TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 9, Sayı 3, Eylül 2012

Journal of
TURKISH SCIENCE EDUCATION
Volume 9, Issue 3, September 2012

http://www.tused.org

Eighth-Grade Students' Perceptions of Biotechnology: A Case Study

Şengül Saime ANAGÜN[1]

[1] Assist. Prof. Dr., Eskisehir Osmangazi University Faculty of Education, Department of Elementary Education, Eskisehir-TURKEY

Received: 22.07.2011 **Revised:** 25.04.2012 **Accepted:** 03.06.2012
The original language of article is English (v.9, n.3, Eylül 2012, ss.191-206)

ÖZET

The aim of this qualitative study, which was based on a case study conducted in a primary school in Turkey, was to examine eighth-grade students' perceptions of biotechnological issues in terms of social, ethic and economic aspects. The study sample consisted of 18 eighth grade students. The data were collected with videotapes and an open-ended questionnaire. A content analysis was conducted on the transcripts of videotapes through a model of analytical induction, which sought to extract the implicit conceptions about several aspects under study. As a result of the analysis of data from the open-ended questionnaire and videotapes, it was found that the students did not truly understand what biotechnology is and they had uncertain views about the social, ethic and economic effects of biotechnology on their daily lives. The advantages of genetic engineering of both plants and animals which were most commonly affirmed by the students were improved storage properties and improved growth although fewer students thought that these qualities were true of plant products. Most of the students were strongly supportive of medical applications of biotechnology to avoid genetic diseases.

Anahtar Kelimeler: Biotechnology, Genetic Engineering, Socio-scientific Issues, Primary Education, Case Study.

INTRODUCTION

Educating scientifically literate students, who are able to understand the nature of science and technology, is the focus of science education reform movements. Preparing students into their future life as scientifically literate citizens remains an important goal of science education (Laugksch 2000). This goal for science education has provided the impulse for a review of an appropriate science curriculum for the 21st century. Today, scientific literacy not only comprises knowledge of science but also implies knowledge about the nature of science. It also requires one to look at science in the light of the production, interpretation, communication and negotiation of scientific knowledge as well

Corresponding Author email: ssanagun@ogu.edu.tr
© ISSN:1304-6020

as the impact of science on society and the environment (Kolstø, 2001; Organization for Economic Co-operation and Development, 2006; Wolfensberger, Piniel, Canella & Kyburz-Graber, 2010).

In a democratic society, public evaluation of science requires the participation and involvement of as many citizens as possible, and this is only possible by understanding what science is and how it is produced. Many science educators advocate that discussion of socio-scientific issues in the classroom has been shown to be extremely useful both in terms of learning about the contents, the processes and the nature of science and technology, and in terms of students' cognitive, social, political, moral and ethical development (Hammerich, 2000; Kolstø, 2001; Reis & Galvao, 2009; Sadler, 2004). Discussion of socio-scientific issues gives students reflection and examination opportunity of relevant connections among science, their own lives and the quality of life in their community (Driver, Leach, Millar, & Scott, 1996; Driver, Newton, & Osborne, 2000; Kolstø, 2001, 2006; Sadler, 2004; Zeidler, 2003, Zeidler, Sadler, Applebaum, & Callahan, 2009). In this context, learning and teaching about socio-scientific issues has become much more important. Teaching socio-scientific issues in science and technology course aims to engage students in decision making regarding current social issues with moral implications embedded in scientific contexts (Sadler, 2004; Zeidler& Keefer, 2003; Zeidler& Sadler, 2008; Zeidler, Sadler, Simmons & Howes, 2005; Zeidler et al. 2009).

Discussion of socio-scientific issues in science curriculum gives students an opportunity for promoting scientific literacy. Socio-scientific issues are also an essential tool for educating responsible citizenship regarding decision-making processes (Millar & Osborne, 1998; Monk & Dillon, 2000; Osborne, 1997; Zeidler et al., 2005). As a socio-scientific issue, biotechnology, and genetic engineering in particular, is about to become one of the most important scientific revolutions of the 21st century.

Definitions of biotechnology include almost all forms of biological activity in addition to those that require the involvement of genetic engineering. Biotechnology is widely used in many areas such as pharmaceutical industry, medicine, agriculture, food industry, environmental protection, offering benefits to producers, the environment, and humanhealth (Institute of Food Technologists, 2000, cited in Hladnik, Peklaj, Košmelj, Hladnik & Javornik, 2009). The new technologies that makes life easier, such as the development of high efficient products, the usage of gene therapy in order to cure cancer, and the production of micro-organism based medicines are, for sure, very beneficial for the humanity (Darçın & Güven, 2008). Biotechnology can be applied in a variety of ways such as cloning, use of stem cells in medical research and therapy, use of hormones and antibiotics in animal production, use of genetically modified organisms for drug synthesis, and production of genetically engineered food stuffs. These issues require an understanding of the impact of the society on scientific endeavor and the impact of scientific endeavor on the society (Lee, Abd-El-Khalick & Chai, 2006).

Advances in biotechnology raise numerous questions and doubts regarding potential risks as well as a multitude of ethical and social issues (Reis & Straughan, 1996). Many science education researchers support that biotechnology instruction brings up important political, economic, ethical and educational questions. Students as members of future society must receive an effective education in order to understand these questions and their answers (Stewart & Van Kirk, 1990; Lewis & Wood-Robinson, 2000; Marbach-Ad, 2001; Mohapatra, Priyadarshini & Biswas, 2010). Gene technology was one of the first technologies through which the public participated in discussions on the possibilities of its application. Public perception of biotechnology is really multifaceted and cannot easily be

generalized. There are differences in perceptions relating to age, gender, education, culture, and with respect to the types of biotechnological products and services (Qin & Brown, 2007 cited in Hladnik, Peklaj, Košmelj, Hladnik & Javornik, 2009).

The reason for the differences of perceptions is lack of discussions in schools about such subjects. Discussion of biotechnological issues is not a common practice in science classes. Many teachers do not have management skills related to classroom discussions and the required knowledge to undertake discussions about biotechnological issues, namely the social, political, ethical and economic aspects of the issues at stake (Levinson, 2004; Reis and Galvão, 2004, 2009, Simmons & Zeidler, 2003). Other teachers feel the restraints imposed by the excessive number of topics in science curriculum (Levinson & Turner, 2001; Reis & Galvão, 2004). It is also true that many science teachers see their task as teaching facts, so they avoid discussion of the social, moral and ethical implications of science and technology in class (Levinson, 2001; Levinson & Turner, 2001).

Ethical concerns are among the most important factors for individual decision-making. Risk of science and technology has the potential to be a critical theme in scientific literacy as well as science education. For example, Kidman (2009) states that it is not just content that is important in biotechnology education, but providing students with "opportunities to form their own views, based on their understanding of risks, benefits and disadvantages of modern biotechnology" is also significant (Cited in Gardner & Jones, 2011).

Most of the research about biotechnology focuses on the relationship between student knowledge and their attitudes towards biotechnology (Chen & Raffan 1999; Lock & Miles 1993; Gardner & Jones, 2011; Özel, Erdoğan; Uşak, & Prokop, 2009; Sürmeli & Şahin, 2009; Türkmen, & Darçın, 2007). Schools can have a decisive role in promoting an understanding of science that allows students to recognize what is at stake in a given controversy, reach an informed opinion and participate in discussions, debates and decision-making processes since the construction of a democratic society where the decisions concerning scientific and technological issues are not made exclusively by specialists (Reis & Galvao, 2004). It is essential that advances in genetic and modern biotechnology, which create opportunities on the one hand and bring about risks on the other, be understood accurately and in detail by students in primary education. For this reason, future generations should be equipped with unbiased and accurate information in educational institutions about genetic engineering techniques and practices and be raised as individuals who are aware of issues and problems that they might often face in the future (Bal & Keskin, 2002). Turkish Ministry of National Education's Science and Technology curriculum emphasizes the significance of the fact that genetic engineering and biotechnology applications are entirely understood (MEB, 2008). The way the basic concepts of genetics and biotechnology, which are included in the 8th Grade science curriculum, are taught will play a key role in this process. Inadequate comprehension of the basic genetic concepts as prescribed by the curriculum will make it difficult to understand increasingly complicated genetic complications. Finally, this grade level is the last year of compulsory education and it should be kept in mind that students represent the upcoming generation of citizens and purchasers.

AIM

The aim of this study was to examine eighth-Grade students' perceptions about biotechnology and possible advantages and dangers of biotechnology and genetic engineering studies.

METHODOLOGY

The study was designed as a case study. Case study research is a qualitative approach in which the investigator explores one or more bounded systems (cases) over time, through in depth data collection involving multiple sources of information and reports a case description and case-based themes (Creswell, 2007).

Participants of the study: The teacher involved in this study, Meryem, had already collaborated with the researcher on her master thesis. Meryem had been a teacher of Primary Science for two years when this study was carried out. After finishing her degree in Primary Science Education at a university in Turkey, she started to do her master's degree. While she was doing her master's degree in Primary Science Education, she also started to teach in an elementary school as a science teacher in central Turkey. In her master thesis, she aimed to describe the level of the knowledge, value and behavior of 8th Grade students towards biologic diversity. This study gave her a chance to work on biology and especially on endangered animals and plants. Meryem also attended a summer camp named as "Karapınar Desertification Model Nature School" supported by Science and Society Department of Scientific and Technological Research Council of Turkey (STRCT). Meryem stated that she joined this camp due to her interest in biology and especially in the environment in science education. She also said that this camp was useful for her to increase her knowledge and awareness about the natural phenomena. As a dynamic and hard-working teacher, she enjoyed her professional activity tremendously.

On the other hand, the teacher was not aware of the reasons underlying the observation of these specific classes or of the specific aims of the study. The researcher only informed her that she intended to conduct a study on teaching about biotechnology. Therefore, she was not induced into choosing a certain teaching-learning methodology.

When this study was conducted, The teacher had been working at the same school for the last two years. The school was located in a rural area where families from middle and lower socioeconomic levels lived. The school had a total of nine classrooms and this research was conducted in Science and Technology classroom. The study was conducted in an 8th Grade class of Science and Technology course. The class consisted of 19 (9 female and 10 male) students, but one of the male students was getting special education because of his learning disability. He was excluded from the study and the study sample included 18 students.

Data collection and analysis: Data collection consisted of qualitative data collection methods such as open-ended questionnaire and video recorded classroom discussions guided by the teacher. An open-ended questionnaire was developed based on curriculum achievements. After getting expert opinions, development process of questionnaire was completed. During the investigation, a sequence of classes was planned and implemented by the participant teacher. The "Cell Division and Genetic Heritage" among the 8th Grade units was chosen for the study because it was considered by both the teacher and researcher as one of the most suitable subjects for carrying out discussion about important political, economic, ethical and educational questions regarding biotechnology. Each classroom activity was video-recorded. The researcher adopted the role of non-participant observer.

A content analysis was conducted on the transcripts of videotapes through a model of analytical induction (Bogdan & Biklen, 1992), which sought to extract the implicit conceptions about several aspects under study. This kind of analysis involves classification of meaningful elements according to certain categories that may bring order to the apparent disorder of the raw data. The category construction process, though essentially intuitive, is influenced by several aspects such as the aims and theoretical background of the study, as well as the researcher' conceptions and knowledge.

Implementation Phase: This study involved observing a 5-class sequence out of 22 in total planned and implemented by the teacher. This set of 40-minute classes focused on curriculum topics such as mitosis and meiosis, genetic heritage, DNA and genetic coding, adaptation and evolution. In this unit, the students were expected to comprehend that mitosis ensures asexual reproduction as well as growth, the relationship between sexual reproduction and meiosis and the significance of meiosis for the living beings. The students were also expected to recognize the basic concepts about genetics, Mendelian genetics and genetic diversity. The last but not the least goal of the unit was to have the students associate genetic engineering studies with daily life (MEB, 2008). In the participant teacher's opinion, these topics introduce biotechnological issues such as cloning or genetic engineering.

This section presents some information obtained through classroom activities observation and classroom discussions. The teacher planned a set of activities for the sequence of classes that was included in the present study. The teacher's aim in these activities was to teach basic concepts of genetics (mitosis and meiosis), which is essential to understand the reproductive and hereditary process, and to prepare the students for their future lives for making decisions as scientifically literate citizens. To fulfill these goals, she proposed a varied set of classroom activities such as talking about cartoons, group discussions, doing worksheets and investigations and sharing results with each other by presentations.

At the beginning of the subject before starting the activities, the students were grouped and then introduced to genetic engineering studies by cartoons placed in the textbook. They discussed about the cartoons based on their prior knowledge. At this point, the teacher just listened to them and did not get involved in their discussions. The students talked about their opinions about the cartoons regarding the applications of genetic engineering and biotechnology. The teacher listened to their explanations for negative or positive opinions. She tried to manipulate them into looking at the bright side because there were too many negative ones among the student opinions.

Based on the planned activity, the research questions were given to students by the teacher for investigation. With this assignment it was expected that the students would evaluate positive and negative impacts of genetic engineering and biotechnology studies. After the students finished their researches, the teacher asked them to create their own cartoons related to the subject and to discuss the cartoons. After the discussions about cartoons, the students were delivered worksheets about biotechnology prepared by the teacher and they were asked to underline the important points. Then The teacher tried to guide the students through systematic thinking by asking them questions about what they read. After listening to the students' opinions about the biotechnology applications covered in the text, the teacher tried to attract the students' attention to the areas which she wanted them to learn in particular. After making brief explanations about the applications, the teacher tried to learn about the students' opinions regarding the agricultural biotechnology

covered in the text. This session ended with the introduction of the concept of transgenic and transgenic plants that are produced most following the discussions about medical biotechnology and biotechnology in microorganisms.

During the activity, the teacher was observed to be highly motivated and she played an active role in managing the discussions, asking for explanations, presenting information, summarizing points of view and maintaining student participation. The second part of this activity consisted of news about genetically modified foods. While the students were sharing the news, they also discussed the topic with regard to social, ethical and economical considerations. At this point, they were free to use cartoons from both newspapers and magazines. The teacher believed that these activities would engage the students and help them build up knowledge relevant for the future and develop the ability to think and argue, which is essential for taking part in decision-making processes.

For the last activity, the students were asked to do research and prepare a poster for "Human Genome Project" in groups. In this assignment, the students were expected to investigate the project's history, today and future. During the activity, each group was supposed come up with a critical opinion about eventual advantages and disadvantages of project. For the activity, she recommended Internet sources and books for research. She also suggested analysis and discussion of articles published in books, newspapers, magazines and the Internet. Finally, the conclusions reached by each group were presented and discussed by the whole class.

Classroom observations showed that the teacher supported learning by inquiry-based activities. The importance of the phenomena under study was illustrated through examples related to current scientific and technological progress in the field of genetic engineering, gene therapy and cloning. The teacher also was concerned with diversifying teaching-learning methods and showing the importance of the topics she approached by establishing relations between these topics and certain scientific and technological progress.

Another important aspect of the lessons was student-student and student-teacher interaction. In several classes that involved discussion, the students dominated the discourse and the teacher had a guidance role for students. The activities required the students' active involvement in phenomena, searching information, analyzing and discussing biotechnological issues and presenting work. After introducing the topic and presenting the task, she observed and helped students follow the right ways for their research. She avoided exposing her own opinions and acted as a moderator in discussions and guided the students to a deeper level of comprehension. The teacher tried to help the students understand and explore the implications of different opinions and actions. At the same time, when necessary, she explained the main ideas and assumptions underlying the topic which they were investigating.

FINDINGS

Students' perceptions about biotechnology

Definition and working areas of biotechnology were explained to the students through activities and the textbook. In parallel to these explanations, the first question in the open-ended questionnaire was "What does the concept of biotechnology mean to you?" As a result of the analysis of the students' answers to that question, the following were found:

- bio: the living beings, biotechnology: technology practiced on the living beings (S1, 6, 7, 18)

- the studies conducted through technology on human life (S2, 11)
- A branch of science aimed at doing something useful for human beings (S3, 9)
- A branch of science finding solutions to the problems the living beings have (S4, 8, 12)
- Carrying out studies with living cells in health, stockbreeding and agriculture (S5, 10, 15)
- A branch of science dealing with DNA of plants (S13)
- A branch of science examining the genetic structure of the living beings (S16)
- Conducting scientific studies on organic and nonorganic substances (S17)

It was found that only three of the students (S5, 10, 15) were able to come up with a broad definition of the concept of biotechnology. Most of the other students stated their perceptions about the concept in a way connoting "living" and "technology" Some of the students involved in the study (S4, 8, 12) referred biotechnology as "a branch of science finding solutions to the problems of living beings" and therefore indirectly mentioned its range of applications in general. Some of the students (3, 9) associated biotechnology only with human beings while some others (13, 16) gave responses in relation to genetic structure.

Students' perceptions about genetic engineering studies

The students were asked to express their own ideas about the positive and negative aspects of genetic engineering with regard to biotechnology. They discussed the subject in the classroom. During the discussions about the appreciated aspects of biotechnology studies, they stated their opinions about the relationship between biotechnology and economy. Claiming that people could not afford to buy organic products because of their high prices, the students said that transgenic products were preferred because they were cheap and that the society regarded this situation as positive. The students also stated that they did not want to eat genetically modified food. The teacher tried to inform them about this subject properly and to encourage them to evaluate this subject objectively and she herself participated in the discussions. The students reached the common conclusion that genetically modified products carried some risks despite their positive aspects. The students then stated that they appreciated the biotechnology applications in health and regarded studies like finding cures for illnesses and developing medicine as positive efforts:

> T: I want you to seek an answer to the question 'Which genetic engineering studies do you appreciate? Why?'
> S5: I appreciate the studies aimed at finding cures for human beings' illnesses. I mean, who does not want see that their relatives or friends are cured?
> T: That's right. Finding cures for illnesses by means of biotechnology is appreciated by the society, too.
> S6: Mme, I still feel confused about it. Doesn't it cause any harm while trying to find cures for illnesses?
> T: Yes, sometimes it may. For example, new genes added to some plants may be transferred to other plants in some ways. To illustrate, a gene related to a wild species may pass to other plants, and guess what… the genetic structure of these plants may be spoilt. Then when we need that wild plant, the alien gene may be a problem and we do not want it. We need a particular property in that plant but we cannot find it there anymore because we have already lost it. I'm talking about that kind of problems.

In addition to in-class discussions, Table 1 shows the responses given by the students to the open-ended questions in the questionnaire about the positive and negative aspects of genetic engineering studies.

Table 1. *Students' perceptions about genetic engineering studies*

Positive Aspects of Genetic Engineering	**Negative Aspects of Genetic Engineering**
Increasing the number of trees by means of cloning (S1,12, 13, 18)	Turning useful plants into harmful ones by changing their genes (S1, 5, 8, 13)
Cures for human diseases (S2, 3, 5, 9, 10, 13)	Breaking the food chain (S2, 7)
Solutions to the problems of the living beings and environment (S4)	Producing new species by changing plants' and animals' genes (S3, 12)
Solution to hunger problem (S6, 7, 8)	Damaging living beings' natural structure (S4, 9, 10)
Solution to endangered animals (S7)	Harmful effects of Genetically Modified Foods (GMF) on the economy (S6)
Increasing shelf life (S10)	Poor nutritional value of GMF (S7, 14)
Saving seed productivity content (S10)	Being unkind towards animals (S11)
Producing silk by putting spider in goat milk (S10)	
Producing low-fat crisps by growing quality potatoes (S10)	

One of the students (S4) said *"Genetic engineering finds solutions for the problems of the living beings and environment"* whereas another student (S10) said *"By means of genetic engineering, more quality products are gained and shelf life is increased"*. The same student expressed positive opinions about biotechnology by giving interesting examples and said *"By means of genetic engineering, silk is produced by putting spider in goat milk"* and *"Low-fat crisps are produced by growing quality potatoes"*.

The students also mentioned some topics which raised controversies in the society as negative aspects of biotechnology. One of the students (S10) made a remarkable point by saying *"the genetic properties of fruits and living beings are changed and they are not natural anymore*". The student openly expressed a concern about 'spoilt nature', a common concern shared by almost everyone. The students also expressed their concerns about the broken food chain and foods with poor nutritional value. On the other hand, only one student (S11) felt uncomfortable about being unkind towards animals and highlighted the ethical dimension of genetic engineering studies. Finally, two students (S3, 12) explained that they saw the issue as "*producing new species by changing plants' and animals' genes"*.

In order to clarify the students' opinions during the discussions, the teacher asked "which area would you like to study in if you were a genetic engineer?" Some of the students' answers to that question are below:

- producing something like a pill as food and getting rid of the obligation to eat two or three times a day,
- developing a drug (product) against food that contains harmful substance,
- the number of trees is decreasing; increasing their number by cloning,
- decreasing the calorie of some food like chocolate,
- finding cures for some animal diseases. In bird flu, for example, many animals were killed; finding a solution for this situation by means of biotechnology,
- decreasing drug dosages,
- designing a machine to determine if genetics properties of fruits are modified.

These responses could be interpreted to mean that the students appreciated biotechnology studies and supported development of these studies for the sake of humanity.

Students' perceptions about the relationship with biotechnology and food deficiency

In order to obtain more detailed information about the students' opinions, they were asked "Do you think biotechnology studies may be a solution for the food shortage problem in the world?" Some of the students mentioned the positive aspects of biotechnology and stated that these studies could solve the problem. Below is an example of in-class discussions about positive opinions:

T: Well, does biotechnology have positive aspects?
S8: Of course it does. It may help get more production.
T: OK. What does getting more production affect positively?
S8: We can obtain the same product in larger amounts.
S4: There are many countries suffering from hunger. Maybe, we can help them if there is more production.

By pointing out that production increase could be used to help the countries with poor economic conditions once the needs of their own country were met, the students highlighted the significance of the social aspects of the issue. They also added that the world's hunger problem could be solved in this way. Another group of the students, however, mentioned the negative aspects of biotechnology studies and claimed that these studies would never be supported and consequently they could never solve hunger problem. Table 2 shows the students' opinions about this subject.

Table 2: *Students' perceptions about the relationship between biotechnology and food shortage*

Positive Perspective	**Negative Perspective**
Production increases as plant diversity increases (S 1, 7, 10, 12, 18)	It is not consumed because it is genetically modified (S4, 13)
Cloning becomes a solution for hunger problem (S2, 9)	Cheap but harmful (S5, 13)
Quality product in a short time (S3)	Low nutritional value (S7, 15)
Low prices increases purchasing power (S6, 11, 17)	Better if not genetically modified (S8, 16)

As can be seen in Table 2, the majority of the students thought that biotechnology studies could find a solution to food shortage because of its positive features such as "*increasing the diversity of species thanks to genetic modification of plants and gaining more products in shorter periods as a result of biotechnology studies*". However, few students said "*the society will not prefer these products and genetically modified products will have low nutritional value*" and stated that these products would not be consumed much because of negative perception among the society.

Students' perceptions about genetic engineering studies in a social aspect

During the in-class discussions, the teacher asked the student who said "I would design a machine to determine if genetics properties of fruits are modified if I were a genetic engineer" why she thought so. At this point, the discussions were about the inadequacy of

the relevant laws in the country. The students expressed their disturbance about not knowing which products were genetically modified in Turkey. Also, the students evaluated genetic engineering studies in a social point of view. The following are the students' opinions about the subject:

- High prices of organic products cause people to buy GMF (S1)
- It's good that these studies find cures for illnesses but GMF have some harms. I'm indecisive about it (S2, 10)
- They create problems in the society. The society shows reaction because of its doubts (S3, 7)
- The society feels pleased because they find cures for people's problems (S6, 9, 18)
- People can buy meat because of low prices, which brings about a balanced diet. (S11)
- They create chaos in the society (S13, 18)

The students' responses showed that they had confused feelings about biotechnology studies in terms of social aspects. There were some students expressing positive opinions due to the features of biotechnology such as finding cures for people's illnesses and solving some problems as well as some other students pointing out that not knowing about the content of genetically modified food would lead to doubts in the society:

> T: What do you think about eating genetically modified food?
> S4: I cannot trust it.
> T: Why don't you trust it?
> S7: Well, because I don't know what is in it.
> S8: Actually, we shouldn't be worried, but I think we don't know much about it because it is something new for us. That is why we don't trust it.
> T: But these studies are new for everyone not just for you. You have some hesitations maybe because you are not informed enough. Your thoughts may change in time as you get to know more about it.

The teacher pointed out that there might be some hesitations in the society due to not having enough knowledge about the subject and the society needed to be provided with details.

Students' perceptions about genetic engineering studies in an ethical aspect

During the in-class discussions, the students stated that they did not approve biotechnology studies in an ethical point of view and said they were *"against"* studies conducted on animals because they hurt animals. In addition they expressed their objection to cloning by saying "*these animals are put into the nature but they cannot adapt to the nature*". The students' responses about the subject are below:

- Good aspects of GMF may not be recognized (S1, 15)
- It's good that these studies finds solutions to illnesses (S5, 9)
- They are against animal rights and, in a sense, they are torture for animals (S8, 12)
- They lead to different illnesses (S10)
- Breeding studies prevent extinction of some species (S17)
- The society is not informed efficiently (S13)

While the students criticized biotechnology studies because they tortured animals and led to different diseases, they supported these studies because breeding rehabilitation studies prevented the extinction of some animals. Moreover, the students stated that they

did not approve the fact that the society was not informed about the subject properly. On other hand, the students appreciated the fact that several illnesses could be cured by means of biotechnology studies.

Students' perceptions about genetic engineering studies in an economic aspect

During the in-class discussions, the teacher had the students talk about the economic consequences of biotechnology studies. The following are the findings obtained from both the in-class discussions and written opinions:

- Export increases in parallel to production and economy of the country is improved (S1, 6, 7, 10, 18)
- The needs are met in our country (S2, 14)
- GMF are not of good quality, so not many people consume them (S3, 4, 15)
- People have to buy them because of their low prices but they are harmful (S5, 7, 8, 12)
- They are good in terms of economy but unhealthy (S9, 16)
- Low prices increase consumption and leads to a balanced diet (S11)

While some students regarded low prices as positive in terms of economy, they still expressed few negative opinions. A common opinion among the students was that the production increase would be good for the country's economy and the country would gain income by means of export. The economic aspect was emphasized during the in-class discussions:

> S10: Mme, in terms of social aspects, isn't it true that people have to buy genetically modified food because organic products are expensive?
> T: Of course, this is something about economic conditions. If a person cannot afford to buy organic food, that person has to buy the other type. This is something about the economy and development level of our country.

Finally, the teacher and students evaluated biotechnology studies in terms of economic aspects by noting the relationship between buying products and people's income.

DISCUSSION AND CONCLUSION

The findings from this study indicate that many concepts related to biotechnology and especially genetically modified foods were not well understood by the majority of the students. The textbooks used in the course explain that biotechnology involves various applications by using live cells in agriculture stockbreeding and industry. The textbooks also state that biotechnology studies cover a wide range of applications such as obtaining genetic products to be used in curing and preventing illnesses, producing proteins to repair damaged cells or to fight against infectious diseases and producing vitamin tablets, fruit yogurt, qualified plant seeds and seedling seeds. The students' responses and the discussions showed that they could not efficiently internalize the knowledge covered in the textbooks. Similarly, findings from some other studies reported that individuals cannot exactly explain the subjects about biotechnology, genetic engineering and cloning (Chen & Raffan, 1999; Gunter, Kinderlerer & Beyleveld, 1998; Inaba & Macer, 2003; Lewis, Driver, Leach & Wood-Robinson, 1997). Gunter, Kinderlerer & Beyleveld (1998) examined opinions on genetic engineering of plants among British students. The results showed that, despite the students' poor understanding of biological science, they seemed less reluctant about genetically modified food. It could therefore be suggested that the findings of this study are similar to the findings reported by other similar studies.

The advantages of genetic engineering of both plants and animals that were most commonly affirmed by the students were improved storage properties and improved growth although fewer students thought that these qualities were true of plant products. The participants also thought that genetically modified food would be cheaper than other food. Similarly, the students did not claim that food stuffs produced by genetic engineering would be healthier to eat and they saw such food as unsafe. Similar findings are reported by Hill, Stanisstreet, Boyes & O'Sullivan (1998), Dawson (2007), Seethaler & Linn (2004) and Saher, Lindeman & Hursti (2006) about the students' ideas about genetically engineered food-stuffs and biotechnology processes.

In general, the students were in favor of genetic engineering applied to plants but not to animals. They thought that the process would be unkind for animals. Similarly, Chen & Raffan (1999), Dawson & Schibeci (2003), Massarani & Moreira (2005), Prokop, Leskova, Kubiatko & Diran (2007) and Hladnik et al., (2009) also stated that students find genetic modification of microorganisms and plants more acceptable than that of animals and humans.

Majority of the students thought genetic engineering of organisms would cause risk to the environment and it was a threat to biodiversity. The students realized that genetic modification of crops enhanced an organism's ability to become an invasive species. Many of the students were aware of the fact that genetically engineered crops would interact with the diversity of habitats and it would affect the ecosystem. Nevertheless, the majority of them were not aware of the fact that sexual crossing of genetically modified crops with an existent weed species can lead to the generation of super weeds, genetically modified food can lead to production of toxic or allergic proteins and risk in genetically modified food is related to the nature of the introduced genes and their products rather than the method used to improve the variety.

Different trends were observed among the participants of the present study. The results showed that most of the students were strongly supportive of medical applications of biotechnology to avoid genetic diseases. It was found that the students supported genetic modification in order to make people more resistant to diseases, find new cures for genetic illnesses and reduce the risk of having fatal diseases. On the other hand, the students also thought that vaccines and medicine developed through genetic engineering were unsafe for human health and pharmacist had to give information about this subject to their patients. The students also argued that genetically engineered products should be labeled for product information so that the public could have information about the structure of the products they bought. A study by Hill et al. (1998) revealed that the majority of British students accepted the idea that food stuffs produced by genetic engineering was safe for human health and they thought that genetically engineered products should be labeled for product information.

In summary, the results of this study revealed the perceptions of a group of 8th Grade students about the application of genetic engineering and biotechnology. In spite of the high publicity of the issues about new biotechnologies in the media, the study results revealed that the knowledge of the students about genetic engineering remains rather unconfident (Marlier 1992; Hill et al., 1998; Mohapatra, Priyadarshini, & Biswas, 2010). In order to inform students about biotechnology and its products, first of all the teachers should be trained and equipped with appropriate knowledge and skills. Evidence suggests that introducing students explicitly to these topics will improve understanding and reduce uncertainty (Dawson & Schibeci 2003). Students also need to be taught about explicit decision making skills if they are to make informed choices about genetic engineering

(Dawson & Taylor 2000). Moreover, students need to be supported with relevant formal and informal sources of information so that they can follow contemporary developments of biotechnology and genetic engineering studies. Also, students could be supported with course content, which facilitates comprehending these issues. Finally, as an informal source of information, the media should present accurate information about these issued based on scientific data.

REFERENCES

Bal, Ş., & Keskin, N. (2002, September). Evaluation of students' attitudes and opinions about genetic engineering applications by means of group discussion. 5th National Congress of Science and Mathematics Education. Ankara: ODTU. (16-18 September) Retrieved from www.fedu.metu.edu.tr/UFBMEK-5/b_kitabi/PD in 20.10.2010

Bogdan, R. & Biklen, S. (1992). *Qualitative research for education*. Boston: Allyn and Bacon.

Chen, S.Y. & Raffan, J. (1999). Biotechnology: Students' knowledge and attitudes in the UK and Taiwan. *Journal of Biological Education*, 34(1), 17-23.

Creswell, J.W. (2007). *Qualitative Inquiry and Research Design: Choosing among five approaches.* Thousand Oaks, California: Sage Publications.

Darçın, E. S. & Güven, T. (2008). Development of an attitude measure oriented to biotechnology for the pre-service science teachers, *Turkish Science Education,* 5 (3), 72-81.

Dawson V (2007) An exploration of high school (12-17 year old) students' understandings of, and attitudes towards biotechnology processes. *Research in Science Education* 37(1):59–73

Dawson, V., & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology process. *Journal of Biological Education* 38(1), 7-12.

Dawson, V. & Taylor, P. (2000). Do adolescent's bioethical decisions differ from those of experts? *Journal of Biological Education*, 34, 1-5.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Bristol, PA: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287-312.

Gardner, G. E. & Jones, M. G. (2011) Science instructors' perceptions of the risks of biotechnology: Implications for science education, *Research in Science Education*, DOI 10.1007/s11165-010-9187-0

Gunter, B., Kinderlerer, J.,& Beyleveld, D. (1998). Teenagers and biotechnology: A survey of understanding and opinion in Britain. *Studies in Science Education*, 32, 81-112

Hammerich, P. (2000). Confronting students' conceptions of the nature of science with cooperative controversy. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 127-136). Dordrecht: Kluwer Academic Publishers.

Hill R, Stanisstreet M, Boyes E, & Sullivan O. (1998) Reactions to a new technology: students' ideas about genetically engineered foodstuffs. *Research in Science and Technology Education* 16(2):203-216

Hill, R., Stanisstreet, M., O'Sullivan, H. & Boyes, E. (1999) Genetic engineering of animals for medical research: Students' views, *School Science Review,* 80(293): 23-9.

Hladnik, H. C., Peklaj, C:, Košmelj, K., Hladnik, A & Javornik, B. (2009). Assessment of Slovene secondary school students' attitudes to biotechnology in terms of usefulness, moral acceptability and risk perception, *Public Understanding of Science*, 18(6), 747-758.

Inaba, M. & Macer, D. (2003). Attitudes to biotechnology in Japan in 2003. *Eubios Journal of Asia and International Bioethics,* 13, 78-90.

Kolstø, S. D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socio-scientific issues. *Science Education*, 85(3), 291-310.

Kolstø, S. D.(2006) 'Patterns in students' argumentation confronted with a risk-focused socio-scientific issues', *International Journal of Science Education*, 28 (14), 1689-1716

Laugksch, R. (2000). Scientific literacy: a conceptual overview. *Science and Education*, 84, 71-94.

Lee, H., Abd-El-Khalick, F. & Choi, K. (2006) Korean science teachers' perceptions of the introduction of socio-scientific issues into the science curriculum, *Canadian Journal of Science, Mathematics and Technology Education*, 6: 2, 97-117

Levinson, R. (2001). Should controversial issues in science be taught through the humanities? *School Science Review*, 82(300), 97-102.

Levinson, R. & Turner, S. (2001). *The teaching of social and ethical issues in the school curriculum, arising from developments in biomedical research: A research study of teachers*. London: Institute of Education, University of London.

Levinson, R. (2004). Teaching bioethics in science: Crossing a bridge too far? Canadian *Journal of Science, Mathematics and Technology Education*, 4(3), 353-369.

Lewis, J., Driver, R., Leach, J., & Wood-Robinson, C. (1997). Young people's understanding of, and attitudes to the new genetics project. Working Paper 2: Understanding of basic genetics and DNA technology (A): The Written Probes. University of Leeds, Centre for Studies in Science and Mathematics Education, Learning in Science Research Group.

Lewis J, Wood-Robinson C (2000) Genes, chromosomes, cell division and inheritance-do students see any relationship? *International Journal of Science Education*, 22, 177-195

Lock, R. & Miles, C. (1993). Biotechnology and genetic engineering: students' knowledge and attitudes. *Journal of Biological Education*, 27, 267-273.

Marbach-Ad (2001) Attempting to break the code in student comprehension of genetic concepts. *Journal of Biology Education*, 35(4):183-189

Marlier E (1992) Euro barometer: Opinions of Europeans on biotechnology in 1991. In: Durant J (ed) *Biotechnology in public: A review of recent research.* Science Museum Publications, London

Massarani, L. & Moreira, I. (2005). Attitudes towards genetics: A case study among Brazilian high school students. *Public Understanding of Science*, 14, 201-212

Mohapatra, A. K., Priyadarshini, D. & Biswas, A.(2010). Genetically modified food: Knowledge and attitude of teachers and students, *Journal of Science Education Technology*, 19, 489-497.

MEB (2008). *Primary Education Science and Technology Course Curriculum*. Ankara.

Millar, R.& Osborne, J. (1998). *Beyond 2000: Science education for the future.* London: Kings College.

Monk, M. & Dillon, J. (2000). The nature of scientific knowledge. In R. Millar, J. Leach and J. Osborn (Eds.), *Good practice in science teaching: What research has to* say (pp. 72-87). Buckingham: Open University Press.

Organization for Economic Co-operation and Development. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD.

Osborne, J. (1997, September). Science education for the future-The road ahead? Paper presented at the ESERA Conference, Rome, Italy.

Özel, M.; Erdoğan M.; Uşak, M.; Prokop, P. (2009). High school students' knowledge and attitudes regarding biotechnology applications. *Educational Sciences: Theory & Practice*, 9 (1), 297-328.

Prokop, P., Leškova, A., Kubiatko, M. & Diran, C. (2007) Slovakian students' knowledge of and attitude toward biotechnology, *International Journal of Science Education*, 29(7): 895-907.

Qin, W. & Brown, J. L. (2007). Public reactions to information about genetically engineered foods: Effects of information formats and male/female differences, *Public Understanding of Science*, 16; 471-88.

Reis, P. and Galvão, C. (2004). The impact of socio-scientific controversies in Portuguese natural science teachers' conceptions and practices. *Research in Science Education*, 34(2), 153-171.

Reis, P. & Galvão, C. (2009). Teaching controversial socio-scientific issues in Biology and Geology classes: A case study, *Electronic Journal of Science Education*, 13 (1), Retrieved from http://ejse.southwestern.edu

Reis, M. & Straughan, R. (1996) *Improving nature? The science and ethics of genetic engineering*. Cambridge: Cambridge University Press.

Sadler, T.D. (2004). Moral sensitivity and its contribution to the resolution of socio-scientific issues. *Journal of Moral Education*, 33(3), 339-358.

Sadler, T. D. & Zeidler, D. L.(2009) Scientific literacy, PISA, and Socioscientific discourse: Assessment for progressive aims of science education, *Journal of Research in Science Teaching,* 46(8), 909-921.

Saher M, Lindeman M, & Hursti U. K. (2006) Attitude towards genetically modified and organic foods. *Appetite* 46(3):324-331

Seethaler S, & Linn M (2004) Genetically modified food in perspective: an inquiry based curriculum to help middle school students make sense of tradeoffs. International *Journal of Science Education*, 26(14):1765-1785

Simmons, M.L. & Zeidler, D.L. (2003). Beliefs in the nature of science and responses to socioscientific issues. In D.L. Zeidler (Ed.), *The role of moral reasoning and discourse on socioscientific issues in science education* (pp. 81-94). Netherlands: Kluwer Academic Press.

Stewart J. H. & Van Kirk J (1990) Understanding and problem solving in classical genetics. *International Journal of Science Education*, 12: 575-588.

Sürmeli, H. & Şahin, F. (2009). University students' attitudes towards biotechnological studies, *Çukurova University Journal of Faculty of Education,* 3(37), 33-45.

Türkmen, L., & Darçın, E. S. (2007). A comparative study of Turkish elementary and science education major students' knowledge levels at the popular biotechnological issues. *International Journal of Environmental & Science Education*, 2 (4), 125-131.

Wolfensberger, B., Piniel, J., Canella, C. & Kyburz-Graber,R. (2010). The challenge of involvement in reflective teaching: Three case studies from a teacher education project on conducting classroom discussion on socio-scientific issues, *Teaching and Teacher Education*, 26, 714-721

Zeidler, D. (2003). *The role of moral reasoning on socioscientific issues and discourse in science education*. Dordrecht: Kluwer Academic Press.

Zeidler, D.L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In: D.L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education* (pp. 7-39). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Zeidler, D.L., & Sadler, T.D. (2008). Social and ethical issues in science education: A prelude to action. *Science and Education*, 17, 799-803.

Zeidler, D.L., Sadler, T.D., Simmons, M.L., & Howes, E.V. (2005). Beyond STS: A research-based framework for socioscientific issues education. Science Education, 89, 357-377.

Zeidler, D.L., Sadler, T.D., Applebaum, S., & Callahan, B. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching*, 46, 74-101.