Student Primary Teachers' Knowledge and Attitudes Towards Biotechnology—Are They Prepared to Teach Biotechnological Literacy?

Marina Casanoves de la Hoz[1] · Anna Solé-Llussà[2] · Juan Haro[3] · Niklas Gericke[4] · Cristina Valls[5]

Abstract

The speed of development of biotechnology within agriculture, industry, and medicine has changed our lives, and we need a biotechnological literacy to understand it. This implies that teachers in primary schools need to be biotechnologically literate in order to educate future generations. The aim of this study was to investigate Swedish pre-service primary school teachers' knowledge of and attitudes towards biotechnology and contextualize the results by comparing them with a corresponding group of Spanish teachers. Data was collected using the established questionnaire instrument Biotech XXI and analyzed statistically. The findings demonstrate that Swedish pre-service primary school teachers have knowledge gaps relating to the basic genetic concepts that underpin biotechnology, although they are aware of biotechnological applications. Their attitudes are quite positive towards biotechnological applications in health, but less so to buying and using genetically modified products. Higher levels of knowledge were correlated with more positive attitudes, indicating an attitudinal basis for expanding the knowledge of and teaching practices for biotechnology among primary teachers. The level of knowledge and attitudes in the Swedish sample were similar to those of the Spanish teachers, suggesting a similar situation may be prevalent in many countries. The results indicate a need to reconsider the science curricula within pre-service primary school teacher training programs in order to better prepare primary teachers for teaching biotechnological literacy.

Keywords Attitudes towards biotechnology · Biotechnological literacy · Genetic education · Pre-service teachers' understanding · Primary education

✉ Cristina Valls
cristina.valls@urv.cat

1   Faculty of Educational Sciences and Psychology, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili, Carretera de Valls S/N, Tarragona, Catalonia 43007, Spain

2   Faculty of Educational Science, Psychology and Social Work, Department of Specific Didactics, Universitat de Lleida, Lleida Av. de L'Estudi General, 4., Lleida, Catalonia 25001, Spain

3   Faculty of Educational Sciences and Psychology, Department of Psychology, Universitat Rovira i Virgili, Carretera de Valls S/N, Tarragona, Catalonia 43007, Spain

4   Department of Environmental and Life Sciences, Karlstad University, Universitetsgatan 2, Karlstad 65188, Sweden

5   Faculty of Educational Sciences and Psychology, Department of Biochemistry and Biotechnology, ARGET Research Group, Universitat Rovira i Virgili, Carretera de Valls S/N, Tarragona, Catalonia 43007, Spain

Introduction

During the twenty-first century, biotechnology is one of the science disciplines that has undergone the most rapid development, with significant implications for our society (Usak et al., 2009). Biotechnological applications raise ethical, social, and philosophical questions (Salvadó et al., 2013), and for most biotechnological applications, it is the public that judges their desirability and determines their success (Costa-Font & Mossialos, 2006). Therefore, it is important that primary education fosters biotechnological literacy early in children's schooling (Chabalengula et al., 2011); such literacy often contains knowledge and attitudinal dimensions (Bromme & Goldman, 2014; Carver et al., 2017). In response to the biotechnological revolution, many curricula around the world now include biotechnology (Klop & Severiens, 2007). However, this poses educational challenges to teachers, especially primary teachers, who often have limited biotechnological knowledge (Chabalengula et al., 2011). As primary school

teachers have a large influence on the development of future generations' biotechnological literacy, it is important that we understand their knowledge and attitudes towards biotechnology, so that we can identify any need to revise and develop the biology curricula and guidance for the teachers.

Background

The Importance of Biotechnological Literacy

In order to involve society in the decision-making process about scientific policies, we need well-informed citizens who are able to make insightful decisions based on scientific conclusions. In this context, science education worldwide promotes, as an important goal of science teaching, scientific and technological literacy (Bybee et al., 2009; Roberts, 2007; Zoller, 2012).

The need for scientific literacy has been highlighted as important in the specific field of biotechnology (Salvadó et al., 2013; González et al. 2013; Carver et al., 2017). Biotechnology can be defined as the fastest growing industry in the production of commercial applications and products throughout the world (Straathof et al., 2019). Biotechnological literacy as a subset of scientific literacy is therefore important to enable people to consider and critically evaluate associated issues, to make informed decisions, and to develop opinions based on knowledge. Biotechnology is underpinned by scientific knowledge of the field of genetics (Bahri et al., 2014). Without a basic knowledge of genetics, it is difficult to evaluate biotechnological applications (Gericke & Smith, 2014).

Over the last few decades, interest in biotechnological literacy has increased among science education researchers (Kidman, 2009; Klop & Severiens, 2007; Sorgo & Ambrozic-Dolinsek, 2009). These studies have assessed teachers' and students' perceptions and understanding of different aspects of biotechnology, including knowledge, fears, beliefs, and ethics related to the use of these new technologies. Some studies have highlighted the importance of introducing biotechnological knowledge into teacher training curricula in order to improve pre-service primary school teachers' self-efficacy in teaching about biotechnology (Delamarter, 2015; García-Carmona & Cruz-Guzmán, 2016).

It has been shown that pre-existing attitudes and beliefs influence the way teachers understand what they learn during their training, and how they implement the content in their daily practice at school (Cebesoy & Öztekin, 2017; Jiménez-Salas et al., 2017; Lee & Ginsburg, 2007). Research also indicates that what teachers consider to be correct and important also influences the way they teach (Buehl & Beck, 2015). In the case of biotechnology, this has been illustrated within higher education (Solli et al., 2014). Teachers with more positive attitudes towards science include science topics more often in the classroom and use active learning methodologies (Haney et al., 2002; Orhan & Sahin, 2018). In order to enable all teachers to promote biotechnological literacy in primary education, we therefore first need to know pre-service primary school teachers' existing knowledge and attitudes.

International Studies on Knowledge and Attitudes Towards Biotechnology

In the first decade of the twenty-first century, there was a great interest in, and recognition of the importance of, exploring public knowledge of and attitudes towards the rise in biotechnological applications in society (e.g., Barnett et al., 2007; Condit, 2010; Gaskell et al., 2010). However, in the second decade, only a few studies have been published on this topic, yet the evolution of biotechnology and its impact in society have increased, as, for example, with the development of the gene scissors Crispr/Cas9 (Doudna & Charpentier, 2014). This has led to a call to revisit the issue and see whether knowledge and attitudes towards biotechnology have changed as a consequence of these new applications.

Previous large, generalizable studies on knowledge and attitudes towards biotechnology have been conducted at a public level rather than in school contexts. The best baseline for comparisons is provided by the Eurobarometer surveys, conducted within many countries in Europe, including Sweden and Spain. However, the most recent survey on knowledge and attitudes towards biotechnology was published in 2010 (European Commission, 2010). According to European Commission (2010), about one in five adults in Europe is qualified as well-informed about biotechnology.

An important aspect of previous studies is that a difference in public attitudes and knowledge was found between northern and southern European countries. For example, in the Eurobarometer 2010 study, Sweden was ranked third among the 15 participating European countries, while Spain was ranked 12th. The Eurobarometer 2010 study also compared trends in optimism towards biotechnology and genetic engineering between the countries: 74% of Spanish citizens were optimistic about using these technologies, compared with 63% of Swedish citizens. In line with those finding, Magnusson and Hursti (2002) found that most Swedish consumers had moral and ethical doubts about eating GM foods, which were not outweighed by perceived attributes like better taste or lower price. However, less tangible benefits such as being better for the environment or healthier seemed to increase their willingness to purchase GM foods.

To conclude, as can be seen in the European Commission (2010) data, there were large differences between European countries in attitudes towards genetically modified (GM) food. The

most positive attitudes to producing and consuming GM food were found in the Czech Republic, Slovakia, Portugal, and Spain, while Sweden, Italy, Austria, and Germany were among the most negative. It is clear from this that country-specific results should be contextualized within a European-wide context, and countries should be compared using the same instruments. To contribute to such comparison, in the study presented here, we investigated Swedish pre-service primary school teachers' knowledge and attitudes towards biotechnology and compared the results with previously obtained results from Spain using the same instrument and a comparable sample of pre-service primary school teachers. The participants (Spanish and Swedish) are seen as representatives of northern and southern European countries, respectively, that reportedly differ substantially in attitudes and knowledge regarding biotechnological issues (European Commission, 2010). Comparison of attitudes and knowledge of participants in these contrasting educational and cultural settings was expected to provide more general insights into student primary teachers' readiness to teach biotechnological literacy.

Teachers' Attitudes and Knowledge Towards Biotechnology

Teachers can play a central role in promoting biotechnological literacy. Biotechnological education and literacy are included in the biology curricula of most countries (Klop & Severiens, 2007), including Sweden (Education, 2011) and Spain (Real Decreto, 1105/2014). Genetics is commonly taught in secondary school, but applied sciences such as biotechnology, in which pupils meet science as part of their everyday lives, should be taught in primary education (Laugksch, 2000), as many values and beliefs are formed at this level of schooling.

Most studies to date have only investigated public understanding of biotechnology, e.g., Carver et al. (2017). Only a few studies appear to have investigated primary school teachers' attitudes and knowledge in biotechnology, in five different countries: Slovakia (Prokop et al., 2007), Lithuania (Lamanauskas & Makarskaite-Petkeviciene, 2008), Slovenia and Turkey (Šorgo et al., 2011), Turkey (Darçin, 2011), USA (Chabalengula et al., 2011), and Spain (Casanoves et al., 2015). The study from Slovakia found that student teachers held numerous misunderstandings about biotechnologies, but with a significant correlation between positive attitudes and increased level of knowledge (Prokop et al., 2007). The Lithuanian study of Lamanauskas and Makarskaite-Petkeviciene (2008) similarly revealed that knowledge about biotechnology among student teachers was poor and that no significant differences between student teachers studying biology and those studying other subjects were found. Šorgo et al. (2011) found in a study of Slovenian and Turkish teachers that knowledge of genetics and biotechnology influenced their attitudes towards genetic modification in a slightly positive direction.

In another study of Turkish teachers, no correlations could be seen between knowledge level and attitudes (Darçin, 2011). A study from the USA showed that most pre-service primary school teachers had positive attitudes to the use of biotechnological applications and the genetic modification of food and plants. However, the majority of those pre-service primary school teachers disapproved of the genetic modification of humans and animals (Chabalengula et al., 2011). A Spanish study (Casanoves et al., 2015) showed that pre-service primary school teachers were aware of biotechnological applications, but knew less about the actual technological procedures. The Spanish pre-service primary school teachers' attitudes were positive towards the use of biotechnology for medical purposes and were highly interested in the topic.

Overall, most research about attitudes to and understanding of biotechnology is about 10 years old, and data from many specific contexts, such as Swedish pre-service primary school teachers, is missing. This exposes an important research gap because pre-service primary school teachers will be highly influential in shaping future generations' knowledge and attitudes towards biotechnology. The aim of this study was therefore to explore this issue by investigating pre-service primary school teacher students' knowledge of and attitudes towards biotechnology.

Aim and Research Questions

The study analyzes Swedish pre-service primary school teachers' views of two aspects of biotechnology to address the following research questions: (i) the level of their biotechnological knowledge, (ii) their attitudes towards biotechnology, (iii) and the correlation between knowledge and attitudes. (iv) A comparison was then made between the data from the present Swedish sample with data collected previously from Spanish pre-service primary school teachers (Casanoves et al., 2015), in order to see whether there were any differences in knowledge and/or attitudes between a northern European country and a southern European country.

Methods

Participants and Data Collection

The study was conducted with a sample of 155 student primary teachers (26.61 ± 7.21 years old; 86% female and 14% male) from a large teacher training university in the middle of Sweden. The students were taking one of three different teacher training programs: "preschool education" (including first years at primary education), "primary education (grades 1 to 3)," and "primary education (grades 4 to 6)." Within those programs, the students' took a general science course during one semester, which had only limited content

related to biotechnology. The students had also had a general science course in their previous secondary schooling, which covered genetics and biotechnology to some extent.

A paper questionnaire was distributed to the students in class by the first author. Hence, all the participants were given the same instructions under controlled conditions.

The Spanish data came from a previous sample of 407 student teachers from two educational universities in two major cities in the province of Catalonia. All participating students were taking a program called "preschool and primary education," and the questionnaire had been distributed to them in the same way (Casanoves et al., 2015).

Both studies followed the ethical guidelines of the respective countries; participation was voluntary, and the responses were anonymized.

Instrument Design

The instrument used was the Biotech XXI questionnaire. This had been developed in a previous study and validated with a sample of Spanish pre-service primary school teachers (Casanoves et al., 2015). The reliability and validity of the Swedish data are accounted for here. The instrument is based on a biotechnology framework, including topics such as genetics, molecular biology, and genetically modified organisms (GMO). It contains items taken from previously published and validated surveys (Chabalengula et al., 2011; European Commission, 2010; Klop & Severiens, 2007; Prokop et al., 2007), as well as novel items constructed to implement the framework. The questionnaire consisted of three distinct sections. The first section was designed to obtain socio-demographic information about the respondents. The second section comprised 21 true/false/don't know items that assessed the respondents' knowledge of biotechnology, including genetic knowledge and biotechnological applications; see Table 1. The third section was a 4-point Likert-scale questionnaire with 45 items, for which respondents rated their opinions on statements about biotechnological applications as 1 (strongly disagree), 2 (disagree), 3 (agree), and 4 (strongly agree), see Table 2. For a full and detailed description of the instrument, see Casanoves et al. (2015).

Table 1 Knowledge items with the most frequent correct responses among Swedish teachers. In the column "correct answer," T (true) and F (false)

Number	Item	Correct answer	Responded correctly (%)	Responded incorrectly (%)	Don't know (%)
1	AIDS is a genetic disease	False	83	14	4
2	Bacteria are used in the elaboration of daily products (cheese, vinegar, vitamin C)	True	80	6	14
3	Only when we eat GM food we eat genes	False	78	7	15
4	In our body, there are more bacteria than people in the world	True	77	8	14
5	A good hygiene helps to prevent genetic diseases	False	75	15	9
6	Children resemble their parents because they share the red blood cells	False	72	8	21
7	It is possible to change the genetic characteristics of a plant to make it more resistant to a given plague	True	65	9	26
8	Mutations are only possible by genetic manipulation in the laboratory	False	65	16	19
9	A high production of vitamins by a fruit is only possible by genetic manipulation of that fruit	False	63	11	26
10	Through genetic modification, foods with higher nutritional values can be achieved	True	50	13	37
11	Microorganisms are used to purify sewage	True	48	11	41
12	A yogurt is a biotechnological product	True	41	17	42
13	Insulin is obtained by the use of genetically modified (GM) bacteria	True	38	16	46
14	Genetic material exchange between different species is only possible by manipulation in the laboratory	False	35	32	32
15	The most powerful toxic substances are naturally occurring	True	34	30	36
16	GMO have a high number of toxic substances	False	33	19	48
17	Chemically, the genetic material (DNA) is identical in all the organisms	True	32	41	28
18	In the kidney cells genome, you can also find the information about the color of your hair	True	27	26	47
19	Genetically modified organisms (GMO) are larger than normal	False	21	26	53
20	Crocodiles have the same genetic material as ostriches	True	17	34	50
21	A GMO is always a transgenic	False	8	22	70

In order to administer the questionnaire to the Swedish student teachers, the questionnaire was translated into Swedish based on a developed English standard version of the original (Casanoves et al., 2015). A second independent back translation was then made into English to secure the validity of the translation. Some changes were made based on the back translation, and the final items piloted with a group of 15 Swedish pre-service primary school teachers to make sure the questionnaire were understood as intended.

Statistical Analysis

Analyses were performed using SPSS Statistics 20. First, we checked the reliability of the second (knowledge items) and third (attitudes) sections of the questionnaire by calculating Cronbach's α (CA). Second, we conducted an exploratory factor analysis (principal component analysis with varimax rotation) to find the factorial structure of participants' attitudes towards biotechnology. We used a Horn's parallel analysis and Screen test to select the optimal number of factors. The factorial scores of each participant were interpreted from their attitudes towards biotechnology, from 1 (strongly disagree) to 4 (strongly agree). These scores were later entered into a K-means cluster analysis to group participants with similar attitudes. We also calculated some correlation coefficients: Pearson's correlation coefficient (r; between quantitative variables), a biserial-point coefficient (rpb; between nominal and quantitative variables), a biserial coefficient (rb; between ordinal and quantitative variables), and a rank-biserial coefficient (rrb; between ordinal variables).

Finally, the knowledge and factorial scores from the Swedish and the Spanish samples were compared using independent sample t-tests. In addition, Pearson's chi-square tests were performed to compare the percentage of correct answers in the knowledge section between the two samples ("don't know" answers were considered to be incorrect answers). Analyses of the reliability and validity of the Spanish data can be found in Casanoves et al. (2015).

Results

Knowledge of Biotechnology

The biotechnological knowledge section of the questionnaire comprised 21 questions. The CA value for this section was 0.66, which is acceptable according to Nunnally (1978). Table 1 shows the 21 items ordered from the highest to the lowest percentage of correct answers. The first 10 items were answered correctly by more than 50% of the Swedish student teachers, while the last 11 items represent questions that were answered incorrectly, or marked as "don't know," by more than 50% of students.

As shown in Table 1, we found that the Swedish pre-service primary school teachers lacked knowledge about many basic concepts of genetics and about some aspects of biotechnology related to GMO. For instance, 68% of the students answered incorrectly, or did not know, that DNA is chemically identical in all organisms. Only 21% knew that GMOs are not necessarily larger than other organisms, and many were unsure about whether GMO contained toxic substances. However, the respondents had a fairly good understanding of some of the biotechnological applications. For example, 80% of the students were aware that bacteria are used in the manufacture of cheese and vinegar, among other daily products, and 65% of students knew that it is possible to change genetic characteristics in order to increase an organism's resistance to disease, increase nutritional values, or increase productivity.

Attitudes Towards Biotechnology

This section consisted of 45 items; the reliability score (Cronbach's α) was 0.81, indicating high reliability. In general, the Swedish student teachers had a relatively neutral attitude towards biotechnology, with an average score for each of the 45 items of 2.61 (± 0.89), just above the overall mean of 2.5.

Each participant's attitude towards biotechnology was interpreted using a factorial score based on the mean value for each item. The suitability of the respondents' data for the analysis was supported by two measures: the Kaiser–Meyer–Olkin test, with a value of 0.74, and the Barlett's test, which was statistically significant ($p < 0.001$). We included the responses to the 45 attitude items in an exploratory factor analysis, resulting in four factors that explained 37.7% of the total variance (see Table 2). Three items were deleted because their factor loadings were lower than 0.3. The four explanatory factors that were examined further were named: *general opinion of GMO applications, personal feelings towards GMO, biotechnology and health, and interest in biotechnology.*

General Opinion of GMO Applications

This factor had an average score of 2.58 (± 0.16); see Table 2. It included 14 items (Cronbach's $\alpha = 0.586$) that expressed perceptions and opinions about the use of GMO at individual and societal levels. However, the majority of the students did not have a clear standpoint for most of the items in this factor. For example, 57% of the students did not think that consumption of GM foods was dangerous, but 67% of them said that genetic manipulation should be more strictly regulated. Hence, the student teachers' opinions were diverse and inconsistent within this factor, which could explain the relatively low CA value.

Table 2 Factor structure and loading of the 42 items related to attitudes towards biotechnology

Number	Item	Average rating	SD rating	Loading item factor	Strongly negative	Attitude (%) Negative	Positive	Strongly positive
Factor 1: general opinion of GMO applications								
1	Consumption of GM foods is dangerous.[*d]	2.58	0.81	0.68	9.68	33.55	45.81	10.97
2	Genetically altering living beings is to play God.[*]	2.68	1.00	0.61	14.19	28.39	32.26	25.16
3	Genetic manipulation will drive to the extinction of a large number of species.[*]	2.50	0.77	0.58	9.68	37.42	45.81	7.10
4	I would forbid the sale of transgenics in my country.[*]	2.47	0.78	0.57	9.68	41.29	41.29	7.74
5	The genetical modification of fruits and plants to be fresh for a longer time.[C]	2.87	0.84	0.54	3.23	32.26	38.71	25.81
6	Genetic manipulation is no ethical.[*]	2.63	0.74	0.53	5.81	34.84	49.68	9.68
7	The addition of genes to a plant to make it plague-resistant is unacceptable.[*]	2.65	0.79	0.53	7.74	30.97	49.68	11.61
8	The fast evolution of science threatens humanity.[*]	2.79	0.89	0.49	9.03	25.16	43.87	21.94
9	There should be limits to what can and cannot be investigated.[*b]	2.50	0.94	0.47	14.84	36.13	32.90	16.13
10	I am opposed to the transfer of genes between plants and animals.[*d]	2.30	0.82	0.46	17.42	41.29	35.48	5.81
11	Genetic manipulation should be more strictly regulated	2.76	0.77	0.43	5.81	27.10	52.26	14.84
12	The application of biotechnology will make the future more dangerous.[*]	2.43	0.76	0.40	11.61	38.71	45.16	4.52
13	If I get a dish in a restaurant made out of transgenic food, I would not eat it.[*c]	2.47	0.82	0.39	11.61	38.71	40.65	9.03
14	The genetic modification of a sheep to produce medicines.[a]	2.43	0.84	0.33	12.26	43.23	34.19	10.32
Factor 2: personal feelings towards GMO								
1	If genetically modified food was cheaper, I would buy it	1.92	0.79	0.72	30.32	51.61	13.55	4.52
2	The alteration of the genes of a fruit to make it more tasty.[c]	1.84	0.74	0.64	34.84	48.39	14.84	1.94
3	The labeling of the transgenic products is clear enough	1.85	0.62	0.60	27.74	60.00	12.26	0.00
4	I would buy GM food	2.14	0.81	0.60	22.58	44.52	29.03	3.87
5	If genetically modified food was healthier, I would eat them more often.[c]	2.50	0.93	0.59	18.06	26.45	43.23	12.26
6	I would feed my children with food produced with GM bacteria	1.95	0.74	0.57	27.10	52.90	17.42	2.58
7	The genetic modification of a bacteria to produce food	2.37	0.78	0.47	12.90	43.23	38.06	5.81
8	Society should decide what is right or wrong in science	2.32	0.79	0.42	14.19	45.81	34.19	5.81
9	GM foods can help alleviate world hunger.[c]	2.77	0.82	0.34	7.10	26.45	49.03	17.42
10	Biotechnology does not play any role in environmental protection.[*]	2.94	0.70	0.32	1.94	21.29	57.42	19.35
11	Biotechnology is used to produce chemicals in a less polluted way	2.48	0.69	0.31	5.16	47.10	41.94	5.81

Table 2 (continued)

Number	Item	Average rating	SD rating	Loading item factor	Strongly negative	Negative	Positive	Strongly positive
						Attitude (%)		
Factor 3: biotechnology and health								
1	Biotechnology makes our lives easier.[c]	2.98	0.62	0.63	1.94	14.19	67.74	16.13
2	I agree with the genetic investigation in medicine	2.95	0.77	0.61	3.87	20.65	52.26	23.23
3	I would support the use of GMO for non-food purposes	2.39	0.79	0.61	14.19	36.77	44.52	4.52
4	Biotechnology can improve our life style	2.98	0.74	0.59	3.87	16.77	56.77	22.58
5	The use of GMO for medical therapy and the study of diseases.[c]	2.79	0.65	0.59	2.58	26.45	60.65	10.32
6	Biotechnology is evil for nowadays society.[*]	3.06	0.64	0.56	1.94	11.61	65.16	21.29
7	The use of GMO to fight against diseases	2.61	0.72	0.49	5.81	34.84	51.61	7.74
8	The law about GMO is strict enough	2.37	0.68	0.47	7.74	50.32	38.71	3.23
9	I agree with the genetic transformation in embryos to cure hereditary diseases.[a]	2.65	0.90	0.44	12.90	25.16	45.81	16.13
10	A scientific discovery is not "good" or "bad," is how we use what matters.[b]	3.43	0.70	0.42	1.29	8.39	36.77	53.55
11	Science makes our lives easier.[b]	3.19	0.79	0.40	3.23	13.55	43.87	39.35
12	The clonation as a tool to save endangered species.[d]	2.59	0.84	0.31	10.32	32.90	44.52	12.26
Factor 4: interest								
1	I would like to know more about GM food.[d]	3.10	0.85	0.84	5.81	14.19	44.52	35.48
2	I would like to have more information about GM food	3.15	0.91	0.80	7.10	12.90	37.42	42.58
3	I would like to increase my knowledge about GMO	3.08	0.86	0.74	5.16	17.42	41.29	36.13
4	I would like to be aware of scientific advances	3.21	0.77	0.72	3.87	9.68	47.74	38.71
5	Biotechnology is boring.[*]	2.57	0.89	0.45	11.61	34.84	38.06	15.48

The Table shows respondents' attitudes (positive or negative) towards biotechnological issues. Responses to items presented as negative sentences were reversed in order to obtain a visually meaningful graphical representation of a positive or negative attitude to the different aspects of biotechnology included in the survey. Items with reversed answers are identified with an asterisk. Items from published instruments are identified by superscript letters:

[a]Chabalengula et al. (2011)

[b]European Commission (2010)

[c]Klop (2008)

[d]Lamanauskas and Makarskaite-Petkeviciene (2008)

Personal Feelings Towards GMO

The second factor had a mean value of 2.28 ($\pm$0.38); see Table 2. It consisted of 11 items mainly representing personal feelings and consumer tendencies towards GMO products (Cronbach's $\alpha = 0.768$). In general, the student teachers had negative attitudes towards GMO-produced food and would avoid the consumption of GM food, even when the benefit to the consumer in terms of tastier or cheaper food was considered (items 1, 2, 5, and 7 of factor 2). However, if the genetic modification of food production was focused on healthier products, there was a tendency towards being more likely to buy it.

Biotechnology and Health

The third factor had a mean value of 2.83 ($\pm$0.32) and included 12 items (Cronbach's $\alpha = 0.775$); see Table 2. The

main theme of this factor was biotechnological innovations in health care applications. The students had more positive attitudes to using new biotechnological advances for health purposes. For example, 71% of the students agreed with the use of GMO for medical therapy and the study of diseases, and three in four respondents approved of the use of genetic investigations in the development of medicine.

Interest in Biotechnology

The fourth factor had a mean value of 3.02 (± 0.26) and comprised 5 items related to interest in biotechnology (Cronbach's $\alpha = 0.792$); see Table 2. In general, the students were very interested in knowing more about biotechnological topics. For example, 77% of the students declared that they would like to improve their knowledge about GMO.

Clustering of Attitudes Towards Biotechnology

We then analyzed whether clusters of individuals could be identified among the sample of Swedish students, by performing a K-means cluster analysis. The result was two interpretable clusters (see Fig. 1), which differed significantly regarding factor 2, personal feelings towards GMO ($t(155) = 2.58$, $p < 0.01$), and factor 3, biotechnology and health ($t(155) = 13.59$, $p < 0.001$). However, the clusters did not differ significantly for factor 1 (general opinion of GMO applications) or factor 4 (interest in biotechnology) (all $ps > 0.05$). We called these clusters "the skeptical" and "the confident."

The Skeptical

Cluster 1 included 48 students. These students were more negative than the others about the use of biotechnology in medical applications to improve living standards and the consumption of GMO products. They showed a lower mean score in attitude towards biotechnological applications in healthcare (factor 3), suggesting that they were less inclined to support genetic investigations into medicinal development, and the use of GMO in medical therapy (item 2 (2.95 ± 0.77) and item 5 (2.79 ± 0.65) from factor 3). They did not want to eat GM food, or members of their family to eat it, even if it would be cheaper or tastier (item 1 (1.92 ± 0.79), item 2 (1.84 ± 0.74), item 4 (2.14 ± 0.81), and item 6 (1.95 ± 0.74) from factor 2). Furthermore, they did not like the idea of using GM bacteria to produce food, and they felt that the labeling of transgenic products is not clear enough (item 3 (1.84 ± 0.62) and item 7 (2.37 ± 0.78) from factor 2).

The Confident

Cluster 2 included 107 students. These students were more positive towards GMO products generally. They were more positive about eating GM food, and offering GM food to their families (item 1 (1.92 ± 0.79), item 4 (2.14 ± 0.81), item 5 (2.50 ± 0.90), and item 6 (1.95 ± 0.74) from factor 2). They agreed that medical applications of biotechnology could improve living standards, and they trusted biotechnological applications for medical therapy, the study of diseases,
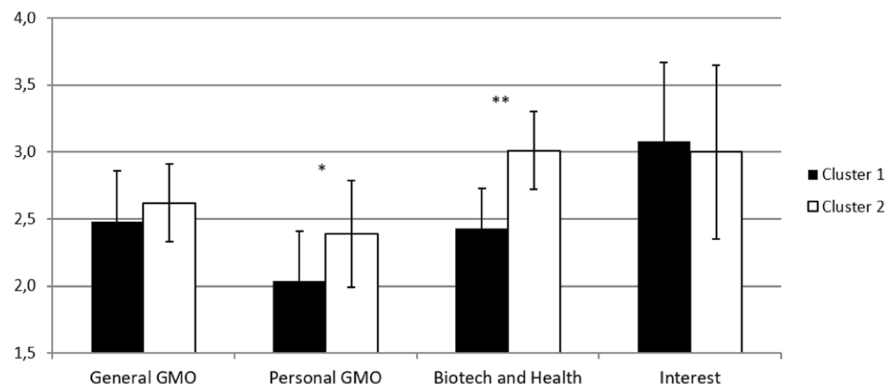
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cluster 1_The scepticals	2.48	0.38	2.04	0.37	2.43	0.30	3.08	0.59
Cluster 2_The confident	2.62	0.29	2.39	0.40	3.01	0.29	3.00	0.65

Fig. 1 A graphical representation of the K-means cluster analysis of attitudes towards biotechnology. General GMO corresponds to factor 1, personal GMO corresponds to factor 2, STS corresponds to factor 3 (biotechnology and health), and interest corresponds to factor 4 of the exploratory factor analysis. **Significance of $p < 0.01$ and *$p < 0.05$ using the t-test statistical analysis between factors of each cluster. The attitude scale ranged from 1 (strongly negative) to 4 (strongly positive)

and genetic transformation in embryos to cure hereditary diseases (item 9 (2.65 ± 0.90) from factor 3).

Correlations Between Knowledge and Attitudes

Correlation coefficients were calculated to examine to what extent the socio-demographic data, knowledge scores, and attitude scores of the student teachers were related (Table 3). Significant correlations were observed between knowledge and attitude scores. Pre-service primary school teachers who scored better marks in the knowledge section had more positive attitudes towards biotechnological applications related to health, and they showed more interest in increasing their knowledge of biotechnology-related topics. This was illustrated by the correlations found between knowledge and factor 3 (biotechnology and health) and factor 4 (Interest in Biotechnology); see Table 3.

Comparison Between Swedish and Spanish Samples

Once analyses of the Swedish data were complete, we compared the results statistically with data from a similar Spanish sample, see the "Methods" section and Casanoves et al. (2015).

Knowledge of Biotechnology

We carried out an independent *t*-test in order to compare the knowledge sections from the Swedish and Spanish questionnaires. The results showed no differences between the samples regarding total knowledge scores, $t(560) = 1.05$, $p > 0.05$, suggesting that Swedish and Spanish students have similar levels of knowledge relating to genetics and biotechnological applications.

Attitudes Towards Biotechnology

For the Spanish sample, the average value relating to attitudes was 2.69 (± 0.89). Four factors were identified in the Spanish respondents' attitudes to different aspects of biotechnology; see the "Background" section and Casanoves et al. (2015) for an outlined description. These were GMO, biotech and health, science–technology–society, and interest in biotechnology. The factor analysis for the Swedish data also divided the attitude items into four factors: general opinion

of GMO applications, personal feelings towards GMO, biotechnology and health, and interest in biotechnology.

A comparison between the Swedish and Spanish students' perceptions relating to attitudes towards biotechnology was made by calculating Pearson's correlation coefficients between the factor loadings of the 45 items in each questionnaire. The results revealed a correlation between the factor called "GMO" (factor 1) in the Spanish sample and the factor called "personal feelings towards GMO" (factor 2) in the Swedish sample ($r = .56$, $p < .01$). These factors had a similar basis relating to students' personal opinions about the implications and consequences of using new technologies related to GM products and their personal behaviors about consuming those products.

We also found a positive and significant correlation between the factor called "science–technology–society" (factor 3) in the Spanish sample and the factor called "general opinion of GMO applications" (factor 1) in the Swedish students ($r = .49$, $p < .01$). These factors indicated a common concern about the applications of GMO in global and social contexts.

The factor called "biotechnology and health" (factor 2 for Spanish and factor 3 for Swedish student teachers) showed a positive and significant correlation between the countries ($r = .54$, $p < .01$). It appeared that Spanish as well as Swedish student teachers grouped items related to new biotechnological applications in the field of healthcare in a similar way.

Finally, the factor called "interest in biotechnology" (factor 4 in both countries) included the same five items in both countries and showed a high correlation between the samples ($r = .81$, $p < .01$).

The high correlations between these four factors from each country indicated a high factorial similarity between the data sets and, thus, allowed us to compare the factorial scores of the Spanish and Swedish students. Because the samples differed in a number of participants, we selected a random subset of 155 participants from the Spanish sample to conduct *t*-tests (Bruce, 2015) (Fig. 2). The results showed a significant difference between the factor called "science–technology–society" (factor 3) for the Spanish sample and the factor called "general opinion of GMO applications" (factor 1) for the Swedish sample ($t (308) = 3.204$, $p < .01$). This indicated that Spanish respondents (mean 2.71, SD 0.41) were in general slightly more positive in their attitudes

Table 3 Correlations between socio-demographic data, knowledge scores, and attitude scores

	Parents	Knowledge	General GMO	Personal GMO	Biotech health	Interest in biotechnology
Knowledge		.067	.017	.262[**]	.169[*]	
General GMO			.329[**]	.336[**]	.017	
Personal GMO				.427[**]	.134	
Biotech health					.244[**]	

Reported statistical significance: [*]$p < 0.05$; [**]$p < 0.01$
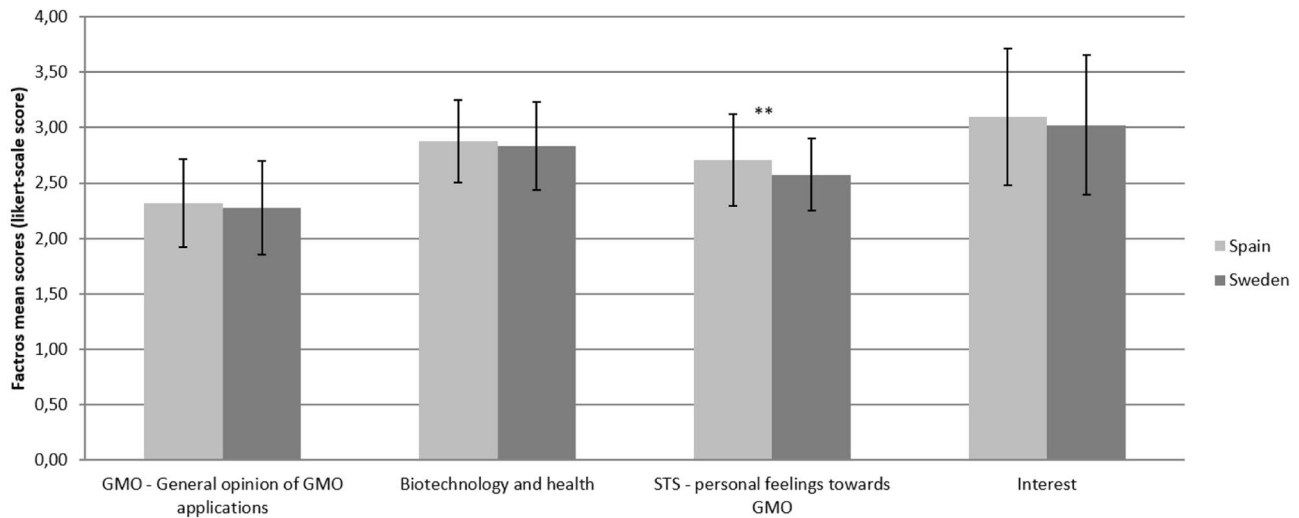
Factors Comparison

Fig. 2 A graphical representation of independent *t*-test for factor comparisons. Factor 1 Spain (GMO) with factor 1 Sweden (General GMO), factor 3 Spain (STS) with factor 2 Sweden (personal GMO), factor 2 Spain with factor 3 Sweden (biotechnology and health), and interest in biotechnology corresponding to factor 4 in both countries. **Significance of $p < 0.01$. The attitude scale ranged from 1 (strongly negative) to 4 (strongly positive)

to issues concerning applications of GMO than the Swedish pre-service primary school teachers (mean 2.58, SD 0.33).

No statistically significant differences were found between the factor "GMO" (factor 1) from the Spanish sample and the factor "personal feeling towards GMO" (factor 2) from the Swedish pre-service primary school teachers. Both populations showed a slightly negative attitude towards buying or consuming GMO (Sweden, mean 2.28, SD 0.42) (Spain, mean 2.32, SD 0.40). Furthermore, the student teachers displayed similar attitudes to the factor "biotechnology and health" (factor 2 for Spanish and factor 3 for Swedish) in both countries; our analysis did not find any significant differences between the average values of these two factors (Spanish mean 2.88, SD 0.37 and Swedish mean 2.83, SD 0.40). Hence, attitudes towards biotechnological applications in healthcare were generally positive in both countries. Finally, the factor "interest in biotechnology" (factor 4 in both countries) showed no significant differences between the two countries. Both Spanish (mean 3.10, SD 0.62) and Swedish respondents (mean 3.02, SD 0.63) expressed a high interest in biotechnological issues.

Discussion

This study analyzed Swedish primary education pre-service primary school teachers' knowledge and attitudes towards biotechnology and then compared them with a similar dataset from Spain. The two countries were chosen to represent a northern European and southern European country, respectively.

Swedish Pre-service Primary School Teachers' Biotechnological Knowledge

The knowledge test revealed that Swedish pre-service primary school teachers scored a high percentage of correct answers for questions related to understanding genetic disease and applications of biotechnology. Lower scores were obtained for questions related to basic concepts of genetics as well as questions related to GMO. The European Commission (2010) study revealed that Europeans in general did not score highly regarding knowledge of the basic concepts of genetics. In accordance with these earlier findings, the Swedish and Spanish, pre-service primary school teachers discussed here show a lack of knowledge about basic genetics that could negatively influence their ability to address biotechnological applications in their teaching. However, there were some exceptions to this trend. Most of the Swedish pre-service primary school teachers (78%) in our study knew that both GM food and non-GM food contained genes, which was higher than in a study by Magnusson and Hursti (2002) carried out almost 20 years ago, which found that only 67% of Swedish consumers could answer a similar question. Hence, some positive trends were seen.

Both Swedish and Spanish pre-service primary school teachers achieved a higher percentage of correct answers on questions related to uses of biotechnology compared with studies of Slovakian (Prokop et al., 2007), Turkish (Usak et al., 2009), and Lithuanian (Lamanauskas & Makarskaite-Petkeviciene, 2008) student teachers. But in relation to

questions concerning more basic genetics, such as DNA structure and cell management of genetic information, both Swedish and Spanish pre-service primary school teachers showed the same meagre knowledge level as found in other countries, such as Turkey, Slovakia, Slovenia, Lithuania, and Lebanon (Darçin & Güven, 2008; Erdoğan et al., 2012; Lamanauskas & Makarskaite-Petkeviciene, 2008; Sorgo & Ambrozic-Dolinsek, 2009).

Because of a lack of understanding of basic genetic concepts, an understanding of more complex biotechnologies may be difficult for these pre-service primary school teachers. Our study indicates that the lack of knowledge identified some 10 years ago still seems to exist. It seems that biotechnological literacy has not yet been accomplished, and primary teachers will therefore presumably struggle to develop this literacy among future generations.

Swedish Pre-service Primary School Teachers' Attitude Towards Biotechnology

One of the aims of this study was to analyze the Swedish pre-service primary school teachers' attitudes towards biotechnology. They showed an average score for attitudes to biotechnology of 2.61 (± 0.89), indicating a neutral attitude. The students could generally be defined as opponents to buying GM products, but supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnological and scientific advances. The Swedish pre-service primary school teachers were not judging the "biotechnology" as such, but they did seem to judge its purpose and use. This could be indicative of an underlying utility–value system that is influencing a shift in attitudes towards GMO applications, based on what the technology is being used for. Hence, GMO is acceptable when it is being used to save human lives or prevent disease, but it is not acceptable for enjoyment or economic gain. In accordance with this idea, a previous study by Magnusson and Hursti (2002), of a population of Swedish consumers, showed similar results. Our Swedish pre-service primary school primary teachers had similar values for items included in factor 3 "personal feelings towards GMO," in which their attitudes about buying, consuming, or producing GM products were assessed. The attitudes of our Swedish student teachers therefore seem to be similar to attitudes of the population as a whole, and these attitudes do not seem to have changed much over the last 15 years.

However, these attitudes are not in line with scientific statements that describe GMO as being relatively unproblematic (Almomani et al., 2020; Brosig & Bavorova, 2019; Carver et al., 2017) but are instead an expression of a value system relating to the purpose of the technology. This value system seemed to predominate in the skeptical group, which made up a third of the respondents. Because of the limited level of scientific understanding of related genetic concepts, it is likely that these attitudes and values will influence the way these students go on to teach about GMO and biotechnologies. Therefore, it is important to provide schools and teacher training with adequate teaching materials that cover the basic scientific facts and make clear the differences between knowledge, values, and ethics.

We also looked for any possible correlations between student knowledge level and attitudes towards biotechnology. Students with higher scores in the knowledge section of the questionnaire also expressed more positive attitudes towards biotechnology related to health applications and a higher interest in biotechnology. There is therefore some evidence that gaining knowledge can lead to more positive attitudes, as has also been found in studies from the UK (Costa-Font & Mossialos, 2006), and Slovenia and Turkey (Šorgo et al., 2011), but in contrast to studies from the USA (Chabalengula et al., 2011) and Turkey (Darçin, 2011). This issue requires more research before generalizations can be made, but our study suggests that improving student teachers' knowledge of biotechnological issues could lead to more positive attitudes towards biotechnology.

Comparison Between Swedish and Spanish Pre-service Primary School Teachers

No significant differences between the Swedish and Spanish pre-service primary school teachers were found regarding knowledge. This suggests that Swedish and Spanish students have the same level of knowledge about biotechnology and do not support the differences found by European Commission (2010).

Four very similar factors were found in both studies, thus the Swedish and Spanish pre-service primary school teachers' perceived attitudes towards biotechnology were very similar. The level of positive attitudes was also similar. Significant differences were only found regarding the application of GMO within society, suggesting that Spanish pre-service primary school teachers were more positive towards the application of GMO than Swedish pre-service primary school teachers. These findings are in line with previous research that has consistently shown that European, and particularly Nordic, citizens' rejection of GM food is strong and persistent (Bredahl, 1999; Magnusson & Hursti, 2002). However, it is noteworthy that no significant differences were found between the remaining attitude factors; any other differences were relatively small, and we conclude that there are more similarities than differences in Swedish and Spanish pre-service primary school teachers' attitudes towards biotechnology. The differences detected in earlier studies, such as European Commission (2010) and Gaskell et al. (2006), between northern and southern European countries

are not prominent in our study. It might be that teachers in different European countries have more similar attitudes than the population at large, or that the attitudes have grown more similar in Europe over the last decade. This is an important hypothesis to pursue in future research.

Limitations of the Study—and Future Research

This study used a validated instrument, with the potential to provide generalizable findings. However, the use of non-randomized samples is a limitation of the research design, as is the relatively small sample size. We cannot claim that the results are valid for all Swedish pre-service primary school teachers, but the results do provide an indication. Swedish teacher training is regulated by national authorities and therefore has a similar curriculum across its universities, and students attending primary teacher training have similar demographics, making the selected group of students a good representation.

Moreover, this study only covers two national contexts (Spain and Sweden) representing contrasting educational and cultural settings but providing very similar results. Therefore, in future research, it would be interesting to expand the scope of the study to investigate the generality of the results in other educational and cultural settings.

Implications for Teaching and Teacher Training

Teachers' knowledge and attitudes towards biotechnology are important because they will be teaching future generations within primary schools about biotechnology and its implications for society. This will be difficult to accomplish by teachers with gaps in their knowledge of basic genetics. Many personal, social, and cultural background factors can be hypothesized to influence student teachers' knowledge and attitudes towards biotechnology, and education is only one of these. However, we believe education is of paramount importance. It has been shown that younger pupils (12-year-olds versus 17-year-olds) have less favorable attitudes towards biotechnology (Dawson, 2007), indicating the importance of what they learn during their early years in primary education.

In the quest to develop biotechnological literacy, it is important for primary teachers to have a basic biotechnological knowledge, which is helped by a positive attitude. Teachers may not be inclined to like science and technology and its applications (van Alderen-Smeets et al., 2012), but a positive attitude is vital if they are to teach these topics. The results revealed by our "confidents" provide an attitudinal basis for developing the knowledge and teaching practices of biotechnology among primary teachers. We have shown

that a developed curriculum of teacher training can inoculate a fertile ground, but it is a matter of policy and instruction to develop this further. In order to improve teacher knowledge, there is a need to create new educational material for them, or to train them about new advances in biotechnology, as shown successfully in previous studies (Casanoves et al., 2016; Solé-Llussà et al., 2018).

Declarations

Ethics Approval Not applicable.

Informed Consent Not applicable.

Conflict of Interest The authors declare no competing interests.

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