dawson, 2016; Wisch et al. 2018). These investigations use different methodologies and refer to different regions. However, beyond these differences that hinder making direct comparisons or inferences, we are interested here in taking up the main contributions that these works have made in the area and that constitute the background for this work.

In relation to the students' knowledge, the investigations carried out in different countries coincide in the persistence of difficulties to understand key concepts of biotechnology (Gunter et al. 1998; Dawson and Schibeci 2003a; Dawson 2007; Prokop et al. 2007; Concannon et al. 2010; Fonseca et al. 2012; Wisch et al. 2018). These studies indicate the problems of understanding from the term biotechnology to specific applications. In relation to the applications of biotechnology, students are able to identify activities related to genetic engineering, such as cloning, gene therapies, GMOs, among others, but very few students name the traditional biotechnology activities that use the benefit of biological processes, such as the production of bread, wine or beer. Particularly for GMOs, some research reports difficulties in understanding GMOs, recognizing the procedures required for their processing, and identifying foods derived from GMOs (Dawson 2007; Pedrancini et al. 2008; Wisch et al. 2018), while others find that students do achieve this knowledge in school (Mohapatra et al. 2010). Finally, there are papers that compare students' understanding of biotechnology in two time periods in the UK (Lewis 2014) and in Taiwan (Chen et al. 2016). They indicate an increase in the number of students who are able to express understanding in biotechnology concepts. However, no similar studies are recorded for other countries (Hammann 2018).

The study of student attitudes towards biotechnology has also been carried out in several countries and has led to the recognition of similar trends (Gardner and Troelstrup 2015). A characteristic feature is that students generally find genetic modification in plants and micro-organisms more acceptable than in humans or animals (Gunter et al., 1998; Dawson and Schibeci 2003 b; Klop and Severiens 2007; Chen et al. 2016). Specifically, there is a predominance of positive attitudes for the use of stem cells (Fonseca et al. 2012; Witzig et al. 2013). In general, when expressing their views on biotechnological applications, they indicate that their acceptance depends on the conditions and objectives of the manipulation (Sáez et al. 2007; van Lieshout and Dawson, 2016). Also, in expressing their positions on biotechnological SSI, they make value judgments that involve multiple conceptual, ethical and moral aspects (Levinson 2006; Klosterman and Sadler 2010; Erduran and Kaya 2016; Jiménez-Aleixandre and Evagorou 2018). Finally, by virtue of the different research linked to attitudes towards biotechnology, the authors propose a framework for the conceptualization of attitudes towards biotechnology that recognizes five factors: Personal acceptability of gene technology for public use; Attitudes toward research in gene technology; Moral and ethical implications of gene technology for public use; Concern regarding the regulation of risks associated with biotechnology and trust in groups or authorities to communicate about biotechnology.

3. Methodology

To identify the conceptions and attitudes towards biotechnology of secondary school students in Córdoba (the second largest city in Argentina), we developed a descriptive study. Secondary school education in Argentina is structured in six years, starting in Year 1 at an approximate age of 12 and ending in Year 6 with 17 years old. The first three years are general training and the other three years are oriented training. According to the educational community and its training interests, each educational institution can choose which orientation to offer. For this study, all the public schools in the city of Córdoba with natural science-oriented training were selected, making a total of 21 schools. In each school, students of Year 3 and Year 6 were surveyed, resulting in a total of 836 students of Year 3 and 471 students of Year 6.

A semi-structured questionnaire with nine items was used as an analysis instrument (Appendix 1). For the construction of the questionnaire, those instruments used for similar purposes and which were reviewed in the theoretical references were analyzed. Some questions were adapted and modified according to the specific context of this research. Two complementary actions were carried out for validation of the questionnaire. First, an expert evaluation was carried out involving two biotechnology specialists and two science education researchers. This review allowed for the re-structuring of some questions and the inclusion of new concepts in the questionnaire. Second, we conducted a validation test of the instrument with volunteer students taken from the study universe (secondary schools in Córdoba), but not belonging to the study population (public schools with natural science-oriented training), so as not to invalidate any of the members of this population.

Twenty students (10 students of Year 3 and 10 of Year 6) participated and made suggestions to improve the clarity of the questions. Based on the collected recommendations, the instrument was corrected and modified until its final version was reached.

For the analysis, open responses were categorized based on the regularities discovered and through a process of decontextualization and recontextualization of the data, that is comparing each segment with the others assigned to the same category (Hammersley and Atkinson, 2007). Both the frequencies of these categories that emerged from the data and those from the answers to the closed questions were analyzed through the statistical analysis program SPSS (Statistical Package for the Social Sciences).

4. Results

In this section we present the results organized according to the research objectives. Consequently, we first present the results obtained in relation to the students' knowledge followed by their attitudes towards biotechnology and its applications.

4.1. Biotechnology Concept

To find out what students understand by biotechnology, we asked an open question, and six categories and their indicators were constructed based on the different answers obtained:

a) Traditional Definition: considers activities, such as the domestication of animals, taking advantage of the curative properties of some plants, production of food using microbial fermentation processes, etc.

b) Definition focused on Genetic Engineering: only includes Genetic Engineering processes without considering processes linked to traditional modification, nor its multidisciplinary character.

c) Multidisciplinary Definition: includes both traditional and modern processes, so it is seen as a multi-disciplinary knowledge-based activity that uses biological agents to make useful products or solve problems.

d) Etymological Definition: uses the etymology of the word to express that it refers to a link between biology and technology.

e) Misconceptions

f) No answer

Categories a, b, and c bring together answers that involve knowledge related to biotechnology; the remaining categories indicate the absence of such knowledge. Depending on the frequency with which we find these categories, it is observed that very few students were able to express a response that shows understanding of the term (Fig. 1).

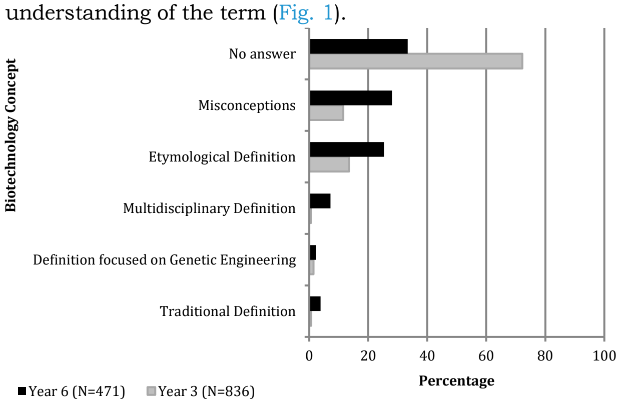

Fig. 1. Biotechnology concepts expressed by Year 3 and Year 6high school students

4.2. Concepts on Biotechnological Activities

We study how students relate to different biotechnology activities with the term biotechnology. Although most of the students were not able to define this term, it was found that they were able to identify several thematic areas very or moderately related to biotechnology (Fig. 2).

The responses of students in both groups showed a similar trend. However, in general, the percentage of Year 3 students who establish a high or medium relationship with biotechnology is equal to or less than Year 6 students (Fig. 2). Biotechnology activities that require genetic engineering were the most identified by students, such as vaccine development, cloning or monoclonal antibody production. On the contrary, the activities that were less related to biotechnology were those linked to traditional biotechnology, such as bread, wine or beer making and food preservation or production. Also, fewer students linked biotechnology with bioethics.

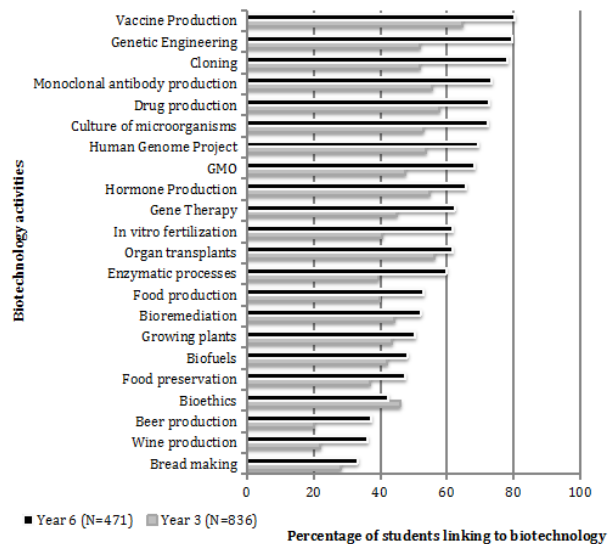

Fig. 2. Comparison of the relationships that Year 3 and Year 6 students establish between different activities and biotechnology

4.3. Concepts about GMO

The questions concerning this concept were not answered by 92% of the students in Year 3. Therefore, only the results linked to the answers given by the students in Year 6 are presented below. Only 26% of the students managed to identify what GMOs are and 18% said that the development of a GMO requires genetic modification (Fig. 3).

On the other hand, we inquired about the students' perception of the possibility of having used a transgenic organism or product derived from a transgenic. We found that few students gave an affirmative answer. One item most frequently identified by the students was soy (10%), and then generally vegetables and fruits (6%), specifically tomato (3%) and corn (2%).

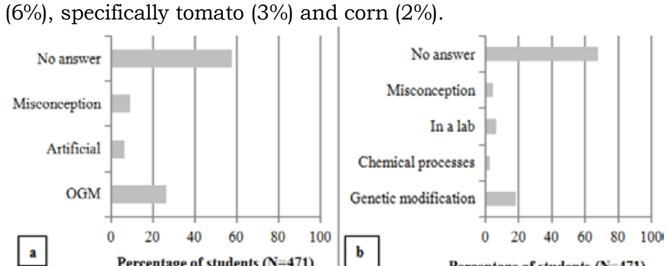

Fig. 3. a) GMO concept; b) Concept of the GMO production

4.4. Knowledge in context

Another aspect we sought to evaluate was how they used biotechnology knowledge in social issues. For this purpose, we proposed a situation contextualized with Dengue disease, since this is an endemic health problem for some areas of Argentina with a high social impact. The situation presented three increasing levels of conceptual demand as detailed in Table 1.

Table.1 Levels of conceptual demand, knowledge required and proposed work instruction

Levels of Conceptual Demand	Knowledge Required	Work Instruction
Level 1: identify scientific knowledge.	Concept of DNA sequencing	What is DNA sequencing? (multiple choice question)
Nivel 2: Level 2: select and integrate knowledge from different science and technology disciplines and relate it to everyday situations.	Vaccine concept	A dengue vaccine is being studied; a vaccine is a solution that contains... (multiple choice question)
Level 3: apply scientific and technological knowledge and understanding of science in a variety of situations.	Experimental design	Design an experiment to test the effectiveness of an insecticide developed from the knowledge provided by the DNA sequencing of the *Aedes aegypti* mosquito. (open question)

From the results obtained, we found that only 23 % of Year 6 students showed knowledge of the concept of DNA sequencing, and most of Year 6 (57 %) and Year 3 (92 %) students did not manage to give an answer about it.

In turn, the concept of vaccination was understood by only 20.2% of students in Year 6 and 9% in Year 3. Most provided answers that revealed conceptual confusion. For example, 39.3% of Year 6 students and 32% of Year 3 students stated that "vaccines are a set of antibodies against the viral disease" .

Students' knowledge in relation to doing science presented the lowest percentages. In particular, when students were asked to design a scientific experiment, we observed that less than 1% of the students in both years were able to solve the design of an experiment including the handling of variables, a control situation and the comparison of data. The following answer is an example of this type of resolution:

"In the laboratory I would put in 2 equal containers, the same amount of water and larvae, leaving also larvae in a container in normal conditions, that is with water (same level as in the others). In 2 containers I add in each one 1 different insecticide and after a certain time I make a count of larvae and compare with the larvae container to which I did not add insecticide (control sample). From that data I say which insecticide is more effective." (Year 6 Student, 17 years old, School C).

On the other hand, 21% managed to design an experiment controlling variables and foreseeing a process of comparison of results, but not including a control or control situation.

4.5. Students' Attitudes towards Biotechnology

The general attitude expressed by Year 6 students (67%) regarding biotechnology focused on the fact that "while there are advantages and disadvantages, its applications are beneficial". While only 31% of Year 3 students had this reservation, another 31% indicated that it was mainly beneficial to people's lives.

In terms of specific applications, it was observed that most students in both years find genetic modification of plants and microorganisms more acceptable than in animals or humans; this acceptance is conditioned by the objectives pursued. In this sense, the acceptance of the modification of human cells for gene therapies stands out, and on the other hand the disagreement with the modification of plants so that their maturation is slower and then their duration is longer, or the modification of fruits to improve their taste (Fig. 4). Therefore, it could be said that in the evaluation made by the students there is a tendency to accept those biotechnological applications that can benefit human beings in their health, but reject those that are applied to food.

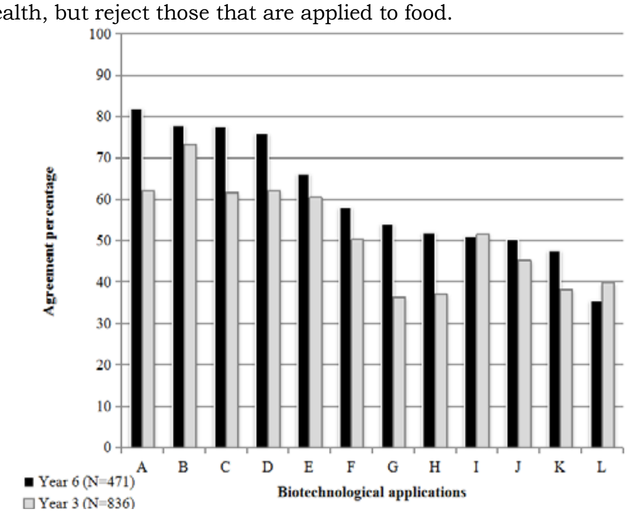

Fig. 4. Degree of agreement in the face of biotechnological applications. A: In microorganisms to produce drugs; B: In bacteria to improve food; C: In human cells for gene therapy; D: In plants to improve their nutritional value; E: In plants for their cultivation in saline soils F: Plant cloning; G: In cows to produce drugs; H: In plants for insect resistance; I: In fruits to improve their taste; J: In animals to improve the quality of their meat or milk; K: In plants to delay their maturation; L: Animal cloning

4.6. Stem Cell Handling

Another position studied was linked to the use or handling of stem cells for the development of gene therapies. In the case of Year 3 students, 59% did not answer this question and 22% agreed. Although few students made arguments to take this position, most of the justifications expressed showed that students confused gene therapies with assisted reproduction techniques or expressed no understanding of the concept of stem cells.

As for Year 6 students, we found that 38% did not answer this question whereas 3% indicated that they could not make a decision by expressing that they visualized both benefits and possible problems. For their part, 44% agreed and indicated that they accepted it because the purpose was appropriate, specifying that genetic diseases could be cured or treated by manipulation. In turn, as found by Fonseca et al. (2012), 23% expressed the conditions under which they would accept such manipulation, for example:

"I agree that gene therapies are done to improve or correct problems of the individual but not to create a model by changing the color of the eyes or skin etc." (Year 6 Student, 17 years old, School Q).

Finally, other students indicated that they would need more information to be able to take a stand, for example:

"I think it might be a good possibility but I also don't want to and can't justify much [⋯] It is a great topic of debate since it reaches the field of ethics and what by nature happens. Therefore, it would be much better if we were trained to speak and debate correctly (Year 6 Student, 17 years old, School B).

Those students in Year 6 who indicated that they did not agree with the handling of stem cells made up 15%, of which 6% did not support their decision, while the remaining 9% had three types of arguments. In the first type, students indicated that it would not be moral (5%) and expressed ethical, moral or religious grounds. The second type (3%) were arguments that it would be better to keep things "natural" because all technology brings risks and these may not currently be known. Finally, the third type (1%) expressed misconceptions.

5. Discussion

In relation to the students' knowledge about biotechnology, in this work we found similar results to some of those recorded in the literature. Specifically, the low proportion of students that achieve an understanding of the term biotechnology coincides with what Dawson (2007) found for different age groups in high school in Australia.

In the same way, in line with other authors (Fonseca et al. 2012; Dawson 2007), students identify and link biotechnology with those applications that require genetic engineering rather than traditional biotechnology processes. In relation to GMOs, the low percentage of students who understand what a GMO is and how it is made is consistent with that recorded by Dawson (2007) and Wisch et al. (2018), who indicate the persistence of a general lack of understanding about GMOs. However, it contrasts with the results recorded by Mohapatra et al. (2010) in India, who found that most did understand the concept of GMOs and the procedure required for their development in general terms.

A characteristic GMO identified most often by the students was soybean. These findings coincide with those found by Pedrancini et al. (2008) in Brazil, who highlight that the GM foods most recognized by students are those most frequently mentioned in the mass media.

Likewise, it is not surprising that soy is the most identified component, since Argentina is one of the main producers of GM soy worldwide and it is naturally "talked about" in different fields and media.

In relation to the application of biotechnological knowledge in context, we observe that students evidence a mono-conceptual reasoning, that is, a type of reasoning from which the solution to the problem is interpreted as depending on a single variable. This way of reasoning has been recorded as one of the most common difficulties in the resolution of experimental activities (Zimmerman, 2000). In turn, these difficulties may respond to the simplification of analogical and material work inherent in research activities carried out in schools (Manz et al. 2020).

In search of some explanations to this situation, we find it interesting to analyze the characteristics of the didactic proposals that the teachers indicated to carry out in their classrooms and that we present in another study (Authors, 2018). In this respect, the high frequency of traditional strategies proposed by teachers (presentations, dictating, reading of texts, etc.), makes us think that possibly the type of approach to "doing science" that is carried out in the classrooms, is linked to simplified situations of scientific activity that provide an image of cumulative, finished and mainly explanatory science (Hodson 2014).

Regarding attitudes, we studied two factors of the conceptual framework proposed by Gardner and Troelstrup (2015): personal acceptability of gene technology for public use and moral and ethical implications of gene technology for public use. For the first factor, we found similar results to those recorded by other authors (Dawson and Schibeci 2003b), since most students of both years find genetic modification of plants and microorganisms more acceptable than in animals or humans; this acceptance is conditioned by the objectives pursued. At the same time, there is a majority trend to accept biotechnological applications that can benefit human health, but reject those applied to food. This reservation of students to the modification of food is similar to that registered for other countries (Gunter et al. 1998; Klop and Severiens, 2007; Chen et al. 2016).

With respect to the second factor, as we have expressed in the theoretical references, biotechnological applications are characterized by debates in society in which different actors and social forces interact (Kolstø 2001; Sadler and Zeidler 2005). When evaluating the students' position on the manipulation of stem cells for gene therapy, although we found a general tendency to accept them, some students disagreed and gave reasons similar to those recorded by other authors. Such is the case of ethical, moral or religious justifications (Sadler and Fowler 2006; van Lieshout and Dawson 2016); arguments referring to the need to keep things "natural" (Gunter et al. 1998; Dawson and Schibeci, 2003b; Sáez et al. 2007) and finally, expressions that account for mistakes in the concept of stem cells (Concannon et al., 2010; Wisch et al. 2018).

6. Conclusion

In this paper we proposed to characterize knowledge and attitudes towards biotechnology and its applications in high school students in Córdoba (Argentina). No previous studies were found that recorded this information in Argentina.

From the results obtained we found that very few students manage to express an answer that shows understanding of the term biotechnology. They identify as biotechnological applications those that are linked to genetic engineering rather than to the traditional processes of biotechnology. Specifically, in relation to GMOs, very few students demonstrate an understanding of what a GMO is and how it is made. The examples of GMOs given by students are in line with those most frequently mentioned in the mass media such as the example of "soybeans," which are the most widely produced transgenic crop in Argentina.

In the application of biotechnological knowledge in context, students present conceptual limitations, in general they do not respond to these statements and those who do (with the exception of a minority) exhibit a mono-conceptual reasoning from which it is interpreted that the solution to the problem depends on a single variable. Therefore, for Argentina it is clear that there is a demand for a transformation of how and what is being taught about biotechnology in secondary schools (Steele y Aubusson, 2004).

In relation to attitudes, most students find genetic modification of plants and microorganisms more acceptable than in animals or humans, and accept biotechnological applications that may benefit human health, but reject those applied to food. Faced with an application that can be presented as a SSI, such as the manipulation of stem cells for gene therapy, the students' position was generally one of acceptance.

Based on these results, we consider it important to highlight that when participating in SCC debates, students' positions are conditioned by multidimensional relationships in which knowledge, feelings, moral values, worldviews, etc., interact (Klop and Severiens, 2007; van Lieshout and Dawson 2016). Therefore, we consider that our results show the need to rethink the biotechnology education offered by high school and promote learning contexts so that students have the opportunity to put knowledge into play, develop critical thinking with value judgments involving scientific, technological, economic, environmental, ethical and other aspects (Levinson 2006; Klosterman and Sadler 2010; Erduran and Kaya 2016; Jiménez-Aleixandre and Evagorou 2018).

One way of approaching this is through the development of specific teacher training proposals. Placing our work in its context, we consider it necessary that these proposals link the biotechnological developments of the place and the main debates that people face there. Specifically, biotechnological issues linked to GMO cultivation and food production would need to be addressed. At the same time, it is necessary to experiment with specific didactic strategies to deal with biotechnological contents in their complexity. One strategy for this is the development of training proposals focused on problem-based learning (Authors, 2010). Thus, from contextualized problematic situations it would be possible to recreate the central discussions that are derived and to deepen about them from both a conceptual and an attitudinal perspective.

7. Compliance with Ethical Standards statement

We declare that we have no conflict of interest.

Ethics approval: Approval was obtained from the Secretary of Science and Technology. National University of Córdoba (Argentina). The procedures used in this study adhere to the tenets of the Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study.

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Appendix 1. Questionnaire

I) Complete the following information

School: Year: Age: Sex:

II) Answer the following questions:

1) What is Biotechnology?

2) Mark with a cross (X) the sentence that best represents your point of view about Biotechnology:

☐ Biotechnology improves people's lives
☐ Biotechnology makes people's lives worse
☐ Biotechnology does not impact on people's lives
☐ While there are advantages and disadvantages,their applications are beneficial.
☐ While there are advantages and disadvantages, their applications are detrimental.
☐ Other What?

3) For each activity mark with an (X) what you think is its relationship with Biotechnology:

	Closely related	Medium related	Little related	Nothing related
Vaccine Production				
Culture of microorganisms				
Beer production				
Growing plants				
Bread making				
In vitro fertilization				
Genetic Engineering				
Human Genome Project				
Enzymatic processes				
Bioethics				
Monoclonal antibody production				
Cloning				
Hormone Production				
Wine production				
GMO				
Bioremediation				
Food production				
Gene Therapy				
Drug production				
Food preservation				
Biofuels				
Organ transplants				

4) What is a GMO?

5) How do you think a GMO is made?

6) Have you used a GMO (or any product derived from a GMO) in your daily life? Which one(s)?

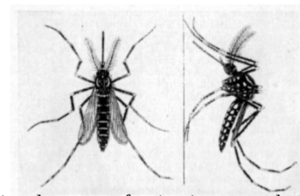
7) Check the option that best represents your point of view regarding each of the following biotechnological processes:

	Totally Agree	Agree	Disagree	Totally Disagree
Modify plant genes so that they can be grown in saline soils				
Modifying bacterial genes for food improvement				
Modify fruit genes to improve taste				
Modify plant genes to increase their nutritional value				
Modify tomato genes to make their ripening slower and then longer				
Inserting genes from microorganisms into corn to provide resistance to insects				
Clone plants that present characteristics of interest (rapid growth, higher nutritional quality, resistance to pests, etc.)				
Apply genetic engineering to cows to produce medicines				
Modifying genes in human cells for the treatment of genetic diseases (gene therapies)				
Manipulate animal genes to improve the quality of your meat or milk				
Apply genetic engineering to microorganisms to produce drugs				
Clone animals with characteristics of interest (meat, milk, rapid development, survival, etc.)				

8) Would you agree to the use and manipulation of stem cells for the development of gene therapies? Justify your answer.

9) Read the text and resolve the following activities:

Dengue fever is a viral disease endemic to a region of Argentina and some neighboring countries. It is transmitted by the bite of the Aedes aegypti mosquito. Currently, work is underway to create a vaccine to prevent the development of the disease, but for the moment the only way to avoid it is through the elimination of the vector, that is, the mosquito.

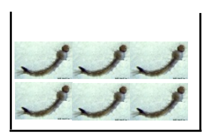


In 2007 an international group of scientists completed the sequence of the mosquito genome. The effort to sequence its DNA is an attempt to collaborate on research into insecticides and possible genetic modifications to prevent the spread of the virus.

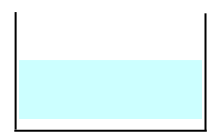
a) Check the option you consider correct regarding what is DNA sequencing

☐ Knowing how many DNA molecules the mosquito has
☐ Knowing which combinations of amino acids make up the mosquito's DNA
☐ Knowing the order of nucleotides in the mosquito's DNA
☐ Knowing what kind of alleles a mosquito has
☐ Knowing the life cycle determined by the mosquito's DNA

b) We wish to test the effectiveness of an insecticide developed from the knowledge provided by the DNA sequencing of the *Aedes aegypti* mosquito. Different materials that could be used are listed below. With the materials you consider necessary, design an experiment to test the effectiveness of the insecticide. .



Water with *Aedes aegypti* mosquito larvae



Water container

Insecticide with a 10% concentration

Insecticide with a 50%

Note that the drawing is only a representation of the material, you can use as many copies of containers, larvae or bottles of insecticide as you think necessary.

c) A vaccine against Dengue is being considered; a vaccine is a solution that contains:

☐ A chemical that prevents viruses from entering the human body

☐ Active viral particles but in very small amounts which serve as antigens but do not develop the disease

☐ Complete viral particles, subunits or live attenuated viruses that serve as antigens but do not develop disease

☐ A set of antibodies against the viral disease