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Knowledge and Attitudes Towards Biotechnology of Elementary Education Preservice Teachers: The first Spanish experience

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Due to the important impact that biotechnology has on current Western societies, well-informed critical citizens are needed. People prepared to make conscious decisions about aspects of biotechnology that relate to their own lives. Teachers play a central role in all education systems. Thus, the biotechnological literacy of preservice teachers is an important consideration as they will become an influential collective as future teachers of the next generation of children. The attitudes toward science (and biotechnology) that teachers have affect their behavior and influence the way they implement their daily practice of science teaching in school. This study analyzes the attitudes and knowledge of Spanish preservice teachers toward biotechnology. We designed a new survey instrument that was completed by 407 university students who were taking official degree programs in preschool and primary education. Our results point out that although they are aware of biotechnology applications, topics concerning the structure of DNA, management of genetic information inside the cell, genetically modified organism technology and the use of microorganisms as biotechnological tools were not correctly answered. According to our attitude analysis, Spanish preservice teachers could be defined as opponents of genetically modified product acquisition, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and other scientific advances. Our results show a positive correlation between better knowledge and more positive attitudes toward biotechnology. A Spanish preservice teacher with positive attitudes toward biotechnology tends to be a student with a strong biology background who scored good marks in our knowledge test.

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Introduction

Over the last few decades, there has been a revolution in the field of biological research. Genomics and its related technologies (or modern biotechnology) have the potential to become one of the most important scientific and technological revolutions of the twenty-first century (Kirkpatrick, Orvis, & Pittendrigh, 2002). In 2010, the European Commission launched the Europe 2020 Strategy that is designed to help the nations of the European Union (EU) to come out stronger economically from the current crisis and to prepare their economies for the next decade's challenges (European Commission, 2010a). Biotechnology has been seen as a major driving force in the creation of better health and welfare for European citizens. Toward this goal, the EU has undertaken many initiatives in recent years to stimulate and coordinate biotechnology developments (European Commission, 2012). Although there is a strong chemical and agricultural base in the EU, issues such as environmental protection, consumer safety, politically strong environmental movements and a general lack of social acceptance of genetic modification technology have been seen as factors affecting the overall development of biotechnology in Europe (European Commission, 2010b).

New scientific methodologies allow cheaper and faster ways to sequence genomes and perform global analyses of these genomes at different biological levels (gene, mRNA, proteins, etc.). In addition, newly developed techniques allow a vast landscape of applications that span the gamut from biomedical research to agriculture. This rapid development of modern biotechnology and genetic engineering has led to a huge gap between what the scientific community understands to be the risk and benefits and what is understood by the society (European Commission, 2010b). While some progress, in terms of basic knowledge, has been made since the Eurobarometer of 1996, the knowledge and information gap between science and society still exists (European Commission, 2010b). However, the perspective of a socially viable science should be shared with citizens and, in this way, socially accepted technological innovations can be created. Thus, it would be advantageous if both citizens (society) and scientist (scientific community) were to share similar perspectives on scientific advances. In this way, citizens and their scientific community would share common perspectives about scientific advances and innovations created from these advances would be much more easily accepted into that society. Otherwise, in a society in which citizens hold different perspectives on science than their scientific community, socially accepted technological innovations will be more difficult to be promoted and supported (Gaskell et al., 2006). However, in order to involve society in the scientific policy, well-informed citizens are needed who are able to make thoughtful decisions based on both scientific conclusions and ethical and moral consideration of the issues.

Following from this position, much research in science education worldwide promotes, as an important goal of science teaching, the scientific and technological literacy of entire populations (Dimopoulos & Koulaidis, 2003; González, Casanoves, Barnett, & Novo, 2013; Jenkins, 1997; Miller, 1998; Salvadó, Casanoves, & Novo, 2013; Zoller, 2012). The underlying notion is that the personal development of knowledge and appropriate mental habits will allow people to become more responsible citizens, better able to create informed opinions, even while living in societies that are becoming increasingly complex and ever more dependent on science and technology. Over the last few decades, interest in the biotechnological literacy of society has increased among science education researchers (Kidman, 2009; Klop & Severiens, 2007; Sorgo & Ambrozic-Dolinsek, 2009; Steele & Aubusson, 2004). These studies have aimed to analyze and develop the content that should be found in any school science curriculum that is intended to promote scientific literacy. To help achieve this purpose, such studies assessed teachers' and students' attitudes toward different aspects of biotechnology, including prior knowledge, fears, beliefs and ethical views related to the use of these new technologies. It is important to point out that the levels of biotechnological literacy differ significantly among the various European nations. The highest proportion of informed citizens are found in the Netherlands and Scandinavian countries, which reflects their traditionally strong education systems along with their higher degree of awareness of scientific and technical issues. On the other hand, states such as Greece, Ireland, Portugal and Spain appear to have minimally informed citizens regarding biotechnology (Pardo, Midden, & Miller, 2002).

It has been shown that the attitudes of science that teachers have affect their behaviors and influence the ways in which they approach good science teaching in schools (Cantrell, Young, & Moore, 2003). In particular, pre-existing attitudes and beliefs influence the way that teachers understand what they learn during their training and how they implement it in their daily practices at school (Fetters, Czerniak, Fish, & Shawberry, 2002; Lee & Ginsburg, 2007; Roehrig, Kruse, & Kern, 2007). A great many studies demonstrate that teachers with more positive attitudes toward science include science topics more often in the classroom and use active learning methodologies such as inquiry-based learning (IBL) activities, hands-on materials, etc. (Earl & Winkeljohn, 1977; Haney, Lumpe, Czerniak, & Egan, 2002; Shrigley, Koballa, & Simpson, 1988; Stefanich & Kelsey, 1989). Similarly, those teachers who show more positive self-efficacy tend to invest more time in science teaching and developing scientific concepts as well as including more active learning practices in the classroom (Carleton, Fitch, & Krockover, 2008; Lakshmanan, Heath, Perlmutter, & Elder, 2011; Riggs & Enochs, 1990). In addition, together with attitudes, knowledge level in scientific topics directly influences the self-confidence and self-efficacy of teachers in their approach to science activities in the classroom (Maier, Greenfield, & Bulotsky-Shearer, 2013).

Biotechnology is no exception. Elementary teachers may not have to teach complex biotechnology topics in their classroom. However, the more knowledge in biotechnology fundamentals, the more self-confidence teachers will have in this subject and, therefore, it can be assumed to increase the chances that more biotechnology topics will seep into their teaching. Chabalengula, Mumba, and Chitiyo (2011) argued that, as a trusted source of information among elementary students, it is critical for preservice elementary teachers to be well informed about the benefits and challenges of biotechnology. If these preservice teachers are well informed, then they would possess attitudes that would reflect less biased and more accurate information about biotechnology. Interestingly, Klop and Severiens (2007) claim it is important to include an affective component of biotechnology in science education curricula. They argue that this change in emphasis might help students to develop a more balanced attitude toward biotechnology.

Teachers play a critical, central role in the education system. Preservice teachers are therefore an influential collective in that they become teachers of the next generation of citizens. They will obviously have an important role in informing younger students about modern biotechnology and its new related technologies (Chabalengula et al., 2011). The analysis of preservice teachers' attitudes toward biotechnology will help to point out the problematic aspects of biotechnology among this socially influential collective. With the results of such analysis, changes in science courses in teacher education programs could be recommended.

In spite of the central role that teachers' attitudes play in teaching, most studies to date about biotechnology literacy have only investigated high school and university students. Indeed, only four studies have been focused on elementary education preservice teachers, in four different countries: Slovakia (Prokop, Leskova, Kubiatko, & Diran, 2007), Lithuania (Lamanauskas & Makarskaite-Petkeviciene, 2008), Turkey (Darçin, 2011) and the USA (Chabalengula et al., 2011). In counterpoint, data related to Spaniards' attitudes toward biotechnology come from socioeconomic studies (European Commission, 2010b; Lujan & Todt, 2000; Pardo et al., 2002), economic surveys on genetically modified (GM) food products (Angulo & Gil, 2007), while only one study focused on high school students (Saez, Niño, & Carretero, 2008). There are no published studies devoted to the assessment of biotechnology knowledge and attitudes of Spanish university students who are hoping to become elementary schoolteachers. This, then, is the purpose of our study, to better understand the knowledge and attitudes of one segment of the Spanish population, university students in the Catalonia region.

In the present study, we followed the tripartite model of attitudes toward modern biotechnology proposed by Klop (2008). In this model, attitudes are the product of knowing and thinking about biotechnology (the cognitive component), feelings and emotions about biotech issues (the affective component) and behavioral intentions toward biotechnology and its applications (the behavioral component). These three components have been included in the survey performed for the present study.

Purpose

This study analyzes Spanish elementary education preservice teachers' views of two aspects of biotechnology: (i) the level of their knowledge of genetic and biotechnological facts (cognitive component) and (ii) their attitudes toward biotechnology, including both the affective and the behavioral components. Additionally, we collected sociodemographic data to identify the potential correlations between specific attitudes and sociodemographic variables (gender, age, previous training in biology and educational background of their parents). Authors declare no conflict of interest.

Methods

Participants

In this study we requested the collaboration of 407 students who were taking a program called 'Preschool and Primary Education', 270 students in the Faculty of Education at the Universitat Rovira i Virgili, URV (Tarragona) and 137 students in the Faculty of Education at the Universitat Autònoma de Barcelona, UAB (Barcelona). Students were, on average, 22 years old.

Instrument and Instrument Design

Elementary education preservice teachers took a new survey, expressly designed for this study. This new survey was divided into three parts. The first part was designed to obtain the following sociodemographic information about surveyed students: sex, age, previous training in biology and educational background of their parents. The second part consisted of 21 *True/False/Don't Know* items that assessed respondents' knowledge of genetics and some general aspects of biotechnology. Each item had an assertion (either correct or incorrect) that the participant had to evaluate as true or false. This second part aimed to identify participants' knowledge of those basic scientific concepts necessary to follow public debates about biotechnology issues. The last part consisted of a 4-point Likert-scale questionnaire composed of 45 items, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree) of statements regarding (1) the implications of genetic modification in food production and consumption; (2) the implications of genetic modification in medical advances; (3) the social consequences of technological changes and (4) the student's interest in science and biotechnology. To correctly analyze the attitudes toward biotechnology from these items, the answers of negatively formulated items were reversed. In Figure 1, items with reversed answers are identified with an asterisk.

The survey instrument was designed using, as a base, published instruments that assess attitudes toward biotechnology (Chabalengula et al., 2011; European Commission, 2010b; Klop, 2008; Prokop et al., 2007). Some items were taken from these surveys and new ones were formulated. Items from published instruments are identified in Figure 1. Once we had completed the initial draft, we asked a committee of 11 experts in biotechnology, molecular biology, pedagogy and methodology to validate the items. Experts were asked to analyze each item and mark it (from 0 to 10) according to its relevance to the issue and assessing if each item was valid, appropriate and unequivocal. We recorded their comments and observations. As a result of this validation process, some items were rewritten or eliminated.

Factor	No.	Item	Reliability	Attitude: Strongly Negative	Negative	Positive	Strongly Positive
F.1 : GMO	1	I would buy GM food.	0.775	21	45	30	4
	2	I would feed my children with food produced with GM bacteria.	0.679	25	46	26	2
	3	The alteration of the genes of a fruit to make it more tasty.[C]	0.675	29	50	18	3
	4	If genetically modified food was cheaper, I would buy it.	0.644	20	50	26	4
	5	The genetical modification of fruits and plants to be fresh for a longer time.[C]	0.621	20	42	32	6
	6	The genetic modification of a bacteria to produce food.	0.478	12	40	42	6
	7	I would forbid the sale of trangenics in my country.*	0.460	7	22	60	11
	8	Consumption of GM foods is dangerous.*[D]	0.450	8	46	40	6
	9	The labeling of the transgenic products is clear enough.	0.434	27	54	16	3
	10	The law about GMO are strict enough.	0.429	9	50	37	4
	11	If I get a dish in a restaurant made out of transgenic food, I wold not eat it.*[C]	0.365	5	27	60	8
	12	I am opposed to the transfer of genes between plants and animals.*[D]	0.360	10	38	46	6
	13	The addition of genes to a plant to make it plague-resistant is unacceptable.*	0.343	7	27	50	16
F. 2 : Biotechnology and Health	1	Biotechnology can improve our life style.	0.575	1	13	69	16
	2	I agree with the genetic investigation in medicine.	0.561	2	7	51	41
	3	I agree with the genetic transformation in embryos to cure hereditary diseases.[A]	0.560	3	15	48	34
	4	The use of GMO for medical therapy and the study of diseases.[C]	0.543	2	14	55	29
	5	The genetic modification of a sheep to produce medicines.[A]	0.491	22	41	27	9
	6	The use of GMO to fight against diseases.	0.486	3	23	57	16
	7	If genetically modified food was healthier, I would eat them more often.[C]	0.476	6	23	55	15
	8	Genetic manipulation is not ethical.*	0.445	7	30	51	12
	9	Cloning as a tool to save endangered species.[D]	0.426	10	22	44	24
	10	Biotechnology makes our lives easier.[C]	0.420	3	17	67	13
	11	Science makes our lives easier.[B]	0.394	3	24	52	22
	12	A scientific discovery is not "good" or "bad", is how we use what matters.[B]	0.355	1	6	32	60
	13	GM foods can help alleviate world hunger.[C]	0.332	10	30	51	9
F.3 : STS	1	The fast evolution of science threatens humanity.*	0.608	11	27	45	17
	2	There should be limits to what can and can not be investigated.*[B]	0.488	21	33	31	15
	3	The application of biotechnology will make the future more dangerous.*	0.474	5	31	56	8
	4	Biotechnology is evil for nowadays society.*	0.463	1	9	67	23
	5	Genetic manipulation will drive to the extintion of a large number of species.*	0.454	11	38	43	8
	6	Genetically altering living beings is to play God.*	0.446	12	24	37	27
	7	Biotechnology does not play any role in environmetal protection.*	0.367	2	17	58	23
	8	Some numbers are specially lucky for some people.*[B]	0.363	6	27	28	39
	9	Scientific investigations should not interfere with religion.	0.305	16	17	37	30
F.4 : Interest	1	I would like to increase my knowledge about GMO.	0.846	3	6	46	45
	2	I would like to have more information about GM food.	0.822	4	9	40	47
	3	I would like to know more about GM food.[D]	0.785	4	11	43	41
	4	I would like to be aware of scientific advances.	0.676	1	6	47	46
	5	Biotechnology is boring.*	0.353	13	19	55	13

Figure 1. Factor structure and loading of the 40 items related to attitudes toward biotechnology. The figure shows respondents attitudes (positive or negative) toward biotechnology issues. Responses to items presented as negative sentences were reversed in order to obtain a visually meaningful graphic 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]Eurobarometer (2010b), [C]Klop (2008) and [D]Lamanauskas and Makarskaite-Petkeviciene (2008).

Exploratory Factor Analysis

We analyzed the data using SPSS Statistics 19 software and conducted an exploratory factor analysis in order to find the factorial structure of the participants' attitudes toward biotechnology. We employed principal components analysis with varimax rotation, without specifying the number of factors. In order to ensure the suitability of the respondent's data for factor analysis, we calculated the Kaiser–Meyer–Olkin measure of sampling adequacy (Kaiser, 1970) and Bartlett's test of sphericity (Bartlett, 1950). The Kaiser–Meyer–Olkin measure ranges between 0 and 1. A value of 0 indicates a diffusion in the pattern of correlations between items (i.e. the data are not suitable for factor analysis), whereas a value close to 1 indicates that the patterns of correlations are compact and so factor analysis should output distinct and reliable factors. Bartlett's measure tests the null hypothesis that the items included in the factor analysis are not inter-correlated. Thus, if the result of Bartlett's test is significant ($p < .05$), then the data are suitable for a factorial analysis. Finally, we used Horn's parallel analysis methodology and the Screen test for selecting the optimal number of factors.

Cluster Analysis (K-means Clustering)

Once we had performed the exploratory factor analysis, we then carried out a K-means cluster analysis based on the factor scores of the set of attitudes. Cluster analysis is a statistical multivariate technique used to group a set of cases trying to get maximum intragroup similarity and between-group differences, according to the scores on one (or more than one) selected variable. In the clustering process, there are no predefined classes and no examples that would show what kind of desirable relations should be valid among the data and that is why it is perceived as an unsupervised process (Berry & Linoff, 1997; Halkidi, Batistakis, & Vazirgiannis, 2001). Cluster analysis depends on correlation and multiple linear regressions, and it groups the cases with greater similarity by calculating the distance between them, so the closest cases will be part of the same cluster. We used this cluster analysis in order to test some hypotheses concerning the attitudes toward biotechnology of our students. The interpretation of positive or negative attitudes was based on the mean value of each factor. Since we used a 4-point Likert scale, in which students rated their opinions from 1 (strongly disagree) to 4 (strongly agree), mean values above 2.5 are considered positive attitudes and values below this cutoff are considered negative ones.

Correlation Analysis

We carried out some correlation analysis for measuring the degree of relationship between sociodemographic, knowledge and attitude variables. Data from the attitude questionnaire were analyzed as a unique variable and split into factors. Pearson's correlation coefficient (r) was used for measuring the correlation between quantitative variables (age, knowledge and attitude variables). Additionally, point-biserial coefficient (rpb) was calculated between nominal (biology background) and quantitative variables; the biserial coefficient (rb) was calculated between ordinal (parent's background) and quantitative variables, and rank-biserial coefficient (rrb) was calculated between nominal (biology background) and ordinal (parent's background) variables. See Glass and Hopkins (1996) for a description of these correlation coefficients.

Results

We conducted the surveys during the 2012–2013 academic year with university students who were taking degree programs in primary and preschool education. Students in all 4 years of these university degrees were given the opportunity to participate this study. The following results are based on fully completed surveys that resulted in a sample of 407 individuals. Table 1 shows the sociodemographic features of the sample. Respondents were studying to become preschool and primary education teachers, taking two different independent university degree programs. Spanish curriculum for these degrees does not include specific university courses in biology. However, biology content is integrated into a discipline named experimental sciences, which also includes physics, chemistry and geology. Additionally, in Spain, students are permitted to take these programs without any scientific background. In fact, only 27% of respondents declared that they had previously taken some academic scientific courses, in their high school programs. As usual in these types of university programs, females were over-represented relative to males; in our case, 86% of the sample was composed of females.

Knowledge of Basic Concepts Related to Biotechnology

We have designed a new survey to assess elementary education preservice teachers in two aspects: level of knowledge and attitudes toward modern biotechnology and its applications. Regarding the assessment of knowledge level of biotechnology and genetics, there was a 21-item survey for which the answers could be *True/False/Don't Know*. The reliability (Cronbach's α) of the knowledge questionnaire was .721. The 21 knowledge items were split in two data groups. The first data group consists of 12 items that were correctly answered by 50% or more of participants, and the second group corresponds to the remaining 9 items that were answered incorrectly, or marked as 'don't know', by more than 50% of the students (Table 2). In general, the majority of students know that genetic material can be exchanged between different species and that genetic modifications can occur naturally or be driven by humans. Additionally, they know that DNA changes can result in interesting characteristics such as an increase in the resistance to a plague, higher nutritional values or higher productivity (Table 2).

Regarding the least frequent scores in Table 2, we identified an important lack of knowledge about basic concepts of genetics. Topics concerning DNA structure and

Table 1. Sociodemographic sample characteristics (sample size: 407).

Variable	Definition	Values
Age	Age in years	22.02 ± 5.25 (SD)
Gender	Female	86%
	Male	14%
Education	Science background	27%
	Non-science background	73%
Parents education	Primary school degree	32%
	High school degree	45%
	University degree	23%

Table 2. Knowledge items sorted from most to least frequent correct responses.

	Correct answer	Responded correctly (%)	Responded incorrectly (%)	Don't know (%)
It is possible to change the genetic characteristics of a plant to make it more resistant to a given plague.	T	85	3	12
A good hygiene helps to prevent genetic diseases.	F	75	18	7
Bacteria are used in the elaboration of daily products (e.g. cheese, vinegar and vitamin C).	T	75	10	15
Children resemble their parents because they share the red blood cells.	F	74	5	21
AIDS is a genetic disease.	F	72	22	6
Only when we eat GM food we eat genes.	F	69	4	27
Mutations are only possible by genetic manipulation in the laboratory.	F	66	24	10
Through genetic modification, foods with higher nutritional values can be achieved.	T	61	13	26
A high production of vitamins by a fruit is only possible by genetic manipulation of that fruit.	F	57	17	26
In our body there are more bacteria than people in the world.	T	56	8	36
Microorganisms are used to purify sewage.	T	55	2	43
Genetic material exchange between different species is only possible by manipulation in the laboratory.	F	50	23	27
GMOs are larger than normal.	F	36	19	45
A yogurt is a biotechnological product.	T	34	30	36
The most powerful toxic substances are naturally occurring.	T	34	22	44
GMOs have a high number of toxic substances.	F	24	17	59
A GMO is always transgenic.	F	22	31	47
In the kidney cells genome, you can also find the information about the color of your hair.	T	21	26	53
Insulin is obtained by GM bacteria.	T	19	25	56
Chemically, the genetic material (DNA) is identical in all organisms.	T	12	66	22
Crocodiles have the same genetic material as ostriches.	T	9	23	68

Note: In the column 'Correct answer', T (True) and F (False).

cell management of genetic information were not well understood. For instance, 88% of respondents did not know that, chemically, the genetic material (DNA) is identical in all the living beings. Additionally, 76% of students answered incorrectly, or did not know, that in the genome of kidney cells one can also find the information about hair color. One hot topic focused on genetically modified organisms (GMO's). Surprisingly, two-thirds of the students thought that, or did not know whether, GMO's have a higher amount of toxic substances or GMO's are larger than normal. Obviously, the more subtle items about GMO's were mostly answered incorrectly. An interesting result is that, although Spanish preservice teachers are aware of biotechnology applications, items that include the use of microorganisms as a biotechnological tool showed a high 'Do Not Know' response rate (>40%). The use of bacteria to produce insulin and yogurt, or purify sewage was not known by our respondents.

Exploratory Factor Analysis

Using the results of this analysis we described respondents' attitudes toward biotechnology. The reliability (Cronbach's α) of the global survey was .839. An exploratory factor analysis on the responses to 45 attitude items resulted in an identification of four factors that explained 33.2% of the total variance. The Kaiser–Meyer–Olkin measure was 0.787 and Barlett's test was statistically significant ($p < .001$), ensuring the suitability of the respondent's' data for factorial analysis. Five items were deleted because their factor loadings were lower than 0.3. The four factors that were identified describe respondents' attitudes toward different aspects of biotechnology (Table 3).

The first factor, GMO (13 items, factor score average 2.34 ± 0.42), reflects respondents' opinions about and intentions toward consuming products based on GMO's. More precisely, items referred to consumption intentions of GMO-based food, opinions about the use of GM technology for the development of new food products and items that related to GMO legislation policy and labeling. Results pointed out that our respondents would avoid the consumption of GM food, even when there was a clear benefit for the consumer in terms of taste, price and longer product shelf life. Additionally, respondents perceived the need for clearer labeling and stricter regulation of GMO-based products but, at the same time, they expressed disagreement to banning them (Figure 1).

The second factor, Biotech and Health (factor score average 2.91 ± 0.37), demonstrated the respondents' opinions about biotechnology applications to medical purposes. The 13 items of this factor focused on the use of GM technology for research and medical therapy purposes and their opinions about biotechnology implications for a healthy life. Results showed that the vast majority of students agreed that biotechnology is useful and contributes to improve our lifestyle. Additionally, they supported

Table 3. Attitude factors with description, number of items and reliability, based on principal component analyses.

Attitude factors	Description	Reliability (α) (number of items)
1. GMOs	Feelings and consuming intentions toward GMO products.	.816 ($n = 13$)
2. Biotech and Health	Medical applications of biotechnology focused on the improvement of life standards.	.746 ($n = 13$)
3. STS	Relationship between scientific and technological advances and society (roles, implications and consequences)	.589 ($n = 9$)
4. Interest	Interest in increasing respondents' knowledge about science and biotechnology advances	.771 ($n = 5$)

genetic investigation and manipulation, including the use of GMOs, for medical purposes (Figure 1).

The third factor, Science–Technology–Society (STS), included 9 items (factor score average of 2.70 ± 0.42) focused on the respondents' opinions about how scientific and technological advances could affect society and vice versa. This factor also included aspects such as the relationship between science and religion, their fears and feelings about biotechnology and environmental and social consequences of biotechnology advances.

From our results, students do not feel threatened by scientific research and biotechnological advances. Indeed, they consider that new biotechnological applications could be beneficial for society. Respondents do not agree or strongly disagree with the following affirmations: 'The application of biotechnology will make the future more dangerous' (64%, this item showed a score average of 2.67 ± 0.70); 'The fast evolution of science threatens humanity' (62%, item score average 2.68 ± 0.88) and 'Biotechnology is evil for nowadays society' (90%, item score average 3.12 ± 0.58).

More than a half of our respondents (54%) disagree with the affirmation 'Genetically altering living beings is to play God' (score average 2.79 ± 0.97). Respondents were also asked to express their attitude about the legitimacy of science to argue religious issues. In that case, 67% agree with 'Scientific investigations should not interfere with religion' (score average 2.81 ± 1.04). Interestingly, half of the respondents (54%) agreed with the following item: 'There should be limits to what can and cannot be investigated' (score average 2.40 ± 0.98). In this case our students feel that science needs limits to its development, but we have not been able to determine what they should be and who must establish them.

The fourth factor, interest (sum score average of the factor 3.18 ± 0.56), reflected respondents' interest in increasing their knowledge about scientific advances and biotechnological applications mainly focused on GM technology. Results showed that the great majority of students (around 90%) were interested in having more information about GMO and scientific advances. Only one-third held the view that biotechnology is boring (Figure 1).

Segmentation by Attitudes toward Biotechnology

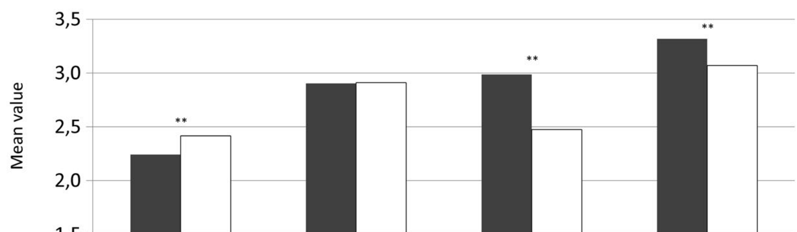
The purpose of this section was to identify whether subgroups could be identified within the larger group of all respondents. The scores of two respondents were eliminated from the analysis because they could not be assigned in any cluster. After performing K-means cluster analysis, we considered that two clusters led to interpretable and interesting groups as we can see in Figure 2. Our results show that Factor 1, GMO ($t(403) = 6.92, p < .00$); Factor 3, STS ($t(403) = 19.426, p < .01$) and Factor 4, Interest ($t(403) = 3.107; p < .01$) displayed significant differences between both groups.

Cluster 1 (175 respondents). This cluster shows positive attitudes toward the aspects analyzed in the factors of Biotech and Health, STS and Interest.

Respondents included in this cluster do not feel threatened by science evolution (Item 1, 3.18 ± 0.71) and perceive that neither biotechnology (Item 4, 3.36 ± 0.55) nor its applications (Item 3, 2.90 ± 0.65) are dangerous (Factor 3, STS). On the other hand, this group has a negative perception toward GM technology for food applications (Item 5, 2.03 ± 0.82 and Item 6, 2.25 ± 0.82) and consumption purposes (Item 1, 1.94 ± 0.78) (Factor 1, GMO). This group expressed negative intentions toward buying GMO products even if such foods are the cheapest (Item 4, 1.85 ± 0.72) or the tastiest (Item 3, 1.72 ± 0.69). They believe that the consumption of GMO food is dangerous (Item 8, 2.53 ± 0.73) and they expressed their agreement with the proposal to ban transgenic products (Item 7, 2.73 ± 0.80).

Cluster 2 (230 respondents). Respondents included in this cluster mistrust the contribution of science and biotechnology in the social development and future of humanity (Factor 3, STS). Moreover, their perceptions of GM technology on food applications and consumption purposes (Factor 1, GMO) showed by respondents in cluster 2 (2.42 ± 0.42) were observed to be less negative than in cluster 1 (2.24 ± 0.42), but still slightly negative (Figure 2).

Interestingly, within our cluster results, we found that both groups held no significant differences regarding Factor 2 ($t(403) = 0.853$; $p = .39$) that described biotechnological applications for health purposes. Thus, both groups shared the same attitudes toward medical applications of biotechnology focused on the improvement of life standards. All students displayed positive attitudes toward biotechnology applications in medicine; they mainly agree that biotechnology is useful and contributes to improve our lifestyle (Figure 1). On the other hand, as previously mentioned, Factor 4 displayed significant differences between the groups. Nonetheless, both groups showed strong interest on biotechnology topics. As we can see in Figure 2, the mean value



	GMO		Biotech Health		STS		Interest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
■ Cluster 1	2,24	0,42	2,90	0,40	2,99	0,32	3,32	0,54
□ Cluster 2	2,42	0,42	2,91	0,35	2,48	0,34	3,07	0,55

Figure 2. Graphical representation of K-means cluster analysis results of attitudes towards biotechnology. GMO corresponds to Factor 1 (genetically modified organisms); Biotech Health corresponds to Factor 2; STS corresponds to Factor 3 (Science–Technology–Society) and Interest corresponds to Factor 4 of the exploratory factor analysis. **Significance of $p < .01$ using t-test statistical analysis between factors of each cluster.

of both clusters is above a value of 3, meaning that they expressed a positive attitude toward this factor.

Correlations Between Sociodemographic Data, Knowledge and Attitudes toward Biotechnology

Correlation coefficients were calculated to determine the relationships between sociodemographic data, knowledge and attitude factors of elementary education preservice teachers in the field of biotechnology (Table 4).

Some of the remarkable correlations showed that older respondents expressed less favorable attitudes to issues included in factor 1 (GMO) (correlation of −.166**) (Tables 3 and 4) as well as more interest in increasing knowledge about science and biotechnology advances (correlation of .144**) (Figure 1). Other correlations linked knowledge level and the GMO factor. Respondents with better marks in the knowledge test showed higher acceptance of GMO factor issues (correlation of .104*). Our results reveal that a preservice teacher with positive attitudes toward biotechnology corresponds to a student with a biology background and a good mark in the knowledge test (Table 4). Hence, this fact indicates that improving population knowledge in biotechnological issues could lead to more positive attitudes toward biotechnology.

Discussion

According to our results, Spanish elementary education preservice teachers' knowledge about biotechnology varies depending on the topic. First of all, the majority of education preservice teachers correctly answered items related to the applications and uses of biotechnology. The majority of students know that genetic material can be exchanged between different species and that genetic modifications can occur naturally or driven by humans. Comparing to similar studies in other countries when asking about the uses of biotechnology, Spanish students have a higher percentage of correct answers on the same items than Slovakian (Prokop et al., 2007), Turkish (Usak, Erdogan, Prokop, & Ozel, 2009) and Lithuanian (Lamanauskas & Makarskaite-Petkeviciene, 2008) students. This is the case, for example, when asking whether DNA changes can result in interesting characteristics such as an increase in the resistance to a plague, higher nutritional values or higher productivity. However, we identified an important lack of knowledge related to the basic concepts of genetics. Topics concerning DNA structure and cell management of genetic information are not well understood by our students. For instance, the concept that DNA is chemically identical in all living beings was only correctly answered by 12% of our respondents, compared to a 22% in Turkey (Usak et al., 2009) or a 33% in Slovakia (Prokop et al., 2007). Interestingly, this item was answered incorrectly by 66% of our students, pointing out that our students are not aware of their own ignorance in this topic. Another hot topic is focused on GMO's. Items related to GMO's show the highest proportion of 'Do Not Know' answers (around 50% in all items related to GMOs), indicating that our students are conscious of their ignorance about GMO's.

Table 4. Correlations between sociodemographic, knowledge and attitude's variables.

	Age	Parents' background	Knowledge	GMO	Biotech-Health	STS	Interest	Attitudes
Bio background	.114*	.011	.184**	.065	.084	.095	.101*	.117*
Age		−.221**	.052	−.166**	.026	.063	.144**	−.007
Parents' background			.085	.034	−.034	−.065	−.056	−.030
Knowledge				.104*	.095	.090	.076	.131**
GMO					.486**	.291**	.049	.775**
Biotech-Health						.288**	.222**	.794**
STS							.143**	.607**
Interest								.399**

Note: Reported statistical significance

*$p < .05$; **$p < .01$.

Summarizing, our results point out that Spanish preservice teachers are aware of the applications of biotechnology but do not have a basic and fundamental knowledge on the biological implications of modern biotechnology on living beings. These two dimensions of knowledge about modern biotechnology (biotechnology applications and basic concepts of biology) were already identified by Klop and Severiens (2007), when analyzing the *cognitive component* of modern biotechnology of Dutch secondary school students. Our results point out that preservice teachers show a low percentage of correct answers in biological topics related to biotechnology such as DNA structure and cell management of genetic information or basic concepts of genetics. This finding is not unique of Spain and it is shared in other countries such as Turkey, Slovakia, Slovenia, Lithuania and Lebanon (Darçin & Guven, 2008; Erdogan, Ozel, Bouiaoude, Usak, & Prokop, 2012; Lamanauskas & Makarskaite-Petkeviciene, 2008; Prokop et al., 2007; Sorgo & Ambrozic-Dolinsek, 2009; Usak et al., 2009).

One of the main goals of this study was to analyze the attitudes toward biotechnology of Spanish preservice teachers. Four attitude factors were identified by our survey: (i) feelings and consuming intentions toward GMO products, (ii) opinions about Biotechnology applications to medical purposes, (iii) opinions about how scientific and technological advances could affect society and vice versa and (iv) interest in increasing respondents' knowledge about scientific advances and biotechnological applications. Taking into account the results of the whole sample, Spanish preservice teachers could be defined as opponents of buying GM products, supporters of biotechnology for medical purposes and highly interested in increasing their knowledge about biotechnology and scientific advances. It is interesting to point out that our respondents (around 90% of them) expressed their desire to have more information and to increase their knowledge in topics concerning GM technology, including GM food. Scientific and biotechnological advances are also interesting topics for our respondents. They mainly agreed with the idea that science and biotechnology are beneficial for their lifestyle and for the future of humanity. However, they feel that science needs limits to its development, although they were not able to determine how they should be and who must establish them.

This study was also focused on the analysis of possible correlations between knowledge level and attitudes toward biotechnology. Our results show a positive correlation between better knowledge and more positive attitudes toward biotechnology (Table 4). This correlation is also valid for the GMO factor, since respondents with better knowledge of biotechnology show higher acceptance of GMO issues. This positive correlation between knowledge level and more positive attitudes toward biotechnology has been previously reported by other authors (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Klops & Severiens, 2007; Lamanauskas & Makarskaite--Petkeviciene, 2008; Prokop et al., 2007; Usak et al., 2009).

Biotechnology is a relevant topic from the economical and scientific points of view but, at the same time, it has social, ethical and cultural implications which directly concern the whole society. The role of teachers in communicating the risks, benefits and challenges of biotechnology is crucial. In this sense, the improvement of the knowledge level of preservice teachers on biotechnology would help them to develop attitudes that promote a deeper reflection on the benefits and complexity of biotechnology (Chabalengula et al., 2011; Klop & Severiens, 2007). Well-informed teachers will be able to handle ethical, social and cultural debates with their students on the implications of biotechnology. In this sense, Chabalengula et al. (2011) argued that if preservice teachers are well informed, then they would possess attitudes that would reflect more unbiased and more correct information about biotechnology.

New teaching and learning methodologies should be developed to promote biotechnological literacy among citizens. Science education, as a broad field, and biological education in particular have to contribute to increasing the knowledge of society in general about the central concepts of modern biotechnology. By improving the biotechnological education of the whole society, citizens will then be better prepared to make conscious decisions about the biotechnology-related aspects of their own lives. The frame of the current paradigm of science education, mainly characterized to be teacher centered, disciplinary, decontextualized and oriented toward low-order cognitive skills, should move to more adaptive paradigms. Science education should employ an interdisciplinary teaching approach, leading to the development of our students' higher order cognitive skills, promoting critical system thinking, problem-solving and decision-making (Zoller, 2012).

One of the most noticeable trends of the last two decades in science curriculum development has been to use contexts and applications of science as a means of developing scientific understanding. Teaching in this way is described as adopting a context-based or Science–Technology–Society–Environment (STSE) approach. In this kind of approach, contexts and applications of science are used as the starting point for the development of scientific ideas (Bennet, Lubben, & Hogarth, 2006). Educational tools following the STSE approach could include different teaching methodologies oriented to increase student motivation and to help them to structure their knowledge, to develop reasoning processes and to implement self-directed learning skills. Interesting teaching methodologies to use in STSE approach are problem-based learning and IBL.

The key to educational innovation, reform and improvement is the teacher. It is now generally accepted that to improve learning in our schools, we need more and better teacher professional learning (Goodrum, 2006). Therefore, one effective way to induce a better knowledge and therefore more informed decisions of society toward new biological sciences and technologies is by promoting biotechnological literacy among teachers. For this reason, our research group is now devoting efforts to the design and assessment of new educational activities that help future teachers to understand and interpret biotechnological issues.

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