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Balancing the pros and cons of GMOs: socio-scientific argumentation in pre-service teacher education

Ayhan Cinici

Department of Science Education, Faculty of Education, Adiyaman University, Adiyaman, Turkey

ABSTRACT

This study investigates the role of the discursive process in the act of scientific knowledge building. Specifically, it links scientific knowledge building to risk perception of Genetically Modified Organisms (GMOs). To this end, this study designed and implemented a three-stage argumentation programme giving pre-service teachers (PSTs) the opportunity to consider, discuss and construct shared decisions about GMOs. The study involved 101 third-year PSTs from two different classes, randomly divided into control and experimental groups. The study utilised both quantitative and qualitative methods. During the quantitative phase, researchers administered a pre- and post-intervention scale to measure both groups' risk perception of GMOs. During the qualitative phase, data were collected from the experimental group alone through individual and group reports and an open-ended questionnaire. *T*-test results showed a statistically significant difference between the experimental and control groups' risk perception of GMOs. Qualitative analysis also revealed differences, for example, in PSTs' weighing of the pros and cons of scientific research demonstrating positive results of GMOs. In addition, PSTs' acceptance of GMOs increased. Consequently, this study suggests that developing familiarity with scientific enterprise may play an effective role in adopting a scientific perspective as well as a more balanced risk perception of GMOs.

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Argumentation; GMOs; pre-service teacher training; risk perception

Introduction

The issue of Genetically Modified Organisms (GMOs) has high value for teaching socio-scientific issues (SSI), as it involves the interaction of economic, ecological, social and biotechnological issues, all of which can help students develop a scientific perspective and balanced risk perception. SSI have been debated by both scientific and non-scientific communities without necessarily reaching a consensus (Zohar, 2008); this is not surprising, given that SSI have been described as ill-defined and disputable, invoking educational, economic, aesthetic, ecological, moral, cultural and religious values (Abd-El-Khalick, 2003; Sadler, 2009). For example, new biotechnological practices such as GMOs have escaped from scientific circles and are causing concern in society at large. Many studies have shown that risk perception of GMOs influences decision-making, attitudes and

CONTACT Ayhan Cinici ayhancinici@gmail.com Department of Science Education, Faculty of Education, Adiyaman University, Altinsehir, Adiyaman 02040, Turkey

behaviour. Moreover, there are many dual-positions and counter-claims with regard to the possible risks and benefits of GMOs in different segments of society (Klingeman & Hall, 2006). Risk perception of GMOs is influenced by cognitive and affective features and have mainly been attributed to individuals' social, economic and educational backgrounds. A brief review of the literature follows.

Risk perceptions of GMOs

A huge body of literature has asserted that there is a distinction between experts' scientifically assessed risk and perceived risk in the eye of the public (e.g. Curtis, McCluskey, & Wahl, 2004). That is, it appears that ordinary people's debates are based mainly on emotions, opinions and informal reasoning rather than being rooted in scientific knowledge (Šorgo, Ambrožič-Dolınšek, Usak, & Ozel, 2011). For instance, Sajiwani and Rathnayaka (2014) examined perceptions of the Sri Lankan public about Genetically Modified (GM) foods. Results showed that respondents from academic and research institutes had higher knowledge of GM foods than non-academic respondents. Also, 70% and 63% of respondents from academic and research institutes, respectively, were willing to accept GM foods, while 21% and 25% of university students and ordinary Sri Lankans, respectively, were willing to accept them.

On the other hand, the perception of GMOs is largely negative in many developed countries, such as the UK, Australia and Japan, because of their unknown environmental and health consequences (Curtis et al., 2004). For example, Lea (2005) conducted a study with 500 Australian adults and found mostly negative beliefs about GM foods. She concluded that public concern about GM foods stems from the perception that they are unnatural, difficult to identify, and have unknown long-term effects on human health and the environment. Furthermore, participants were generally unaware of or disagreed with the benefits of GMOs.

In general, previous studies have shown that individuals' negative emotions and risk perceptions of GMOs are potentially affected by socio-psychological, demographic and cultural factors (Finucane & Holup, 2005; Klingeman & Hall, 2006), personality characteristics (Slovic, 1987), lack of knowledge or understanding of GMOs (Alberts & Labov, 2003; Lewis & Leach, 2006) and media portrayals (Vilella-Vila & Costa-Font, 2008). For example, Marks, Kalaitzandonakes, Allison and Zakharova (2002) found that between 1990 and 1999, the media focused on risks rather than benefits of GMOs both in the U.S.A and the UK and that newspaper coverage was found to be 'negative' in the UK as well as in the U.S.A. Similarly, Vilella-Vila and Costa-Font (2008) examined whether media coverage affected the change in attitudes towards risk perceptions of GM foods between 1999 and 2004 in Spain and the UK. They found that some specific 'media biases' (in reporting and selection) correlate with attitudes and risk perception. They also concluded that the dominant themes rarely displayed a positive emphasis on the potential benefits of GM foods in both British and Spanish media coverage. Tait (2001) emphasised that due to media bias and activities of pressure groups, public response to the introduction of new biotechnological products has become hostile in the European countries since the end of the 1990s. However, as pointed out by Pardo, Midden and Miller (2002), abundant negative criticism echoed by mass media and pressure groups, together with ordinary people's lack of knowledge, does not provide any significant contribution to the debate.

Additionally, many studies show that ethical issues, values and beliefs rather than knowledge and understanding appear to be at the heart of the non-acceptance of GMOs (Scully, 2003). For instance, Šorgo and Ambrožič-Dolinšek (2010) found weak correlations between knowledge and acceptance, and high correlations between attitudes and readiness to accept GMOs. Another study conducted in the UK by Martin and Tait (1992) revealed that people tend to trust sources with negative and value-based attitudes towards biotechnology. Similarly, Sadler and Zeidler (2004) found that a group of students tended to interpret genetic engineering issues as moral problems. Marris (2001) focused on revealing widely held myths that influence the acceptance of GM products. These myths are accepted as self-evident despite rarely being based on scientifically demonstrable risks (Tait, 2001). Researchers therefore have voiced the need to educate the public by facilitating the interpretation of information about GMOs from a more scientific perspective (Marris, 2001; Tait, 2001).

Unfortunately, as discussed above, the unscientific approach of mass media on the public debate concerning scientific/technological developments has made developing a scientifically literate population more difficult and complex. As argued by Levitt, 'the culture, as well as the frankly commercial purpose, of newspaper publishing creates a filter that selects stories – and emphasizes elements within stories – that do not accord with scientific judgment or the reality of scientific work' (Levitt, 1999, p. 231). Consequently, to make more informed decisions about SSI, students need to appreciate the basic science and scientific enterprise underlying the issue.

Argumentation in science education

In the last few decades, there has been a growing number of reform efforts aimed at establishing inquiry-based instructional practices focused mainly on developing contemporary views of science that are consistent with the process of current scientific knowledge building (AAAS, 1993; National Research Council [NRC], 1996; Osborne, Erduran, & Simon, 2004). Thus, these reform efforts have emphasised the need for a 'philosophically valid science curriculum' (Hodson, 1988) to develop learners' more authentic epistemological views of science. Berland and Reiser (2009) summarised these inquiry-based programmes in two contexts: (1) using data and scientific conceptions to build scientific explanations or models about the phenomena under study; (2) engaging in argumentation, including scientific discourse, about the topic. In this view of science and science learning, students act like scientists and learn how to generate and validate scientific knowledge through engagement in the process of testing, revising and building sophisticated explanations (Berland & Reiser, 2009; Kuhn, 2010). Engaging in such activities requires opportunities to create arguments about the reasons and criteria used for choosing one explanation over another, as well as in discussion about the role of evidence in their explanations (Sandoval & Morrison, 2003). Consequently, a vast body of literature supports the idea that using models, making scientific explanations and participating in 'epistemic discourse' (Christodoulou & Osborne, 2014) to support claims within a community are essential practices of authentic inquiry (Berland & Reiser, 2009).

In argumentation, as an epistemic discourse, students struggle to build and support claims with evidence and reasoning which requires the use of criteria for the selection and evaluation of evidence and finally, to persuade others of their ideas (Berland & Reiser, 2009). Thus, argumentation-integrated practices provide students with various opportunities to develop epistemological beliefs about the nature of science understanding and to view science as an epistemic discourse (Duschl, 2008; Duschl & Osborne, 2002).

However, how to include discourse practices in science classrooms and model the process of authentic science is a fundamental concern of science-related research communities (Bell & Lederman, 2003; Duschl & Osborne, 2002). Many studies (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000) have utilised Toulmin's Argument Pattern (Toulmin, 1958) to overcome the difficulties that students encounter during discourse practices. These include arguing and building qualified explanations and sharing them within a community. Toulmin's model (1958) begins with a *claim* as a 'conclusion whose merits we are seeking to establish' (p. 90) which is verified by relevant *data or evidence*. The *warrant* that forms the substance of the justification for the claim is utilised to strengthen relations between the evidence and the claim. The *backing* is statements that serve to support the warrant. Finally, the validity of claims may be limited by the use of *qualifiers*.

Because of its relative simplicity, Toulmin's model has formed the basis of schemas used in many studies for analysing student discourse and designing learning environments which more closely resemble the core practice of the scientific community (Osborne, Erduran, & Simon, 2004). Nevertheless, in a recent study introducing a three-tiered learning progression for scientific argumentation, Osborne et al. (2016) claimed that although Toulmin's (1958) model has provided a main pattern for argumentation, it is not sufficient. Many other attempts were also made based on this claim. For example, Berland and Reiser (2009) identified three goals to design and analyse the interventions of argumentation: (1) sense making, (2) articulating and (3) persuading. They found that students consistently use evidence to specify phenomena and to clarify their understanding, but they do not consistently include the third goal of persuading others of their understandings. The authors attributed this finding to a lack of social interaction. Thus, they proposed that further research could design strategies addressing the social challenges inherent in the discourse practices of argumentation.

For this challenge, Golanics and Nussbaum (2008) proposed collaborative argumentation as an educational context in which question prompts are used to remind students of various arguments. They argued that these practices help students analyse relationships between ideas, change their conceptions to more scientific ones and deliberate on the meaning of evidence for claims. According to Berland and Reiser (2009), students should be encouraged to engage in collaborative discourse and argumentation, and teachers should also create an environment that provokes students to generate more questions, requests for justification and evidence, and attempts at persuading others of their understanding. Ge and Land (2004) also used question prompts to direct students' attention to key points of a problem, help students to construct arguments grounded in evidence and guide the peer problem-solving process.

Argumentation in SSI

In addition to the above suggestions, many other studies have also highlighted the importance of SSI in improving learners' reasoning, argumentation skills and decision-making processes by providing them with social dilemmas with scientific/technological features (e.g. Dawson & Venville, 2010; Foong & Daniel, 2013; Gray & Bryce, 2006; Sadler, 2009). SSI are defined as a 'developed pedagogical strategy' (p. 360) by Zeidler, Sadler, Simmons, and Howes (2005). According to Zeidler et al. (2005), SSI have a strong potential to engage learners in epistemic discourse and help them construct more scientifically valid decisions. Many studies also suggested that while making decisions through socio-scientific argumentation, learners should be motivated to demonstrate skills in evaluating the pros and cons of the controversial issue, arousing social debate. Moreover, learners should face the multi-dimensional (i.e. social, political, economic and ethical) nature of the issue (Oulton, Dillon, & Grace, 2004; Sadler & Zeidler, 2004).

Integrating socio-scientific argumentation into science education is also a primary objective of the Science, Technology and Society framework to link understanding of science content to social justice (Solomon, 1992). In Turkey, SSI have a place in the recent 'Grade 3-8 Science Curriculum' under the 'Science-Technology-Society-Environment' framework, where the emphasis is that students should get scientific and moral skills to solve SSI (MoNE, 2013). SSI also involve suitable contexts for students to actively reflect on and argue about dilemmas (Christenson & Chang-Rundgren, 2015) and develop students' skills in reflecting critically on their own values and stances (Oulton et al., 2004). That is, SSI create a discussion platform to facilitate and demonstrate students' argumentation skills, which also facilitates a more authentic comprehension of the scientific process (Sadler & Zeidler, 2005; Walker & Zeidler, 2007).

In the present study, considering the aforementioned difficulties and barriers to performing qualified argumentation and developing a scientifically literate citizenry that can think rationally and systematically (Peters-Burton & Baynard, 2013), it was a struggle to develop and implement an argumentation-integrated programme that could address all our concerns. Our programme included collaborative discourse in which pre-service teachers (PSTs) participated in screening and investigating scientific reports, discussed them with teammates, built shared group reports and made shared decisions about the dilemmas (Appendix) provided by researcher(s) as prompts. In addition to the collaborative discourse process, PSTs also shared ideas and decisions generated throughout their discourses with other PSTs and academic staff via two mini-symposium sessions and a poster exhibition.

Using socio-scientific argumentation in promoting scientific literacy

In the report of OECD (2001), it was emphasised that developing people's ability to engage in critical thinking and logical decision-making about controversial issues is a primary purpose of international science education. Moreover, in a review about the situation of science education in Europe, Osborne and Dillon (2008) pointed out that students should be taught to be 'critical consumers of scientific knowledge' (p. 8) rather than passively accepting information from others or mass media or even in scientific documents or texts. In this study, thus, we tried to promote a right value perception of the PSTs towards the scientific enterprise as the most valid way of producing reliable knowledge. Of course, to build a conceptualisation of science complying with contemporary view of science, we need to educate scientifically literate students who have not only the subject knowledge that science provides, but also understanding about the intellectual activities in which scientists engage (AAAS, 1993; NRC, 1996; Scottish Executive Education Department [SEED], 2006). That is, scientifically literate students have a right value perception and understanding about the scientific enterprise, as it provides a rational framework on which to evaluate SSI (Peters-Burton & Baynard, 2013). In this regard, Liu, Lin, and Tsai (2011) suggested that to prepare students to be scientifically literate, science teachers should not only handle the complex interactions of science, technology and society but also engage students to the process of socio-scientific argumentation.

Summary

Recent science curricula in Turkey as well as many other countries such as South Africa (Erduran & Msimanga, 2014), China (Wang & Buck, 2015), the UK (Simon, Erduran, & Osborne, 2006), Malaysia (Heng, Surif, & Seng, 2015), and so on, have called for the integration of more argumentation practices. In the elementary science curriculum in Turkey, scientific argumentation is seen as an inquiry-based activity that leads to the development of scientific explanations (Ministry of National Education [MoNE], 2013). Therefore, argumentation is a central goal of science education because of its process, which includes the epistemic, conceptual and social aspects of scientific enterprise (Duschl, 2008). To demonstrate this process, science teachers should focus on how scientists know what they know, and they should design structured activities for students to help maximise their level of participation in scientific argumentation as well as encouraging students to criticise alternative explanations or make evidence-based decisions (Heitmann, Hecht, Schwanewedel, & Schipolowski, 2014). Thus, science teachers have a responsibility to provide students with insight into how science works by the use of 'dialogic knowledge-building processes' which promote argumentation inside the classroom (Kuhn, 2010). However, this may be particularly challenging for teachers if they do not have adequate experience in engaging students in scientific inquiry and argumentation (Windschitl, Thompson, & Braaten, 2008).

As a consequence, we (as educators or/and researchers) should notice that pre- and in-service teachers are largely lacking in practical experience regarding the scientific community and scientific enterprise (Duschl & Osborne, 2002) since scientific knowledge has generally been presented in schools from primary to university as strict explanations rather than scientific arguments to predict phenomena, generate and test hypotheses or ideas (Windschitl et al., 2008). In this case, we should consider how to educate current and future teachers and how to give them more authentic science perspectives. In her recent paper, Erduran (2015) argued that the international science education community must design heuristics including more authentic representations of the complexity of the scientific process approximating the epistemic, cognitive and social–institutional dimensions of science. Following this trend, to reveal how students learn and make decisions about controversial issues, the relationship between scientific enterprise, thinking and argumentation has become an important area in educational research (Chang & Chiu, 2008).

Therefore, in this paper, we designed and applied a three-stage argumentation for PSTs to form more scientifically reasoned decisions about risk perceptions of GMOs rather than passively accepting any information they come across. In this study, the term 'argumentation' refers to argumentative collaborative reasoning, discussion and decision-making processes in small groups, and more specifically, to the quantity and quality of the pros and cons, which we see as an essential part of argumentation and reasoned views (Kuhn, 2010).

Rationale, aim and research questions

As can be seen from the critical review of the literature presented above, simply having scientific knowledge about GMOs may not be enough to develop a scientific perspective with respect to risk perceptions of GMOs. It may also be said that if individuals only have access to the final product of the scientific process, their risk perception of and negative attitudes towards GMOs will likely not show remarkable development in a positive direction.

On the other hand, some risk analysts suggest that to meet the needs of modern industrial societies, the current vicious cycle of negatory approach towards controversial SSI such as GMOs, which could easily paralyse all future scientific and politic efforts to correct deficiencies and flaws, should be moderated. To this end, people should be supported to develop a more balanced scepticism about GMOs (Tait, 2001). To facilitate the development of reasonable suspicion of the possible damages of GMOs to human health and the environment, we can show people the importance of scientific proof and contribute to improving the confidence in the scientific process. According to Simon, Erduran, and Osborne (2006) discussion about controversial ideas is essential to revealing the underlying rationality that is at the heart of the scientific process.

Consequently, we hypothesised that when individuals are familiarised with the process of scientific knowledge building, their scientific perspective and confidence in science and the scientific process can be affected positively, and therefore, their risk perceptions of GMOs can change to a more reasonable and scientific perspective. To this end, our scope in this study, was to design and implement an argumentation-integrated course giving PSTs opportunities to exercise the process of scientific knowledge building that characterises the work of scientists; therefore, we aimed to facilitate the development of a more scientific perspective of PSTs regarding risk perception of GMOs.

Our study specifically addresses the following questions:

1. Is there a significant difference between experimental and comparison groups' pre- and post-test mean scores in terms of risk perception of GM foods?
2. How do the PSTs in the experimental group apply their understanding of GMOs to make decisions, and what is their skill level in citing pros and cons to defend their arguments before and after the course?
3. Do the PSTs' perspectives about the nature and value of scientific knowledge and scientific process develop throughout the argumentation-integrated programme?

Thanks to the reports and group processes ending with a mini-symposium and poster presentation with the participation of all groups, we expect to develop PSTs' ability to formulate what information is scientifically more useful and relevant as pros or cons for their arguments. Thus, the PSTs' understanding of GMOs may go beyond simply accepting information encountered in some way or another, and therefore, PSTs may take on a more scientific perspective.

Educational contexts

The process of course activities carried out in experimental and comparison groups and the purpose of each are described below.

Argumentation-integrated activities in the experimental group

In the course described here, over a sustained period of three-times-weekly class sessions for eight weeks, we focused on eight sub-topics of GMOs that PSTs engage with throughout the course: GMOs in plants, animals, medicine and pharmacology, the impact of GMOs in terms of socio-economics, the environment, human health, GMOs and biosafety, and the ethics of GMOs. The experimental group was divided into eight heterogeneous groups, and then each group chose one of the eight sub-topics. The discourse of each group began with evidence-based discussion and reasoning on a dual-position expository text (see Appendix) about the benefits and risks of their particular sub-topic. Dilemmas provided by the author include the diverging views of the two scientists about GMOs. The inclusion of the dilemmas was aimed at developing the PSTs' views about the empirical, subjective and tentative aspects of science.

In this study, the controversial nature of GMOs as a socio-scientific issue provided us with opportunities to frame discussion sessions and writing assignments in which students could develop awareness of the scientific status of their statements or claims. A three-stage argumentation-integrated programme based upon Foong and Daniel's (2013) argumentation model (see Table 1) was followed in the experimental group:

(1) *Analysing information phase*: First, the researcher(s) made a general presentation of information about GMOs. Then the PSTs gathered information individually from printed and online sources (e.g. newspapers, books and journals) about the sub-topic that they had chosen. Then they prepared an individual report including a decision and the key concepts within the information they had gathered individually.

Table 1. Stages followed in the process of argumentation (from Foong & Daniel, 2013, p. 2336).

Stages	Tasks
Analysing information	• Read information from mass media • Listen to oral information from peers during dialogical argumentation • Identify key concepts within the abundant information • Break down abundant information into smaller segments (i.e. pros and cons, causes and consequences)
Evaluating evidence	• Consider the causes and consequences • Predict the impact of various decisions based on personal experience, values or collected information • Prompt peers for clarity • Probe for integrity of the source of information
Generating and presenting an argument	• Generate an informed decision and present the decision to audience • Articulate reasons to defend the decision

(2) *Evaluating evidence phase*: The PSTs began to evaluate the causes and consequences of the decisions that they had made individually and discussed them with their teammates. In order to foster group argumentation activities, the issue-related dilemmas (i.e. sub-topic of each group) were designed for each group to make their common claims and justify them by providing evidence or evaluating alternative arguments. Dilemmas were given to each group when they sat down in groups and argued on two different theses about the sub-topics of GMOs. Each group was expected to decide on the future use of GMOs.
(3) *Generating and presenting arguments phase*: This final phase involved the PSTs' final arguments based on their experience, interaction with teammates, values and collected information. They wrote a final report, and later, they were asked to write a petition to a relevant government institution including reasoned discussion of the sub-topic of their group. Additionally, over the following two weeks, each group presented their sub-topic to the whole class, and a researcher-guided whole-class discussion was conducted. During the final week, a mini symposium and a poster exhibition about the potential risks and benefits of GMOs were also held with contributions from each group. At the mini symposium, one of the group members was selected as an 'expert' speaker by each group. And in the last week of the study, the mini symposium was held in two sessions, morning and afternoon.

Thanks to these three phases, students put forward reasons as pros and cons to present and defend their decisions. As a result, having accomplished the three stages, the PSTs were theoretically able to more scientifically consider underlying causes of GMO applications.

Teacher-oriented discussions in comparison group

In the comparison group, firstly, the researcher(s) made a general presentation of information about GMOs as in the experimental group. Then, during each of the eight subsequent weeks, the teacher oriented whole-class discussions on one of the GMO sub-topics listed above. Furthermore, they were asked to study the sub-topic that they would discuss during each subsequent week.

Research design and methods

In this study, both quantitative and qualitative methods were utilised. The quantitative phase focused on the determination and comparison of control and experimental groups' risk perception of GMOs by non-equivalent groups' pre-test–post-test quasi-experimental design (McMillan & Schumacher, 2001). In the quantitative phase, 'the risk perception of GMOs scale (pRGMOs)' was administered as a pre- and post-test. To illustrate the quantitative findings about the PSTs' risk perception of GMOs, the study was supported with qualitative data.

The qualitative data were collected only from the experimental group by individual and group reports as well as a questionnaire including six open-ended questions about their final thoughts on the argumentation-integrated course and the effects of the course on their scientific perspective. Individual and group reports provided a valuable source to examine and compare the PSTs' level of using scientific approach regarding GMOs in individual and group settings. The qualitative data were analysed by the deductive and inductive content analysis approach (Patton, 2002) process, which is explained below.

Participants

Totally, 101 pre-service elementary teachers (65 females and 36 males) in their third year from two distinct classes at a public university in a south-east region of Turkey participated in the study. Participants were divided into two groups: experimental ($N = 49$) and comparison ($N = 52$) randomly selected in a science methods course which was compulsory in their third year. They had completed their compulsory science content (General Physics, Chemistry and Biology) and laboratory courses in their first two years.

Data collection instruments

During the data-gathering process, quantitative data were collected through 'pRGMOs' developed by Sönmez and Kılınç (2012) implemented as pre- and post-test. The scale consists of 26 six-point Likert-type items in which PSTs set their preferences from 1 = none to 6 = extremely high (2 = very low, 3 = low, 4 = moderate and 5 = high). Reliability and Cronbach's alpha of the scale were calculated at 0.79, which was found to be reliable.

In the qualitative phase, data were collected only from the experimental group via individual and group reports as well as a questionnaire including six open-ended items attempting to determine their final thoughts about the educational context practised throughout the study.

Data analysis

The quantitative data were analysed using the statistical software SPSS 20.0. Owing to the normal distribution of data in variables, which was tested by the Kolmogorov–Smirnov test, suitable *t*-test procedures (independent and paired sample *t*-tests) were used to identify the differences between experimental and comparison groups' mean scores. Furthermore, in order to calculate practical significances, Cohen's *d* was used. In order to show relative values of the responses, means and standard deviations were also reported.

As for the analysis of qualitative data, first, we analysed the distribution and the numbers of the pros and cons written by PSTs in their individual and group reports. Later, we used deductive and inductive content analysis approaches, respectively. Thus, we aimed to examine and compare the PSTs' decisions and interpretations on GMOs in their writings before and after the argumentation-integrated education programme.

Hsieh and Shannon (2005) divided the deductive content analysis into two approaches based on the degree of involvement of deductive reasoning. The first is the directed content analysis approach, which focused on a priori defined key concepts. In this study, first, we searched words and statements referring to 'science,' 'scientific,' 'thinking' or/and 'research' among individual and group reports as well as open responses to the questionnaire. We chose those (science, scientific, thinking or/and research) key concepts because they might give proof of the first and the last state of the PSTs' scientific perspective. We checked and compared statements referring to science, scientific, thinking or/and research used by the PSTs in their individual or group reports and open responses to the final questionnaire. For this purpose, the collected documents were carefully read by three experts, and the relevant excerpts were selected as proof.

The second approach used, by Hsieh and Shannon (2005), is summative content analysis, which starts with the counting of words or manifesting content. As stated by Hsieh and Shannon (2005), summative content analysis approach looks quantitative in the early stages, but its goal is to explore the usage of the elements in an inductive manner. In this study, the number of reasons given as pros and cons is at the centre of the analysis of the PSTs' argumentations as filtered from individual and group reports. In order to compare the initial and final state of the PSTs' scientific perspective, the number of reasons gathered from individual reports was handled as a preliminary data set, and group reports were handled as a final data set. In the context of GMOs, the PSTs were expected to include at least one pro and one con on their individual or group reports. The average number of scientific reasons listed as pros and cons was evaluated as the key difference between individual and group reports. For example, two PSTs' expressions show how they included both pros and cons in their individual reports:

- ….although the large seed companies (producing GM crops) *claim* that GMOs do not have any effect on health and the environment, there are many study reports proving the contrary (*male-1, GMOs in plants*).
- Although GMOs are *claimed* to have economic advantages, it is foreseen that it will lead to economic injustice for middle and small corporations (*female-1, GMOs in plants*).

In the inductive phase, we analysed the PSTs' passages derived from individual and group reports and the PSTs' open responses to the final questionnaire. The goal of this step was to analyse similarities as well as differences in the PSTs' writings individually or collectively. Besides the qualitative content analysis, we computed and presented the descriptive statistics to compare the frequency of the occurrence of identified elements in the students' answers.

Results

In this section, we focus specifically on how PSTs' forms of reasoning and decisions on perception of risk about GMOs changed over time, and on the conditions that supported these changes.

Quantitative results

Mean scores and standard deviations of pre-interventions are presented in Table 2. In order to determine whether experimental and comparison groups were equivalent or not in terms of risk perception of GM foods, an independent sample *t*-test was conducted on pre-intervention scores of pRGMOs, and no significant difference between

Table 2. Pre-intervention scores on pRGMOs scale for control and experimental groups.

Group	Mean	*SD*	*N*
Experimental	5.03	0.39	49
Control	4.96	0.46	52

experimental and comparison groups was found ($t(199) = 0.87$, $p = .38$). However, Cohen's effect size value ($d = .175$) suggested a low practical significance.

Table 3 displays together the mean scores and standard deviations obtained before and after the intervention. An analysis of paired sample *t*-tests of pre- and post-intervention mean scores of the two groups showed that there was a significant difference between the pre- and post-intervention of each group ($t_{\mathbf{exp.}}(48) = 22.72$; $p = .000$; $t_{\mathrm{comp.}}(51) = 8.26$; $p = .000$). Furthermore, the effect size values for both the experimental group ($d = 3.245$) and the comparison group ($d = 1.145$) suggested high practical significance. That is, in both groups, a significant decline occurred in terms of risk perception of GM foods.

However, if we look for decreases of experimental and control groups' mean scores of pre- and post-interventions (experimental group = −1.38; control group = −0.51), a more dramatic decline can be seen in the experimental group than in the control group Figure 1.

The significance of the difference between the two groups' decrease in risk perception was tested by an independent sample *t*-test procedure, and a significant difference ($t(99) = -11.90$, $p = .000$) was found. Also, Cohen's effect size value ($d = -2.393$) suggested a high practical significance.

Qualitative results about risk perception of GMOs

The number of pros and cons on individual and group reports of PSTs was identified and is presented in Table 4. The statements exemplified below show that positive results based on research on GMOs were evaluated as subjective opinions or findings and were not simply taken as true, while scientific results related to the risks of GMOs were stated as the truth. When many other explanations of the PSTs, including pros and cons about GMOs, were examined, a negative bias emerged:

- It *is claimed* that the lack of sources and need for more economic products are important reasons to produce transgenic products *(male-1, socio-economic impacts of GMOs).*
- …. *It is claimed* that thanks to GMOs, more crops can harvested cheaply …. because of using less pesticide during production *(male-2, GMOs in plants*).
- *Although* it was said that GM crops *may eliminate* the problem of hunger which will occur in the future, *it is clear* that they will *affect* human health adversely in the long run (*male-2, GMOs in plants).*
- *Supposedly*, with gene transfer to cotton from different species, more efficient and resistant transgenic cotton plants could be obtained (*female-*1*, environmental impacts of GMOs).*
- Because of the *suggestion* that the transgenic products are resistant to diseases and insects … an increase was expected in the agricultural productivity (*female-2, environmental impacts of GMOs).*

Table 3. Pre- and post-intervention scores on pRGMOs scale for control and experimental groups.

Group	Mean	*SD*	*N*
Pre-Exp.	5.03	0.39	49
Post-Exp.	3.65	0.28	49
Pre-Control	4.96	0.46	52
Post-Control	4.45	0.38	52

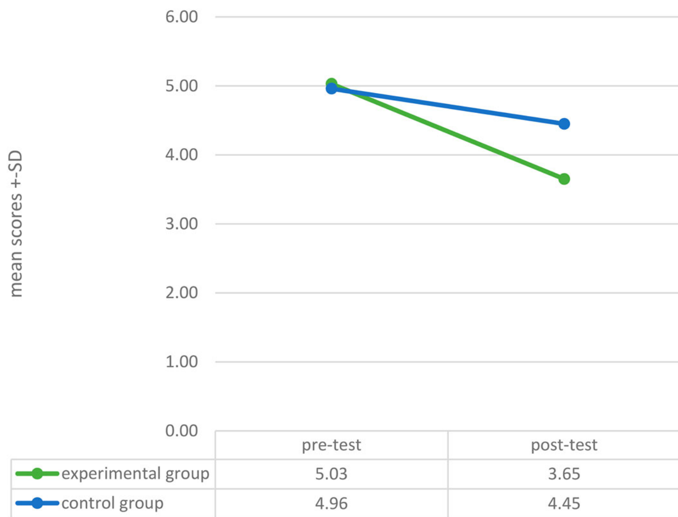

Figure 1. Experimental and control groups' pre- and post-test mean scores on pRGMOs scale.

- *Although* it is mentioned that there are positive aspects of GMOs such as increasing the yield and conferring resistance to pests, for me the most important thing is human health, and so why do we produce GM crops since we do not know what they might cause in the future? (*female-2, GMOs in plants).*
- -Although legal arrangements to prevent the negative consequences of GM crops was made, those arrangements *will not be enough*, because of uncertainty of risks (*female-1 GMOs and biosafety).*
- However, recent research *indicated* that (*male-2, GMOs in plants)*
- … Nonetheless, the use of pesticide *increased* twice and the use of herbicide *increased* 27-percent, and also productivity *decreased* at the same period in Argentina (*female-*2, *environmental impacts of GMOs).*
- Because of gene escape … *has become impossible* (*female-2, environmental impacts of GMOs).*

Table 4. Numbers of pros and cons mentioned individual and group reports.

	Individual report			Group report		
Groups	Mean (Pros and Cons together)	Mean (benefits only)	Mean (risks only)	Mean (Pros and Cons together)	Mean (benefits only)	Mean (risks only)
GMOs in plants ($N = 6$)	0.50	2	4.50	2	5	4
GMOs in animals ($N = 7$)	0.66	2.83	4.33	3	2	4
GMOs in medicine and pharmacology ($N = 6$)	0.35	1.66	3.16	1	2	3
Socio-economic impacts of GMOs ($N = 6$)	1.33	1.83	6.33	4	2	3
GMOs and biosafety ($N = 6$)	0.5	1.25	4	1	2	4
Environmental impacts of GMOs ($N = 6$)	0.62	1.4	4.5	2	2	3
The effects of GMOs on human health ($N = 6$)	1	2.33	2.88	2	3	2
GMOs and ethic ($N = 6$)	0.5	2.2	3.5	2	4	5
Mean ($N = 49$)	0.67	1.94	4.15	2.12	2.75	3.5

The expressions such as 'it is claimed'; 'supposedly' *or* 'although' presented above suggest the PSTs' doubts about the benefits of GMOs. On the other hand, the sureness and trust they felt about the negative findings, including the risks of GMOs, may also be seen by careful examination of what they wrote in their individual reports (e.g. research *indicated* that, the use of herbicide *increased*, productivity *decreased* or *has become* impossible). The expressions implying the PSTs' feeling of distrust in scientific results regarding the benefits of GMOs were determined to have a percentage of 37 in the individual reports. Similarly, the expressions implying the PSTs' feeling of sureness about risks of GMOs were also determined to have a percentage of 83 in the individual reports.

On the other hand, in the group reports, we rarely reached similar conclusions about a higher or lower sense of confidence towards research on the risks or benefits of GMOs. As can be seen in the following examples, an objective and reasonable style of statements was much more common in reporting research findings with reference to both the risks and benefits of GMOs:

- ....Results of this study *found* that the use of GM seeds reduced the use of agricultural pesticide at a rate of 8.4% (*GMOs in plants*).
- The poisonous secretions that GM plants produce against pests *can pass* through soil and damage other species, too (*environmental impacts of GMOs*).

In the group reports, which were written commonly by each group in the framework of shared decisions, certain expressions were identified and numbered, including pros and cons together or separately and presented in Table 4. Both negative and positive opinions of the groups were based mainly on scientific findings. In addition, an effort to balance the pros and cons of GMOs in the group reports can clearly be seen:

- When the studies of various institutions and researchers are examined, it can be seen that there are contradictory reports concerning the effects of GMOs on human health and the environment. While discussing the risks and legal regulations of GMOs, developing strategies estimating economic profits, risk of external dependency and works to diminish aforementioned risks should be considered *(socio-economic impacts of GMOs*).
- The benefits and risks of biotechnological applications should be explained to the people with a scientific and objective language (*GMOs and biosafety*).
- We do not ignore the benefits of GMOs, but because of some unethical aspects of producing GM crops, we do not find it completely appropriate and do not defend its all applications. For us, in order to satisfy basic needs, without damaging humankind and the environment, a balance should kept in the use of GMOs (*environmental impacts of GMOs*).

Despite the PSTs' disapproval of GMOs in their individual reports, they left the door open conditionally for the application of GMOs at the rate of 45% ($N = 22$):

- The world population is growing rapidly and as a result, need for food increased, so in order to meet this need, GMO applications are seen as mandatory. However, the negative effects of these applications on human life should be overcome ((*female-1, socio-economic impacts of GMOs*).

In the individual reports, the most important concern of the PSTs who left the door open for using GMOs conditionally (45%; $N = 22$) was human health. In other words, they thought that GMOs could be used if its risks on human health were minimised (46%; $N = 10$). Other concerns occurred less often, including harm to the environment (23%; $N = 5$), protecting natural species (18%; $N = 4$), and disappearance of small-sized enterprises (13%; $N = 3$):

- In genetic studies, it is likely to create unexpected species in the future due to continuous altering of genes. Hence, it is necessary to map genome of the species whose genetic is altered, and to conserve its natural seeds (*male-3, Environmental impacts of GMOs*)
- … another reason is the risk of dependency on the large companies that produce transgenic seeds. This will eventually become an enormous economic burden for those countries and farmers who do not have this technology (*male-2, GMOs in plants*)

The majority (54%; $N = 12$) of the PSTs, who stated in their individual reports that GMOs could be used in some areas (45%; $N = 22$), emphasised that this technology should not be used in the food sector:

- I find using GMOs in plants and animals to provide food wrong because it causes severe illnesses such as cancer. It should be used only in curing the diseases (*female-1, GMOs in plants*).
- I do not want these [GMO food] products come into my life. Nonetheless, it may come into some areas like medicine, and so on (*male-2, GMOs in animals*).
- … Yes, it can be said that GMOs may have some benefits. But, because its risks and harms are many times more than its benefits, I do not want to consume these [food]. Therefore, GMOs should be applied only to specific areas such as pharmaceutical products and insulin (*female-2, the effects of GMOs on human health*).
- Except for the pharmaceutical industry, I do not think that GMO and its products can be a solution for any problems that are discussed in public (*female-2, GMOs and Biosafety*).

Similar interpretations and recommendations were found in group reports as well:

- Rather than completely refusing GMOs, their area of use can be limited. In the light of the points we mentioned above, we support this technology to be used in medical applications, but we believe that its use in food is dangerous (*the effects of GMOs on human health*).

The interesting point is that although seven groups left the door open for using GMOs conditionally, the group that worked on the sub-topic 'GMOs and ethics' emphasised that GMOs should never be used at all:

- Even if it aims at medical goals, unnatural intervening in genes with biotechnological applications affects natural life and thus human life negatively. Also, it may lead to irreversible consequences. For example, it would be more proper if the authorities try to eliminate GM foods and additives causing diabetes instead of producing cheaper insulin with biotechnological applications to cure diabetes. … Thus, biotechnology should not be sacrificed for economic and political profits.

The remaining seven groups generally emphasised taking precautions against its risks as well as the necessity of not being kept behind in biotechnology for our country. Moreover, development in outlook towards science, being scientific and the scientific process can also be seen from the statements in these reports:

- [under the obligatory circumstances] Turkey should develop itself in biotechnology and produce them by itself instead of buying and using these products. For this, the number of master and doctorate programs and of students in these programs should be increased besides the number of research (*GMOs in animals*).
- … the abundant biodiversity in Turkey should be considered. On the other hand, those people who has counter-arguments on GMOs should avoid exaggerated comments. For instance, there is no natural relatives of the transgenic cotton, soybean and corn, which are commonly grown around the world, in Turkey. Therefore, they argue passionately that the GMOs should never be produced in Turkey, they should declare perceptibly what kind of catastrophes may emerge by producing GMOs (*Environmental impacts of GMOs*).
- When considered with respect to Turkey, it would be more suitable to conduct necessary [scientific] studies and address more details on [the risks and benefits of] this issue without staying out of GMOs technologies at the current stage (*GMOs in plants*).

Qualitative results showing the decrease in PSTs' risk perception of GMOs, presented in Table 5, support the results obtained from the application of pRGMOs as well.

Understanding of the nature and value of scientific enterprise

The data gathered from the open-ended questionnaire provided important clues in terms of the development of the PSTs' scientific perspective. In the questionnaire, PSTs were asked six open-ended items attempting to determine their final thoughts about the educational attainments of the argumentation-integrated programme practised throughout the study. Thanks to the analysis of the PSTs' open responses, we obtained some important clues regarding the development of their understanding about scientific knowledge and scientific process. As a result of the analysis, four categories were determined, in which the PSTs' conceptualisation of scientific process was clustered. These categories are *open-mindedness*, *participation*, *cognitive operations* and *affective elements* (see Tables 6 and 7).

The following responses by two PSTs to the questionnaire provide evidence of the effects of the programme on their scientific perspective:

- In the beginning, I had prejudices about the deficiency of laws or laws being not enforced. However, I realized that there are many legal regulations, and they should

Table 5. Change in the statements of the PSTs about their general understanding of GMOs.

From	To
• Incomprehensive knowledge	• Comprehensive knowledge
• More speculative knowledge	• Obtaining more objective understanding by analysis and synthesis
• View from a narrow perspective	• Having trust towards legal regulations
• Being suspicious towards legal regulations	• Conditional acceptance of GMOs, duo to
• Mostly negative opinion	• Diminishing of natural resources
	• Rapidly increasing need for food
	• Need for the treatment of diseases
	• The risk of exposure to economic woes

be improved after the individual and group *investigations (female-2, socio-economic impacts of GMOs).*

- I used to hear about GMOs, but didn't have much idea what it is. Therefore, the thoughts like 'something harmful' were used to come to my mind whenever I heard it. I started to look at it with a wider perspective after examining the topic multi-dimensionally during this study (*male-1, GMOs in plants*).

The results also showed that the preparation and presentation of group posters and mini-symposium sessions positively affected the PSTs' awareness regarding satisfaction provided by generating and sharing scientific information. Expressions about the process of the course show that the course activities affected their motivation positively in regard to being a researcher as well as having a scientific perspective:

- To inform people gave me an emotional satisfaction and made me happy. This feeling of satisfaction encouraged and motivated me to continue post-graduate education (*female2, GMOs in animals*).
- It was a nice feeling for me to inform people about GMOs (*male-2, GMOs and ethic*).

Table 6. Some clues implying PSTs' conceptualisation of the process of scientific knowledge building, extracted from their ideas regarding the contributions of collaborative discourses.

Categories	Open-mindedness	Participation	Cognitive operations	Affective elements
Codes	• Openness to different views and opinions	• Sharing different points and ideas	• Using rebuttals warrants and backings in argumentation	• Feeling like a researcher
	• Respect for different ideas	• Sharing tasks	• Gaining critical thinking and questioning	• Feeling a sense of responsibility
	• Supporting free thought	• Producing shared purpose, outputs and decisions	• Thinking and reasoning based on evidence	• Desire to research
		• To help the learning of each other	• Evaluating pros and cons together	• Being aware of and more sensitive to what is going on
		• Creating a culture of debate	• Developing more objective viewpoint	• Gaining the courage to self-expression
		• Listening actively	• Utilising the rules of logical reasoning	
		• Combining knowledge and experiences	• Considering scientific ideas	
			• Reinforcing and internalising knowledge base	

Table 7. Some clues implying PSTs' conceptualisation of the process of scientific knowledge building, extracted from their ideas regarding the contributions of mini-symposium sessions and poster presentation.

Categories	Participation	Cognitive operations	Affective elements
Codes	• Sharing opinions with others	• Using different resources	• Happiness of sharing ideas
	• Opportunity to inform/ raise awareness of the audience	• Analysing critically both pros and cons of the issue	• Feeling proud of making an important study
	• Defending the [arguments] in front of the audience	• Contributing the audience to see and consider the issue from eight different perspectives	• Feeling proud of creating concrete and original products
		• Presenting GMOs in a scientific approach	• Satisfaction of informing the audience
		• Ability to express ideas	

- Presenting scientific knowledge and understanding what we have learned in this process made me happy (*female-1, GMOs in medicine and pharmacology*).
- This event [mini-symposium] gave me the feeling that our works were appreciated and noticed (*female-2, socio-economic impacts of GMOs*).
- This event [mini-symposium] is a concrete manifestation of our labor and works (*female-2, GMOs and biosafety*).
- This event [mini-symposium] was a source of pride for me (*female-2, GMOs in medicine and pharmacology*).
- The discussions which were made during activities contributed to the development of my social responsibility (*male-3, GMOs in plants*).
- We informed the people. These activities allowed us to reach people and share our ideas with them (*female-2, GMOs in animals*).

In addition, the emphasis on the scientific perspective and scientific language, which provided clues concerning the change of PSTs' reasoning approach towards more scientific ones, is clearly evident in their responses to the final questionnaire:

- We had the opportunity to inform people about a scientific perspective about an important issue (*female-1, GMOs in plants*).
- We introduced people with a more scientific approach concerning GMOs (*male-3, GMOs and ethic*).
- These activities provided deepening our knowledge on the issue (*male-2, GMOs and biosafety*).
- Thanks to this study period in which we investigated the GMOs multi-dimensionally, I started looking at the issue from a broader perspective (*male-3, socio-economic impacts of GMOs*).
- I think the important features that make university education more significant than high school are to learn how to be able to discuss something in a constructive way and how to be able to produce something new. Those activities are one of the few studies that made me feel that I am an undergraduate (*female-2, GMOs in animals*).
- As a citizen, I provide opportunity to evaluate pros and cons of GMOs scientifically (*GMOs in plants-1, female*).

Discussion and conclusion

This study was aimed at investigating the development of PSTs' scientific perspective regarding their risk perception of GMOs through an argumentation-integrated education programme. The PSTs needed to formulate a line of reasoning as pros and cons based firstly on their individual knowledge and experience, and later, on group tasks including argumentation. In these tasks, we made an effort to simulate the scientific process, including the tasks of seeking, discussing, writing and sharing of knowledge, evidence and reasons.

In the following section, we first evaluate the results of the application of the argumentation process we used. Second, we draw conclusions based on the results of this research and discuss applications of the related literature.

Changes in risk perception

To address our quantitative research question, we conducted independent and paired sample *t*-tests on pre- and post-intervention mean scores of pRGMOs. According to the results, significant differences were found between pre- and post-intervention for both groups. However, we also found a sharper decline in post-intervention mean scores (see Figure 1) in the experimental group than the comparison group. To compare the groups' post-test mean scores, an independent sample *t*-test was conducted, which indicated a significant difference. These quantitative results perfectly suited the purpose of the study related to the development of the PSTs' scientific perspective. Namely, the average pre-test score was approximately *5 points,* which indicates a high perception of risk for the Likert-type scale used in this study. However, post-test mean scores were more or less *4 points,* which is a moderate level of risk perception of GMOs (see Table 3).

Consequently, the decrease in the mean scores at the end of the study can be read as the PSTs' risk perception of GM foods, specifically in the experimental group, evolving from a perspective based primarily on speculative information (Marks, Kalaitzandonakes, Allison, & Zakharova, 2002; Pardo, Midden, & Miller, 2002; Vilella-Vila & Costa-Font, 2008) to a more scientific and reasonable perspective.

PSTs' weighing of pros and cons

The examination of the reports written individually or in groups revealed that the PSTs used evidence to support their opinions about whether GMOs should be used or not, but in the individual reports, they generally tended to ignore or distrust the positive findings about GMOs. These results are similar to previous research which revealed a tendency towards negative perceptions about controversial issues (Curtis et al., 2004; Finucane & Holup, 2005; Klingeman & Hall, 2006; Lea, 2005).

In the individual reports, although a considerable number of PSTs (45%) used sceptical statements regarding scientific research which revealed the positive results of GMOs, we detected judgements (83%) implying certainty regarding the negative ones. These percentages and the fact that this kind of writing is rare in the group reports reinforce the idea that these types of statements demonstrate conscious decision-making.

The PSTs' biased and negative views about GMOs, in the first instance, might affect their confidence negatively in relation to the research revealed positive findings. The following statement by one particular male participant is very significant: 'I used to hear about GMOs but didn't have much idea what it is. Whenever I heard GMOs, an idea used to come to my mind about GMOs that they are something harmful.' This statement can be evaluated as an indication of the media's speculating and dramatising issues, which raise negative perceptions in society (Marks, Kalaitzandonakes, Allison, & Zakharova, 2002; Pardo et al., 2002; Vilella-Vila & Costa-Font, 2008). As stressed by Wong (2003), the demonising of GM foods by slogans such as 'Frankenstein foods' raises concerns among the public about GMOs. Moreover, this escalated risk-related concern may paradoxically prevent the development of more productive or less risky crops and complicate the work of policy-makers and government bodies who wish to engage in functional dialogue on the issue with other stakeholders (Tait, 2001). Thus, developing a more scientific perspective towards GMOs instead of strong 'knee-jerk' negative perceptions mainly based on incomplete, inaccurate and biased information is critical to controlling the activities of companies and giving more attention to Research and Development (R & D) works.

As for the group reports, we observed a clear effort to balance between the pros and cons of GMOs. In the group reports, an increase was also detected in the number of pros and cons in favour of the pros. Moreover, the proportion of getting together the pros and cons in the same context was increased in the group reports.

As suggested by Foong and Daniel (2013), if we ensure that participants are familiar with the context of the issue by actively engaging them in the practices and discourse of science, their arguments are likely to be more reasoned and well-grounded compared with those who are less familiar with the issues. We have detected that the PSTs reflected more reasoned and scientific perspectives in their final group reports than in their individual ones. They used a more reasoned style of language in reporting research findings with reference to the risks and benefits of GMOs. The PSTs developed a more successful scientific argument and reasoned style of language in the group reports. Therefore, we can suggest that the PSTs raised awareness of reasoned views and that therefore, they developed a more scientific perspective. As a consequence, after practising the process of scientific knowledge building that characterises the work of scientists, a change emerged in the PSTs' acceptance of GMOs in relation to the development of their views about the value of the process of scientific knowledge construction and knowing.

Approach to the nature and value of scientific enterprise

The qualitative analyses of the PSTs' open responses to the questionnaire and the reports they created demonstrate that practising the process of constructing and sharing scientific knowledge through argumentation-embedded activities promoted their appreciation, awareness and understanding of the science, scientific process and scientific knowledge. The PSTs' expressions, derived from their open responses to the questionnaire and final reports, put emphasis on 'scientific process' and were evaluated in this context. Moreover, the findings obtained from the questionnaire and the reports provide clues of a particular change in the PSTs' views about GMOs from a narrow and biased frame to a wider and more scientific frame. In the first instance, the PSTs were more suspicious of research concluding in a positive direction about GMOs. However, when we analysed the final group reports, we noticed that they generally used more objective, balanced and scientifically reasoned language in reporting the pros and cons as reasons for their decisions.

On the other hand, data gathered from the PSTs' answers to the open-ended questionnaire provided some important clues about their conceptualisations of the process of scientific knowledge building (see Tables 6 and 7). Results presented in Tables 6 and 7 show that the PSTs emphasised important elements of the argumentation process (i.e. evidence, rebuttals, warrants and backings), essential components of contemporary views of scientific enterprise (Duschl, 2008; Duschl & Osborne, 2002; Erduran, 2015). Furthermore, they used some aspects (i.e. objectivity, logical reasoning) which may be indicators of a positivist science perspective. That is, although the PSTs received no particular training in argumentation pedagogy in this study, they did use some important elements of the argumentation process. However, we also found some indication that the PSTs still had some thought patterns of the positivist paradigm, such as giving excessive importance to concrete evidence, objectivity and logical reasoning. As a consequence, as echoed by many studies (e.g. McDonald, 2010), if students are not given instruction, their Nature of Science (NOS) understanding does not develop sufficiently.

On the other hand, the idea of sharing scientific knowledge and understanding obtained through inquiries and debates in class discussions, the mini-symposium and poster presentation made them quite excited and emotionally satisfied. These events assisted the PSTs in making conscious decisions about GMOs and helped them to understand how science works and why we must trust scientific knowledge. As a consequence, the results discussed above refer to the development of the PSTs' views on science and scientific knowledge, and therefore, this result implies a development in their understanding of the nature of scientific knowledge (e.g. source and value) and the scientific process as suggested by Bell and Lederman (2003).

Conditional acceptance of GMOs

According to the findings obtained from individual or group reports, some PSTs had conditional acceptance of the application of GMOs. However, the rate of acceptance among the group reports was higher than the individual ones. The most common point of reconciliation among the PSTs' provisional acceptance of the applications of GMOs was the idea that GMOs should not be in the food industry. Another point of reconciliation was that the GMOs can be used in the medical and pharmaceutical industries. But interestingly, the group who worked on the sub-topic of 'GMOs and ethics' concluded that GMOs should not be used in any field, including the medical and pharmaceutical industry.

In many studies, it was revealed that objections and concerns were based mainly on ethics or values (Tait, 2001). Ethics-focused and value-oriented tasks rather than ones focused on scientific results may have caused them to form a group opposed to GMOs and an increase in their risk perception. The results of the current study, therefore, support the claim that public debates and concern are mostly fed by beliefs, ethics and value-laden reasoning rather than elements rooted in scientific knowledge (Martin & Tait, 1992; Sadler & Zeidler, 2004; Scully, 2003; Šorgo, Ambrožič-Dolınšek, Usak, & Ozel, 2011).

Furthermore, this research suggests a relatively new factor affecting individuals' perception of risk about GMOs (Alberts & Labov, 2003; Finucane & Holup, 2005; Klingeman & Hall, 2006; Lewis & Leach, 2006; Slovic, 1987; Vilella-Vila & Costa-Font, 2008), namely, views about the value and importance of scientific knowledge and scientific process. As mentioned above, a great number of studies on views about GMOs and biotechnological applications have revealed that people tend to see these issues as value-laden and moral problems and that therefore, they use mainly attitudes, beliefs and ethics as a basis for opinion rather than rational interpretation of scientific information (Marris, 2001; Sadler & Zeidler, 2004; Scully, 2003; Šorgo, Ambrožič-Dolınšek, Usak, & Ozel, 2011; Tait, 2001). Consequently, just presenting the scientific information, which is the final product of the scientific process, is not enough to develop a scientific perspective about risk perception of GMOs. Bell and Leederman (2003) concluded that socio-scientific decisions stem mainly from personal values, morals/ethics, and social concerns. However, this study implies that if students could be familiarised with the process of scientific knowledge building, their scientific perspective and confidence in science and the scientific process can be affected positively to some extent, and therefore, their risk perception of GM crops can move towards a more reasonable and scientific perspective.

Implications and recommendations

The current study contributes an important finding to the literature, in that the more understanding about the nature of scientific knowledge and scientific enterprise students have, the more they develop scientifically balanced risk perception about controversial scientific issues. These results imply that promoting students' epistemic understanding about the nature and value of scientific enterprise may develop their skill in examining the pros and cons of a specific controversial issue. Further research can help the field in understanding other factors concerning socio-scientific decision-making and the role of group dynamics in this process. For example, researchers may investigate group cognition and how it can be constructed to generate more scientific common decisions. They can also delve deeper into how different group dynamics influence reasoning and discourse processes, and how a more authentic scientific enterprise can be accomplished.

As for school science, in argumentation pedagogy referring to scientific enterprise, teachers should design learning sessions in which students are engaged in dialogical knowledge-building processes around investigations in addition to lab-based investigations. Another implication relates to the necessity of explicit argumentation and NOS instruction (Khishfe, 2014; Khishfe & Lederman, 2007) in situating the optimal context for exercising the process of scientific knowledge building.

ORCiD

Ayhan Cinici http://orcid.org/0000-0002-3897-5511

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Appendix

An example of the dual-position expository texts: The effects of GMOs on human health

*Prof. Dr T. Ö.***:** Transgenic crops are observed to cause allergies directly in humans. Experiments conducted on animals showed very negative results. For example, according to the results of the research carried out in the Rowett Institute of Nutrition and Health, a contraction of internal organs, the collapse of the immune system and impairment of blood structure were determined in the mice feeding GM potatoes. In another study conducted within the Russian Academy of Sciences, 55.6% of the mouse pups died within three weeks after birth. Also, in a research conducted last year at the University of Vienna, it was determined that the mice feeding GM foods lost their ability to reproduce largely after 34 generations.

Prof. Dr S. Ç.: The opponents of GMOs argue that the GM crops give rise to toxicity, infertility, allergies, and cancer and so on. These claims have no scientific basis and are a piece of propaganda tactics to organise public against GMOs. Indeed, over 200 scientific articles revealed that these claims are not scientifically appropriate and valid. Furthermore, it is among the measures to be taken against negativity that the GM crops must pass the tests to prove that they are riskless before placing on the market of them and also the results of these tests must be confirmed by a council for science.

The statements of two different scientists included in the above represent two opposing views on GMOs. Please discuss in the group about the information that you obtain to make a common decision and then write a group report containing a detailed explanation and reasons of your shared decision.