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A cross-sectional study of biotechnology awareness and teaching in European high schools

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Abstract

Undoubtedly, biotechnology has a tremendous impact on our daily lives. As a result of this and in parallel to the advancement of knowledge in this field of applied research, consumer awareness of the potential benefits and risks of this technology has steadily increased, leading to a thorough investigation of the public perception of biotechnology in the past years. Indeed, it has become clear that it is in the general interest of science and especially of applied research to inform the public of its advances. A promising next step is to strengthen biotechnology communication in scholastic institutions. In this paper, we investigate the perception of biotechnology in a specific target group, namely high-school students in the 16–20-year-old age range. We conducted a questionnaire-based survey on a total of 1410 students in six European countries to investigate students' perception, concern, scientific knowledge, and awareness. Our data revealed some unexpected patterns of acceptance and concern about biotechnology. Knowledge analysis indicated that pupils lack specific knowledge about biotechnological applications and their interest in biotechnology appeared to be linked to knowledge. Analysis of specific questions about teaching practices at schools suggests that a better targeted choice in media as vehicles for information together with selected speakers could be instrumental in increasing students' interest in science and more specifically in biotechnology.

Introduction

Promoting public understanding of genetics is seen as an essential prerequisite for democratically based policy making and informed public decision-making in this area [1,2]. In the past decade, several studies have been released with a focus on public understanding, perception, and acceptance of biotechnology [1,3–5]. While knowledge is a complex parameter to evaluate, quiz-based evaluation remains the most convenient and frequent approach to assess the understanding about a given topic in a representative sample of the population [1,6,7]. Knowledge is an important factor influencing the formation of opinions, but those opinions can be positive or negative [8]. As knowledge increases, consumers understandably ask more crucial questions about the technology and engage in more elaborate deliberations of benefit and risk [9].

Previous studies have evaluated awareness of the public regarding facts connected to biology and biotechnology, in particular [4,10–12]. Most studies investigating societal aspects of biotechnology used non-restricted samples [11,13,14] giving an overall

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public acceptance and concern about biotechnology. A small number of studies using schools to investigate biotechnology acceptance and concern have been performed in particular countries [15,16]. Because other factors (i.e. age, gender) play an important role in the perception of biotechnology [6], it is relevant to identify and characterize a target group in order to elaborate suitable strategies for communication about biotechnology. Identification of the experts who should vector the communication on biotechnology is another key aspect since reception is likely to be influenced by the nature of the emitter. There is also a general agreement in the scientific community that scientists should be more involved in communication [17].

There are several ways and opportunities to communicate the use and advances in biotechnology to the public. The employment of conventional media (television, newspapers, radio) necessitates commitment from the media key players to inform the public about biotechnology. To circumvent this limitation, the scientific community and other entities interested in delivering information about biotechnology to the public have offered numerous conferences and forums to discuss. However, for public communication strategies to be successful there is also a need for interest from the public itself to receive information. Both conditions usually imply a restriction on the number and categories of people that can be reached. Development of a communication strategy within the scholastic educational system represents an efficient way to circumvent the limitation of the standard communication channels. Since all schools and colleges provide a basic education in life sciences, these institutions can be an effective platform for delivering information on biotechnology and consequently generating structured debates amongst the pupils. Because of their mandatory occurrence in standard school education, life sciences lectures are a suitable opportunity to increase evenly the awareness about biotechnology in the society.

In this paper, we report on a questionnaire-based study of pupils in the past years of secondary school education. The aims of the reported study were: (1) to evaluate the present knowledge and perception about biotechnology in European schools; (2) to investigate the strategies currently deployed to teach biotechnology in European schools; and (3) to identify communication strategies commonly wished by pupils in European schools.

The first part of the questionnaire was developed to investigate knowledge and interest in life sciences and biotechnology in particular. The second part of the questionnaire was designed to identify the communication channels used by life sciences teachers and the type of communication favored by pupils for learning about biotechnology. The study was conducted in schools of six European countries with a total sample size of 1410 pupils. The sampling process, discussed in detail in the following section, provided a European cross-sectional view of the life sciences knowledge and teaching of high school students across Europe. The questions covered knowledge and interest in biotechnology and hence could be used to define strategies to (a) incorporate biotechnology topics into the biological curriculum of high school pupils and to (b) improve the communication of emerging technologies to non-scientists.

Data and methods

The data consist of 1410 pupils from 64 high schools in six European countries, namely the Czech Republic, Germany, Poland, Portugal, Switzerland and Turkey. The survey was performed in October and November 2007. Country coordinators were recruited through the Young European Biotech Network (YEBN Ltd.). The country coordinators then conducted the survey in 9–14 high schools in their countries. The high schools in a country were chosen to obtain a representative picture of the educational system in that country. A pupil questionnaire (Appendix A) was distributed to the pupils from the selected classes and the teacher from each selected class received a teacher questionnaire (Appendix B). The collected sample was well balanced with respect to country, age and gender. Distribution of the number of lecture hours for science in general and for biology in particular were evenly distributed among the schools and therefore considered as representative of the European education system in biology.

The pupil questionnaire was structured as follows. In the first part, questions with a five-point Likert-type scale with 1 = very low, 2 = low, 3 = average, 4 = high, 5 = very high were used to measure the level of concern about environmental issues and food quality and the interest in biology and biotechnology. In the second part, knowledge of biotechnology-related topics was evaluated by eight quiz questions scored in the following way: every correct answer was counted as 1, every wrong answer as -1, and a 0 was assigned to every 'I do not know' answer. In the last part, pupils were also asked to indicate by whom they would prefer to be informed and using which communication medium. These preferences were assessed by a required selection of 2 items from a representative panel of possible answers.

Results and discussion

Food quality and environmental concerns

An ordinal regression on the three-pooled categories (1 = very low and low, 2 = average, 3 = high and very high) was performed to facilitate interpretation since the main interest of the study was in the quality rather than the quantity of the concern statements. A covariate analysis with *gender*, *country,* and *number of years before finishing high school* was conducted, where the latter is referred in the following sections as *years before university* for simplicity. A standard likelihood ratio test was applied to test for significance of the covariates. For the ordinal regression, interaction terms were not considered owing to mathematical complexity. The results indicated that the *concern about environmental issues* did not correlate with *years before university* (P-value = 0.109), but that *country* and *gender* were significantly correlated (both P-values < 0.001). Pupils in Germany, Portugal, Switzerland, and Turkey had a higher concern about the environment than pupils in the Czech Republic and in Poland. Furthermore, female pupils showed on average a higher concern about the environment than male pupils. The means (for the five-point Likert-type scale) stratified for gender and country are represented in Table 1 in Appendix C. An equivalent analysis of the *food quality concern* as response showed a similar pattern. The food quality concern did not depend on the *years before university* (P-value = 0.174), but both *gender* and *country* are significant (both P-values <0.001). The results indicated that pupils in Germany, Portugal, Switzerland, and Turkey had a higher concern about food quality than pupils in the Czech Republic and in Poland, and that female pupils showed on average a higher concern for food quality than male pupils. The corresponding means on the original five-point Likert-type scale stratified for

gender and country are represented in Table 2 in Appendix C. The gender gap for environment and food issues has been discussed and reported in several studies [18–21]. In this study, the gender gap appears to be present also in the pupil age category. The gender gap should not eclipse the observed high interest of the surveyed pupils in topics that are connected to biotechnology (i.e. environment and food quality).

When asked whether genetically modified (GM) plants can be environment friendly, the majority (51%) answered positively while 31% had no opinion. There was no significant difference regarding environment concern between groups answering 'true', 'false' or 'I don't know' to this opinion question (P-value = 0.571). Therefore, environmental concern did not translate into opposition to GM plants. The optimism pattern for genetic engineering was already observed at a similar level in the Eurobarometer survey [13]. When asked "*Would you mind eating GM food?*", 40% of the pupils answered positively, and 43% negatively, with the remaining part being undecided. Pupils answering negatively, meaning that they do not mind eating GM food, showed a significantly higher concern about food quality (P-value < 0.001). The higher concern about food quality in the group of pupils having no objection to GM food consumption was unexpected and might partially reflect some positive aspects connected to GM food, such as biofortification or reduced level of mycotoxin in some GM crops.

Knowledge about biotechnology

Knowledge about biology and biotechnology was evaluated through quiz questions. Pupils were asked to answer eight statements with the 'false'/'true'/'I don't know' options. In Fig. 1, statements with corresponding 'false', 'true' and 'I don't know' percentages are plotted. In order to evaluate knowledge, scores were computed with a positive point for correct answers, a negative point for wrong answers and no point if the answer was 'I don't know'. Because of the importance of knowledge to actively participate in debates about biotechnology and to shape a fact-based opinion, it is appropriate to clearly differentiate absence of knowledge from false knowledge. A linear regression with *score* as response and the covariates *years to university*, *country*, *number of biology lessons* and *gender* (with all possible pairwise interactions) was performed.

The results indicate that only *country*, *gender* and their interaction term are significant (P-values <0.001, <0.001 and 0.002 respectively). Thus the *number of biology lessons* and the *years to university* do not significantly influence the scoring of pupils. The corresponding means for the scores on the original scale stratified by country and gender are given in Table 3 in Appendix C. The *country* covariate implied that Portugal, Switzerland and Turkey had a significantly higher mean score than Poland (P-values all <0.001), the latter having the lowest mean score. Germany and the Czech Republic did not have a significantly higher mean score than Poland (P-values = 0.313 and 0.152 respectively). The gender covariate suggests that men had a higher score than women. The interaction term indicates that the knowledge score difference between men and women is heterogeneous between countries. The Czech Republic and Germany had a significantly higher gender difference as compared to Poland (respectively P-values = 0.043 and 0.031). In Switzerland, Turkey, and Portugal,

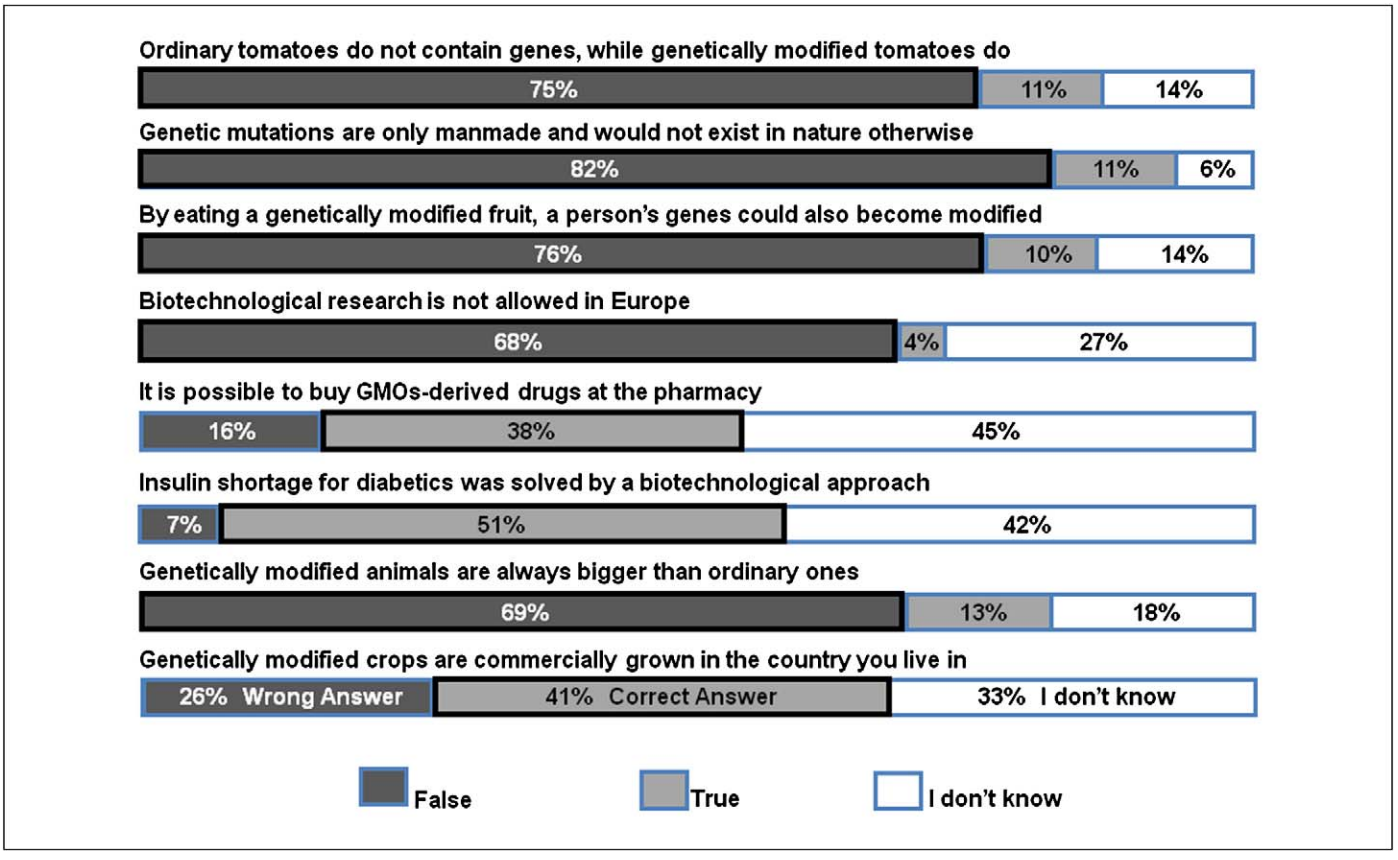

FIGURE 1

Knowledge questions and percentage of responses per category. Correct answers are marked by blacklined boxes.

the gender difference was not significantly different from the one observed in Poland (respective *P*-values = 0.630, 0.303, and 0.188).

Differences between countries for the variable *knowledge score* have also been observed in Eurobarometer surveys [4]. Differences in knowledge score can be explained by differential national controversy about biotechnology and varying emphasis on the biotechnology issue in the official education system. The finding that men are generally more informed on biotechnology than women is in line with the results of the Eurobaromoter [13] and other studies [18–21], where it has been shown that men are generally more knowledgeable about biology and genetics than women. The gender difference in the knowledge score is likely to reflect a bias in technical knowledge interest, since men tend to have more general knowledge of technology than women [22]. While several observations previously made for perception and knowledge could be confirmed, the study revealed that the knowledge about biotechnology in the surveyed schools was higher than the European average for several similar quiz questions reported by Gaskell *et al.* [13].

Percentages of correct answers in single quiz questions can give hints concerning special topics for which knowledge is lacking. On the one hand, it is interesting to note that biology textbook knowledge quiz questions have a majority of correct answers. On the other hand, it is noticeable that most quiz questions about biotechnology application facts (see Fig. 1, knowledge questions 5, 6 and 8) have fewer correct answers. However the decrease in correct answers in those specific questions is in line with an increased number of 'I don't know' answers. Our evaluation showed an interesting lack of knowledge of biotechnology-derived products. Despite controversial debates about biotechnology in Europe, it appeared that pupils are lacking precise knowledge about the presence of biotechnology in their daily life.

Interest in biology and biotechnology

The pupils were asked to grade their interest in three topics, namely biology, biotechnology, and politics, with the latter being a control variable to correct for pupils interested in many subjects in general. However, there was only a negligible proportion of pupils highly interested or not interested in all 3 subjects at the same time, and thus we proceeded with the statistical analysis with all subjects. As for the food quality and environment concerns, an ordinal regression analysis on the three pooled categories (1 = very low and low, 2 = average, 3 = high and very high) was performed to the *interest in biology,* and the *interest in biotechnology*, with the covariates *gender, country, years before university*, *number of biology lessons, and in addition knowledge score*. The latter was chosen to investigate the relationship between knowledge and interest. The results for the regression on biology interest indicated that only *number of biology lessons* (*P*-value <0.001), *years before university* (*P*-value = 0.004) and *knowledge score* (*P*-value = 0.009) were significant. A higher *number of biology lessons* and a higher *knowledge score* both implied a higher interest in biology. In addition, the closer to university, the more pupils were interested in biology. For the *biotechnology interest*, only the *number of biology lessons* and the *knowledge score* are significant (both *P*-values <0.001). Increasing values for both covariables implied an increasing *biotechnology interest*. Compared to the *biology interest*, it seems that the *biotechnology interest* does not change when the pupils approach university, indicating that the number of biology lessons taught over the years does not raise the interest in biotechnology. This may indicate that the biology curriculum is not flexible enough to allow teachers to introduce biotechnology to their class. By contrast, the *number of biology lessons* in a particular year is significant, suggesting that more biology lessons in a given year increase the likelihood that a teacher will introduce some issues concerning

	Industry representatives	Professors	Politicians	Non-governmental organizations	Medical personel	Young scientists	Journalists	Others	**Total first choice**
Industry representatives		4.5%	0.2%	1.0%	3.4%	4.2%	0.6%	0.3%	**14.3%**
Professors	2.7%		0.7%	3.2%	11.9%	16.5%	4.8%	2.7%	**42.4%**
Politicians	0.1%	0.1%		0.4%	0.5%	0.4%	0.2%	0.1%	**1.8%**
Non-governmental organizations	0.4%	0.7%	0.0%		2.1%	4.2%	0.4%	0.4%	**8.2%**
Medical personel	1.3%	2.2%	0.1%	0.2%		5.8%	0.8%	0.6%	**11.0%**
Young scientists	1.5%	3.0%	0.4%	1.5%	2.8%		1.4%	1.3%	**12.0%**
Journalists	0.0%	0.0%	0.0%	0.1%	0.0%	0.3%		0.4%	**0.8%**
Others	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%		**0.3%**
Total second choice	**6.0%**	**10.7%**	**1.4%**	**6.4%**	**20.9%**	**31.4%**	**8.1%**	**5.8%**	

FIGURE 2

Rows represent percentage of first choice and columns represent the percentage of second choice. Total percentages per category are given in bold character. 152 pupils (10.8%) answered two times '*None of the above*'. Note that the per category values do not sum up to 100% since there were incomplete answers.

biotechnology in that year. Extension of pupils' curriculum with additional biology lessons with a focus on biotechnology may increase knowledge about that topic and thus convey interest in biotechnology.

Teaching of biotechnology

Pupils were asked to select their two favourite communicator categories for informing about biotechnology in schools among a list of representatives from different fields (*industry representatives*, *academe representatives* (*professors* and *young scientists*), *politicians*, *NGOs representatives*, *medical personnel representatives, media representatives* (*journalists*), *others*). Fig. 2 shows the percentages per category in the first (vertical) and the second choice (horizontal). *Professors* category was selected by 42.4% of the pupils as first category to obtain information about biotechnology. It is interesting to notice that *Industry representatives* ranks second with 14.3%. This might be partially connected to the lack of application knowledge noticed in the knowledge evaluation. The category *Young scientists* ranked amongst the best categories for both first choice and second choice. This reasserts the given preference to people with expertise and to some extent connected to the academe. Overall, both *Professors* and *Young scientists* were ranking above *Medical personnel*. It is noticeable that both *Journalists* and *Non-governmental organizations* obtained a lower ranking in the first and second answer choice as compared to *Professors*, *Young scientists* and *Medical personnel*. This result is unexpected since consumer organizations and medical personnel usually receive the highest trust in most studies [9]. However, those results are more in compliance with the Eurobarometer studies ranking medical personnel and university scientists respectively in the first and second place in trust evaluation through confidence surplus [13]. From all the possible combinations, *academic representatives* (*professors/young scientists*) had the highest occurrence followed by the combination (*professors/medical personnel*). The primary choice of academe representatives by pupils to bring knowledge about biotechnology into school shows the general good opinion that pupils have about people involved in education and research. Because journalists and NGOs represent the most common sources of information about biotechnology through conventional media channels, pupils might have selected this option to diversify their source of information.

In order to evaluate the media currently used in science/biology lessons, pupils were asked to select the two most frequently used media in science/biology lessons among the following choices: *books*, *magazine, and newspaper articles*, *experiments*, *movies, and cartoons*, *none of the above*. Following this question, pupils were asked to select the two media they would favor for science/biology teaching (see Fig. 3). Concerning the media currently used, the pupils reported *books* as the most frequent. The high percentage of *None of the preceding* is likely to reflect the use of syllabi. This result shows the primacy of books and other book-based media for teaching science/biology in school. It is also important to note that *experiments* and *movies and cartoons* are already part of the commonly used media to teach science in school. Fig. 3 shows the difference between the media currently used and the ones preferred by pupils. It clearly indicates that *books* have a low preference as compared to other media. When asked about the favourite media for learning, *experiments* is by far the most cited. Because pupils were asked to check two options, the study also revealed that the combination *experiments* and *movie and cartoons* was by far the most frequent. The latter combination was selected by one third of the pupils. The pattern of the media currently used in science/biology lessons and the one mostly preferred by pupils shows an overlap for the *experiments* as a teaching tool. The appearance of media channels such as *movies and cartoons* in the preferred support material for teaching biology uncovers an interesting outlook for science communication in schools. The aforementioned channels could be brought to the current biology lessons. This opens new perspectives that can be sustained by emerging communication media. For example, interactive CD-ROMs allowing for the compilation of several biotechnology features (i.e., documentaries, reportages, experiments) developed as short video sequences could represent an ideal media to support science teachers in teaching different science-related topics.

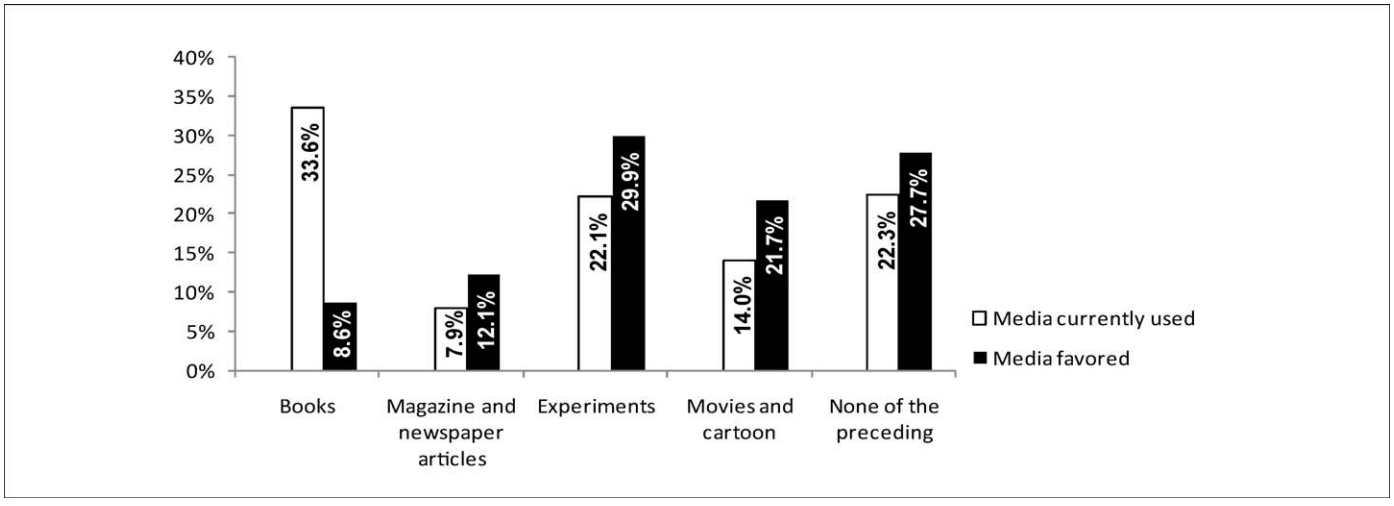

FIGURE 3

Percentage of pupils reporting the current use of media in science/biology lessons (in white) and the media they wish to be used (in black). Pupils could select 2 choices per question, and thus the percentages are with respect to the number of all choices of all pupils. Note that all differences in proportion are statistically significant.

Conclusion

In the past decade, studies to assess the public perception of biotechnology and its applications have been performed in several European countries [4,6,16,23–26]. Some of those studies have included a cognitive component to interpret attitude toward biotechnology among the surveyed people. In Europe, about one in five adults qualify as well-informed about biotechnology while a third of Europeans display a middle-level awareness and understanding [4]. The necessity to raise knowledge about biotechnology has been debated in several government documents and research articles.

The presented study aimed at evaluating the aspects of biotechnology that are still not well understood by pupils and at defining a sustainable and successful strategy to communicate about biotechnology in the last years of high school education in Europe. Ideally, European pupils should reach similar knowledge levels in order to ensure equal participation and contribution to the public debate.

The study revealed that the knowledge about biotechnology in the surveyed schools was higher than the European average for several similar quiz questions reported by Gaskell *et al.* [13]. However, our evaluation showed an interesting lack of knowledge in the use for biotechnology. Despite controversial debates about biotechnology in Europe, it appeared that pupils are lacking precise knowledge about the presence of biotechnology in their daily life. We suggest that biotechnology applications should be included in the teaching program. Pupils should learn the role played by biotechnology in their daily life by being informed on items such as biotechnology-derived products available on the market and the ones in development. The potential of biotechnology should be addressed together with the associated risks.

It was also evident that pupils are eager to receive direct contributions from academe representatives as attested by their preference for professors and young scientists to obtain information about biotechnology. Several possibilities exist to bring academe representatives into schools. The most evident one is to organize a service that links scientists to school-teachers. This service would give the opportunity to teachers to include a scientist's visit when they teach about biotechnology. Another possibility lies in the development of media that would help teachers communicate to their students on biotechnology. On the basis of the information gathered in this survey, it appears that experiments and video sequences are the most favored approaches to learn about biotechnology. Because interactivity is increasing in the emerging media, it is conceivable to elaborate support material in which school teachers can find short video sequences, for example on biotechnology-related experiments. It is possible to include interviews from university scientists that would introduce various biotechnology topics.

College education is an important step where the population can evenly receive information about certain topics of general interest for the society. Biotechnology is certainly among those important topics because of the controversy it can raise. This study identified several aspects on how to improve teaching of biotechnology in high schools. Having shaped the frame to ensure optimal receptivity and interest within the pupils at school, the ground might be prepared for a demystified debate about biotechnology within next generations of decision makers.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.nbt.2010.01.338.

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