SAKARYA UNIVERSITY JOURNAL OF EDUCATION
Original Research Doi: 10.19126/suje.470431

Received: 15.10.2018 Accepted: 15.05.2019
Published: 15.08.2019 August 2019 • 9(2) • 224-242

Investigation of Preservice Teachers' Model-Evidence Link Evaluation Levels Related to GDO

Mehpare SAKA* **Deniz SARIBAŞ****

Abstract. Although genetically modified organisms (GMOs) are scientific issues, their disadvantages as well as advantages are often asserted in society. In other words, they are controversial issues in society. In this context, individuals need to make informed decisions about GMOs which are part of socio-scientific issues. Making informed decisions by critically evaluating on controversial issues is a significant skill. Therefore this study aims to detect pre-service science teachers' evaluation level of model-evidence links. The study was a descriptive survey that uses a qualitative data source and research group consisted of junior students of Science Education Department in a public university in Turkey. The Model-Evidence Link (MEL) diagram developed by the high school science teachers who attended a workshop organized Lombardi, Sibley and Carroll (2013) and adapted to GMO by the same teachers was used as the data collection tool. A rubric developed by Lombardi, Bickel, Brandt and Burg (2016) and adapted to this study by the authors of the present paper was used for analyzing the data. The analyses indicated that pre-service teachers evaluated model-evidence links on the topic of GMOs generally in descriptive and relational level, however, rarely in critical level.

Keywords: Model- Evidence Link, GDO, Preservice teacher.

* Orcid ID: https://orcid.org/0000-0001-9730-8607, Dr., Trakya University, Department of Mathematics and Science Education, Science Education, mehparesaka@gmail.com
** Orcid ID: https://orcid.org/0000-0002-4839-7858, Assist. Prof. Dr., İstanbul Aydın University, Department of Basic Education, Preschool Education, denizsaribas@aydin.edu.tr

1. INTRODUCTION

The basic goal of science education programs is to help students to acquire scientific literacy and to ensure them to grasp the nature of science. In addition to this goal, individuals educated to achieve scientific literacy especially in ethical and moral terms are expected to have developed a skill to make decisions on both personal and social issues. Individuals' skill to assess scientific claims by using their scientific knowledge and to make a decision is important in this context (Zeidler, Sadler, Simmons, & Howes, 2005). At this point socio-scientific issues (SSI), considered disputable issues in general, contain the process of evaluation of scientific claims and arguments from a political, ethic and epistemological perspective (Kolstø, Bungum, Arnesen, Isnes, Kristensen, Mathiassen, Mestad, Quale, Tonning, & Ulvık, 2006). In this context, scientific literacy requires to perform evidence-based evaluation of SSI and to make decisions based on scientific knowledge.

In this country the Science Teaching Programs applied as from 2000 aimed to help individuals acquire the targets of the notion of scientific literacy together with the science-technology-society relationship (MEB, 2000). For this purpose, it was emphasized that individuals must be led to relate science, technology and society with each other to be able to use their knowledge and skills in their daily lives. It was also emphasized that individuals should take responsibility for social events too and think and research in an inquisitive way to make the rightest and remedial decisions in taking such responsibility, and therefore it is important for individuals to develop positive attitude and values for science. In this context it was decided to add SSIs designed to ensure individuals to participate in the decision-making processes for cultural and social events as part of their scientific literacy, to develop and use the necessary scientific knowledge and skills especially in their daily lives, with reference to an educational approach based on researching and questioning, in the science program 2013 and 2017 (MEB, 2013; MEB, 2017).

Although the prominent science research institutes in the worldwide added SSIs in their curriculums to ensure their students to develop both the habit of scientific thinking in accordance with their individual scientific literacy characteristics and the skills of analyzing and making decisions in the 1990s (NRC, 1996; Topçu, Muğaloğlu, & Güven, 2014), this topic was not added in the educational programs of this country until 2013. Thus, it was aimed to ensure students "to use SSIs in order to develop the skill of reasoning, the habit of scientific thinking and the skill of decision-making" (MEB, 2017, p. 9). It was aimed to ensure students to integrate what they learned in school with their daily lives and to develop the skill of making decisions and selecting right solutions when they face problems in their real lives.

SSIs involve different viewpoints in both individual and social terms, and it is difficult to make firm decisions on them. Both moral and ethical viewpoints and scientific methods have a considerable effect on such decisions (Sadler, & Donnely, 2006). Ensuring individuals to develop the skill of making informed decisions on ethical issues by using their cognitive skills required for scientific literacy is included in the skills which individuals are expected to develop in this century. In this context, it is aimed to ensure individuals to be able to analyze, synthesize and assess the data (Zeidler, 2001). SSIs contain different views and approaches, and there is no absolute right or wrong in them, they are situations acceptable or unacceptable to all parties. These issues require to reason in moral and ethical terms and to assess opposite views mutually, are controversial, open to interpretation, and not absolute (Kolstø, 2001; Sadler, & Zeidler, 2005; Sadler, 2004) and require developing ideas and make choices. They include such controversial issues as nuclear energy, global warming, genetically modified organisms, alternative fuels, cloning, stem cells and gen projects, affect society, and may cause the individual to have to make a decision or allegation (Dawson, & Venville 2009; Sadler, & Zeidler 2004).

Genetically Modified Organisms (GMO)

Used in many branches of science including agriculture, medicine, veterinary, biochemistry and environment, biotechnology is not only a branch of research, but also a factor of our daily lives thanks to its use in food, personal effects and pets. In the present the subject of GMO is one of the most controversial biotechnological researches. Defined as altering the characteristics of any living thing or adding new characteristics in it by tampering with its genetic sequence using biotechnological methods, GMO are considerably controversial in both this country and the rest of the world (Kulaç, Ağırdil, & Yakın, 2006). Altering or differentiating an organism by interfering its existing structure is beneficial on the one hand and harmful on the other hand, so that there are different scientific and ethical views on it (Costa-Font, & Mossialos, 2007; Pusztai, Bardocz, & Ewen, 2003). There are opinions that GMO increase the quality and hygiene of foods, extend the shelf life of fruits and vegetables, improve their organoleptic quality, increase the productivity of manufacturing process of animal and vegetable products, and contribute to treatment of diseases, organ transplantation and protection of the environment (Demir, & Düzleyen, 2012). On the other hand, there are opinions that GMO cause allergic reactions and toxic effect and have a negative effect on the environment. These different views and debates cause GMO to fall in the scope of socio-scientific issues. Considering that GMO are in every stage of our daily lives, one might say that it has an effect in political, social, economic and ecologic terms on society.

Education has a considerable effect on increasing individuals' awareness of the issues affecting society and our future. One of the many socio-scientific issues emerging as a result of technological progress and the increase of scientific knowledge, GMO are positively or negatively affected from developments. Therefore, it is now rather a necessity than a need to add the said issues in curriculums. Because students live right within those issues which have started to affect their daily lives, especially through the Media. Therefore, it is now a necessity for students to view those issues from a critic's point of view and to use scientific knowledge right while reasoning those issues in order to assess them right.

It is observed in the courses dedicated to GMO in the curriculums that they generally focus on pre-service teachers' and students' knowledge levels, attitudes and thoughts. Studies conducted on pre-service science teachers' level of knowledge of GMO found that the level in question was low in general (Soysal, 2012; Sönmez, & Kılınç, 2012; Türkmen, Pekmez, & Sağlam, 2017). Furthermore, Türkmen, Pekmez and Sağlam (2017) concluded as a result of the study they performed that in addition to the basic sciences i.e. physics, chemistry and biology, visual and social media, friends and family have an effect on students' knowledge of GMO. In the study they conducted on a group of Year 8 students, Demir and Düzleyen (2012) found that the students misconceived GMO and had incorrect knowledge of GMO. Özden, Akgün, Çinici, Gülmez and Demirtaş (2013) made a similar conclusion in their study. The students told the researchers that they learned about GMO from television and their families and teachers. Therefore, it appears that students perceive GMO as harmful in general (Özden, Akgün, Çinici, Gülmez, & Demirtaş, 2013; Bilen, & Özel, 2012). In another study conducted on a group of high school students, it was found again that they misconception GMO and had a negative impression of GMO in general (Gürbüzoğlu Yalmancı, 2016). Other studies conducted on Year 8 students also indicated that they misconceptioned GMO and had insufficient knowledge of them (Demir, & Düzleyen, 2012; Özden et al, 2013).

The studies conducted on GMO basically focus on the knowledge level and grasp of students and their sources of information about GMO. However, none of the studies available in the literature focused on students' level of evaluation of the relation between the evidence presented in the studies and the arguments. Study of students' and pre-service teachers' level of evaluation of the relation in question will guide education authorities how to design the lessons on GMO and other SSIs included in the teaching programs.

Model-Evidence Link (MEL) diagrams

Results of the studies conducted on inclusion of SSIs in science education indicate that SSIs help individuals to develop the skill of viewing from different points and developing solutions (Sadler, & Zeidler, 2004) and that since SSIs arise from contradicting situation, they help individuals to develop the process of assessing their own thoughts and making decisions (Osborne, Erduran, & Simon, 2004). What is important here is that in making such evaluation, the individual should act with a critical viewpoint and assess the data right. Therefore, the skill of making critical evaluation depends on the skill of finding and assessing the relations between different evidences and explanations (Lombardi, Sibley, & Carroll, 2013). To help students develop these skills, teachers guiding the education process should have field information and the skill of assessing and applying the evidence-based education process (Bruniges, 2005; Hmelo-Silver, Duncan, & Chinn, 2007).

MEL diagrams helping to develop the skill of assessing the relations between evidences and alternative models were developed by Chinn and Buckland (2012) at Rutgers University for use in biology lessons for secondary school students as part of the

PRACCIS (Promoting Reasoning and Conceptual Change in Science) project financed by National Science Foundation (NSF).

Several studies indicate that the MEL diagrams help students to develop skills of assessing and arguing in terms of the relations between evidences and alternative models (Chinn, & Buckland, 2012; Lombardi, Sinatra, & Nussbaum 2013). The diagrams allow students to compare and assess scientific explanations with non-scientific ones. However, almost no study was conducted on students' skills of assessing the MEL especially in SSIs by using the MEL diagrams. Teacher's role in ensuring students to develop the skills of assessing and making decisions from a critical point of view may not be ignored. In order to ensure students to have and develop the knowledge and skills in question, teachers should have not only knowledge on the issues, but also the viewpoint of a good applier. Determination of pre-service teachers' level of evaluation of GMO by using the MEL diagrams will guide the education authorities to ensure the teachers' skill of critical thinking. In this context, this study may be useful in designing the lessons to be provided to help teachers to develop the skill of critical thinking. This study focused on pre-service teachers' level of evaluation of different models of GMO, and seeks answer to the following study question:

What are pre-service teachers' levels of evaluation of the model-evidence link in GMO?

2. METHOD

This study was designed to find how pre-service teachers assess the GMO as an SSI by using the basic qualitative research design (Merriam, 2002). Such research design aims to find how people interpret and experience the information, skills or situations they face in their lives (Merriam, 2013). Therefore, this study aimed to find and describe how pre-service science teachers analyze and interpret the knowledge they have.

Participants

This study was conducted on 26 pre-service science teachers, 23 of whom are female and 3 are male. The pre-service teachers were junior students in a state university teaching in English. This study was conducted as part of the course entitled *Controversial Issues in Science Education* in academic year 2015-2016. The pre-service teachers had taken physics, chemistry and biology courses as part of their bachelor's degree education before taking the above-mentioned class. They also had such pedagogic courses as Principles and Methods of Education, Educational Psychology, and Laboratory Applications in Science Education.

Data collection tool

The Model-Evidence Link (MEL) diagram developed by the high school science teachers who attended a workshop organized by Lombardi, Sibley and Carroll (2013) and adapted to GMO by the same teachers was used as the data collection tool. Considering that the pre-service teachers who were the participants of this study were being educated in English, the data collection tool was presented in its original language i.e.

English to them. The model and evidences included in the MEL diagram relevant to GMO and used as a data collection tool were translated to the Turkish by the authors of this study to present them in this paper.

The MEL diagram consists of two parts. Part One contains two alternative models and four evidence statement designed for the said alternative models. Figure 1 and 2 shows the parts of the MEL diagram.

The two alternative models described below are given in the middle of page one of the diagrams:

Model A: Genetically modified organisms are beneficial for society.

Model B: Genetically modified organisms are not beneficial for society.

The five evidences described below are given around the models:

Evidence 1: There are many viruses, fungi and bacteria that cause plant diseases.

Evidence 2: Unexpected frost can destroy sensitive seedlings. An anti-freeze gene extracted from cold water fish has been introduced into plants such as tobacco and potato.

Evidence 3: Studies show that pollen from B.t. (*Bacillus thuringiensis*) corn caused high mortality rates in monarch butterfly caterpillars.

Evidence 4: Crop losses from plant pests can be staggering, resulting in devastating financial loss for farmers and starvation in developing countries.

Evidence 5: Medicines and vaccines often are costly to produce and sometimes require special storage conditions not readily available in third world countries.

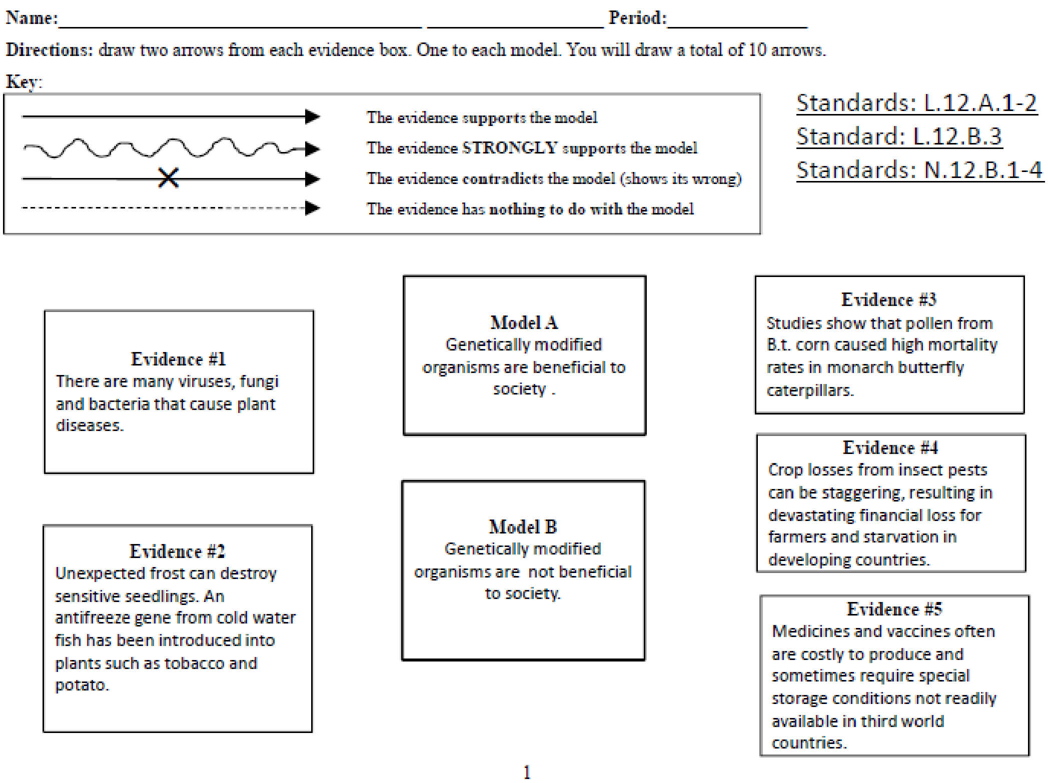


Figure 1. MEL Diagram (Lombardi, Sibley, & Carroll, 2013)

Explanatory scientific texts were given for the evidences presented in the diagram, and the participants were ensured to read the said texts before establishing model-evidence links. The texts given to the participants contained the abstracts of certain papers published in scientific periodicals in addition to various texts from unknown sources. This MEL Diagram developed for GMO is available in a professional improvement website designed for teachers (http://rpdp.net/adm/uploads.news /sciencedis/newsletter_322.pdf). The participants assessed the links between the models and evidences by taking into consideration the texts available in the above-mentioned website.

The text given as Evidence 1 to the participants describes a papaya genome project and states that 80% of the papaya located in Hawaii was genetically modified. It also contains photos of sick and healthy papayas and states that the disease prevents the papayas from growing.

The text given as Evidence 2 to the participants explains that sensitive seedlings are damaged by frost and that the anti-freeze gene extracted from a cold-water fish was administered to tobacco and potato seeds to protect them from frost.

The text given as Evidence 3 to the participants is a paper published in Nature, emphasizing that Bacillus thuringiensis bacterium kills caterpillars. It explains that Bt bacterium was transferred to corn seeds, but not to milkweed. This is thought to be due to the fact that pollens were blown by the wind from corns to seeds. The text explains that some non-governmental institutions conducted the same experiment but did not find the same result, so that the original study might be erroneous. The text explains that harsh debates are exchanged over these two different results.

The text given as Evidence 4 to the participants describes crops lost due to plant pests, explains how the genes of Bt bacterium were transferred to seeds to prevent such loss, and states that the transfer increased the strength of corn.

The text given as Evidence 5 to the participants is the abstract of a paper commenting on ethical questions about the growth of bananas resisted to Hepatitis B by way of vaccination. The text explains that the authors noted opinions of scientists, politicians, non-governmental organizations, media companies and religious groups, and suggests four different ethical dimensions: those who are familiar with it, those who deny its benefits, those who accept it in ethical terms, and those who perceive it as a risk.

The participants were asked to read the texts and then to decide on one of the four different links between the alternative models and five different evidences. The participants were asked to draw a straight line if the evidence supported the model (S); a wavy line if the evidence strongly supported the model (SS); a straight line and the letter X if the evidence contradicted with the model (C); or a dotted line if the evidence had nothing with the model (NTW). There were 8 model-evidence links in total.

The following information was given to the participants about the plant pests during the data collection stage: Various methods are applied to fight the plant pests, and genetically modified corn seeds are widely used in recent years. One of the methods in question is transferring Bacillus thuringiensis bacterium to plants to increase their resistance to the plant pests (Ince, Bahadıroğlu, Toroğlu and Bozdoğan, 2013). After giving the information, the participants were told that the information was sufficient for them to establish model-evidence links in the diagram and to explain those links.

Part Two of the diagram asked the participants to choose three of the model-evidence links they established in Part One and to explain the reasons of the link they established. The bottom part of page two of the diagram contains plausibility evaluation. Part Two of the MEL diagram is given below:

Provide a reason for three of the arrows you have drawn. Write your reasons for the three most interesting or important arrows.

A. Write the number of the evidence you are writing about.
B. Circle the appropriate descriptor (**strongly supports | supports | contradicts | has nothing to do with**).
C. Write the letter of the model you are writing about.
D. Then write your reason.

1. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

2. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

3. Evidence # ____ strongly supports | supports | contradicts | has nothing to do with Model _____ because:

Figure 2. Explanation page of the MEL diagram (Lombardi, Sibley, & Carroll, 2013)

Data Analysis

The explanations made by the pre-service teachers about the links they established were assessed using the evaluation rubric given in Table 1 of the MEL diagram designed by Lombardi, Bickel, Brandt and Burg (2016).

Table 1.

Model-Evidence Link evaluation levels

Category	Description	Score
Erroneous evaluation	Explanation contains incorrect relationships between evidence and model by elimination-based logic. The explanation is inconsistent with scientific understanding and/or includes nonsensical statements.	1
Descriptive evaluation	Explanation contains a correct relationship without elaboration, or correctly interprets evidence without stating a relationship. For example, where the evidence has nothing to do with the model, explanation may not clearly distinguish between lines of evidence and explanatory models. Explanations could also demonstrate "elimination-based logic" to come to a positive or negative weight, when evidence-to-model link weight states that the evidence has nothing to do with the model. For example, an explanation states that an evidence supports one model, but uses reasoning that the evidence contradicts the other model.	2
Relational evaluation	The explanation addresses text similarities, and includes both specific evidence and an associate model or reference	3

	to a model. For example, explanation is correct, with an evidence-to-model link weight of KD, D, Ç or IY) as appropriate. Explanation distinguishes between lines of evidence and explanatory models, but does so in a merely associative or correlation manner that is often based on text similarity.	
Critical evaluation	Explanation describes a causal relationship and/or meaning of a specific relationship between evidence and model. For example, explanation is correct, with an evidence-to-model link weight of strongly supports, supports, or contradicts as appropriate and reflects deeper cognitive processing that elaborates on an evaluation of evidence and model. Explanation distinguishes between lines of evidence and explanatory models, allows for more sophisticated connections, and/or concurrently examines alternative models.	4

This rubric was translated to the Turkish and adapted to this study by the authors. The original rubric contains whether the relationship between the evidence-model link assessment levels and the relationship between the models and evidences was correctly evaluated. However, the MEL diagram developed by the high school science teachers who attended a workshop organized Lombardi, Sibley and Carroll (2013) and adapted to GMO by the same teachers does not determine the correct relationships between the model and evidence. This study too focused on the evaluations made by the pre-service teachers while establishing the relationships rather than determining the right relations between the models and evidences. Since the original rubric was designed by taking into consideration the right relationships too, it was not only translated to the Turkish for this study but also adapted to this study. The adaptation was made without changing the evaluation criteria and categories of the original rubric, only the statements about the wrongness or correctness of the model-evidence relationship were changed by taking into consideration whether the model-evidence relationship was coherently explained. The coherence between the relationship and explanation was determined with reference to the way each pre-service teacher established a causal relationship between the model and the evidence and explained that relationship. Since the MEL diagram given to the pre-service teachers had been designed by the teachers who attended the workshop organized by Lombardi, Sibley and Carroll (2013) and since the model-evidence relationships were not assessed by an expert in the diagram, the statements of right or wrong model-evidence relationships were not used in the adapted rubric. Given that the object of this study was to determine the pre-service teachers' level of assessment of the model-evidence relationships concerning GMO, the act of determining the right relationships was not included in the scope of this study.

Table 2.

Adapted Model-Evidence Link assessment rubric

Category	Description	Score
Erroneous evaluation	The explanation does not refer to the information presented as evidence at all or establishes relationship with some of the information and ignores the basic idea stated in the text. The explanation is inconsistent with scientific understanding and/or includes nonsensical statements.	1
Descriptive evaluation	The relationship established and the explanation look coherent, but the explanation is not detailed at all. For example, the relationship of the explanation made for the evidence with the model may not be clearly distinguished. The conclusion that the evidence is not related to the model may have been arrived by using “elimination-based logic” to come to a positive or negative weight. For example, an explanation states that an evidence supports one model, but uses reasoning that the evidence contradicts the other model.	2
Relational evaluation	The explanation addresses text similarities, and includes both specific evidence and an associate model or reference to a model. Explanation distinguishes between lines of evidence and explanatory models, but does so in a merely associative or correlation manner that is often based on text similarity.	3
Critical evaluation	Explanation describes a causal relationship and/or meaning of a specific relationship between evidence and model. For example, the explanation’s relation with the model has been coherently established and reflects deeper cognitive processing that elaborates on an evaluation of evidence and model. Explanation distinguishes between lines of evidence and explanatory models. Furthermore, more sophisticated connections were established between the models and evidences by taking into consideration the alternative models.	4

Different researchers coding the data on a certain case under certain categories and arriving at a common opinion on the categories and codes in question is considered a method to ensure reliability of qualitative studies (Silverman, 2018; Glesne, 2012). The data collected in this study were analyzed and assessed by the authors independent from each other by using the rubric. After the independent assessments were made, the results of the assessments were compiled and compared. The authors continued to assess until they came to a mutual agreement (Creswell, 2013) on the assessments found to be negative as a result of the comparison. To ensure reliability (Merriam, 1998; Silverman, 2018), examples of the written explanations submitted by the pre-service teachers to prove the conclusions they made.

3. FINDINGS

This study reviewed a group of pre-service science teachers' levels of assessment of model-evidence links by using the MEL diagram. For this purpose, the pre-service teachers were asked to establish a link between each model and evidence, to grade each link as supports, strongly supports, contracts or has nothing to do with the model, and then to choose three of those links and explain them. Their explanations were assessed by using the rubric of the MEL diagram developed by Lombardi, Bickel, Brandt and Burg (2016), as adapted to this study. The analyses of the explanations made by the pre-service teachers on their model-evidence links are given in Table 3. The table shows each MEL as either MA (Model A) or MB (Model B) plus K1, K2, K3, K4 or K5 (Evidence 1, 2, 3, 4 or 5) (for example MAK1, MBK1, etc.).

Table 3

Rubric assessment of the pre-service teachers' explanations of the model-evidence links they established

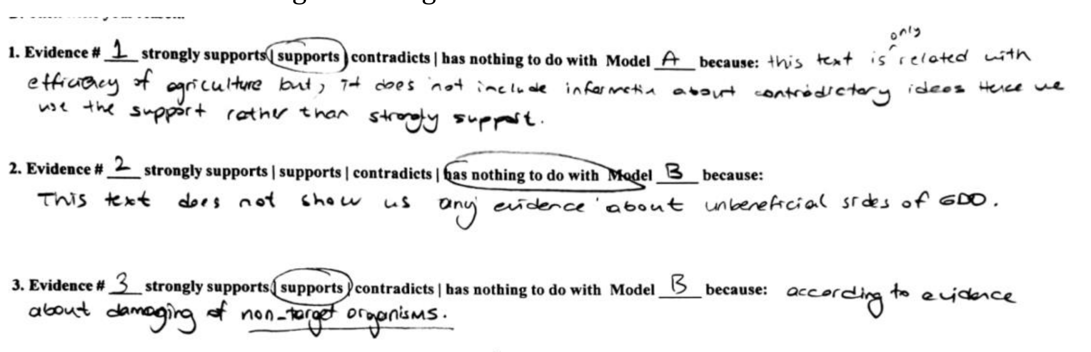
	Grades for Explanations								
MEL	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
MAK1	4	3	3	3		3	3		3
MBK1								3	
MAK2		3	3	3	2	3			
MBK2	4								3
MAK3									
MBK3	1	1	1	1			1	1	2
MAK4						1			
MBK4					2	1			

MAK5					1		1	1	
MBK5					1				
Total Points	9	7	7	7	5*	7*	5	5	8

** Group 5 linked K5 with the both models and Group 6 linked K4 with the both models as shown above. However, only one of the links was taken into account in the total figures to avoid problems with comparison with the other groups.*

As shown in the table, only one group made critical evaluation of the both model-evidence links they established. Five groups explained two of the links they established at the relational evaluation level; two groups evaluated a single link at the relational evaluation level. One group evaluated two links at the descriptive evaluation level; another group explained one link at the descriptive evaluation level. These results indicate that most of the pre-service teachers could not evaluate the model-evidence links in the MEL diagram at the critical evaluation level. The pre-service teachers look to have evaluated the links at the descriptive and relational evaluation levels in general.

After determining the pre-service teachers' levels of evaluation of model-evidence links, the explanations they made on those links were reviewed deeper. It was found that only one group (Group 1) evaluated the links at the critical evaluation level, described both supporting and contradicting evidence in explaining the links, and emphasized the importance of argument and counter-argument. An example of the said group's evaluation of the MEL is given in Figure 1.


1. Evidence # 1 strongly supports | supports | contradicts | has nothing to do with Model A because: this text is only related with efficacy of agriculture but, it does not include information about contradictory ideas. Hence we use the support rather than strongly support.

2. Evidence # 2 strongly supports | supports | contradicts | has nothing to do with Model B because: This text does not show us any evidence about unbeneficial sides of GDO.

3. Evidence # 3 strongly supports | supports | contradicts | has nothing to do with Model B because: according to evidence about damaging of non-target organisms.

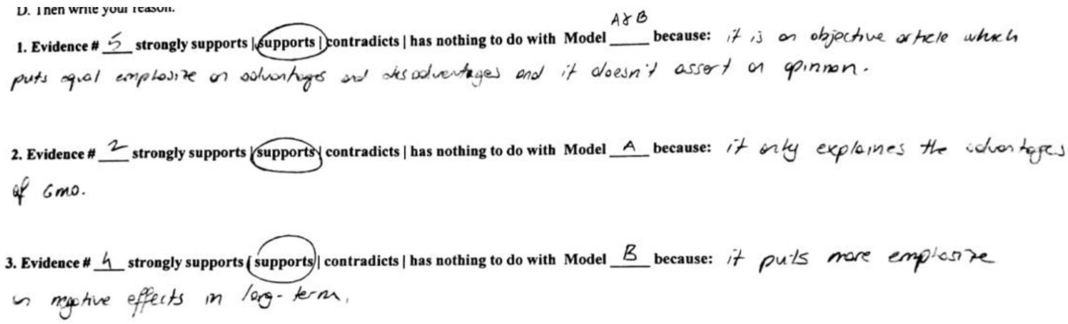
Figure 3. Explanation made by a Group 1 member on MEL

Evidence 1 supports Model A. Because this text is related to the agricultural benefit only, but it does not contain any statement contradicting with the model. Therefore, I chose the statement 'supports' instead of ''strongly supports.

Evidence 2 has nothing to do with Model B. Because it does not mention any non-beneficial aspect of GMO.

The groups who made descriptive evaluation managed to establish coherent model-evidence links, but explained them in a superficial way without elaborating their details in general.

For example, a member of Group 5 explained the MAK2 link by mentioning that the text described certain advantages of GMO, but did not elaborate the advantages in question. An example of the MEL evaluation made by a member of the said group is given below.


D. Then write your reason.

1. Evidence # 5 strongly supports | supports | contradicts | has nothing to do with Model A & B because: it is an objective article which puts equal emphasize on advantages and disadvantages and it doesn't assert an opinion.

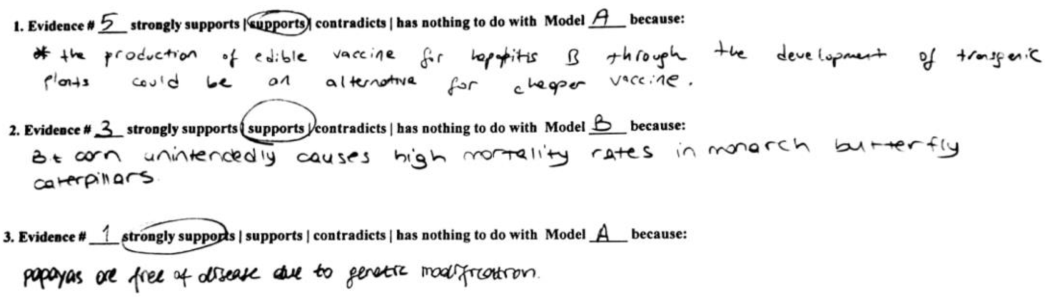
2. Evidence # 2 strongly supports | supports | contradicts | has nothing to do with Model A because: it only explaines the advantages of GMO.

3. Evidence # 4 strongly supports | supports | contradicts | has nothing to do with Model B because: it puts more emphasize on negative effects in long-term.

Figure 5. Explanation made by a Group 5 member on MEL

Evidence 3 supports Model B. Because it emphasizes more negative effects in the long run.

The groups who established erroneous links mentioned only one of the several contradictions described in the text in general or failed to understand the information given in the text, so that the links they established were either meaningless or inconsistent. For example, a member of Group 7 explained his/her MBK3 link by stating that Bt corns killed caterpillars and therefore GMO are not beneficial. However, the text describes two different studies. The text explains that a study found that GMO killed caterpillars at a high rate. It also explains that some other institutions conducted the same experiment but the results they obtained contradict with that of the first study. The said group did not make any reference to these two contradicting results. An example of the evaluation made by the said group for MEL is given in Figure 4 below.


1. Evidence # 5 strongly supports | supports | contradicts | has nothing to do with Model A because:
the production of edible vaccine for hepatitis B through the development of transgenic plants could be an alternative for cheaper vaccine.

2. Evidence # 3 strongly supports | supports | contradicts | has nothing to do with Model B because:
Bt corn unintendedly causes high mortality rates in monarch butterfly caterpillars.

3. Evidence # 1 strongly supports | supports | contradicts | has nothing to do with Model A because:
papayas are free of disease due to genetic modification.

Figure 6. Explanation made by a Group 7 member on MEL

Evidence 3 supports Model B. Because Bt corn kills off caterpillars at a high rate.

As these examples show, the explanations made by the pre-service teachers on the model-evidence links they established were rarely at the critical evaluation level. In the light of these findings, it appears that more and more classes need to be provided to teaching students to debate model-evidence links

4. CONCLUSION, DISCUSSIONS AND SUGGESTIONS

To make decisions on such SSI as GMO one must have information on the issue and notion on the one hand and be able to evaluate evidences and explanations at the critical evaluation level (Sinatra & Hofer, 2016). Therefore, relations between the articles written on these issues and the arguments on them should be debated more at classroom, more studies should be conducted and published on these issues. To meet the need in question, the authors held a class where a group of pre-service science teachers debated certain model-evidence links by using a MEL diagram developed by the teachers who attended a workshop organized by Lombardi, Sibley and Carroll (2013), where the said pre-service science teachers were asked to explain the links, and the explanations made by them were analyzed by the authors.

The findings obtained from this study indicate that the pre-service science teachers were challenged in general to evaluate the link between some evidence given in a text and an argument or counter-argument. However, it was observed that most of the pre-service science teachers evaluated the model-evidence links at the descriptive and relational evaluation levels.

One of the basic aims of science education is to ensure students to develop the skill of critical thinking and argument in order to have the awareness of social responsibility. Thus, scientific information can be transferred and students can develop the skill of decision-making (Khishfe, & Lederman 2007; Kolstö 2006; Sadler, 2011). The use of SSI containing complex and controversial issues in the class helps students to use their scientific knowledge and to debate at the same time (Erduran, Simon, and Osborne 2004; Sadler 2004). However, one might say that the results of this study indicate that the pre-service teachers possess only some of the above-mentioned skills. If education tools are used in the class to present alternative arguments to pre-service teachers and if the latter are ensured to debate those alternatives, it would be useful to help them to learn the issues and notions better and to attend scientific practices (Lombardi et al, 2016; 2017).

Christenson and Rundgren (2015) applied an evaluation tool they had developed on GMO for junior high school and high school students to two students, and observed that both of the students in question could present arguments and rationales, and that one of them could present counter-arguments by using his/her knowledge of biology and other disciplines. The above-mentioned study suggests that it is important to produce arguments with reference to the content and context of the issue and to evaluate those arguments. It is asserted that in addition to scientific knowledge, moral and ethical values and cultural point of view play an important role in the process of making decision on SSI (Braund et al, 2007; Zeidler et al, 2002; Zeidler et al, 2002) and that tools requiring to use the metacognitive skills should be used in this process. If the MEL diagrams used in the present study are used in the class, it may help students to develop the skills of evaluating and decision-making on texts given to them for such SSI as GMO.

Braund et al (2007) found scientific issues and SSI require different argumentation and reasoning. SSI are much more complex, and decisions made on them are affected by not only one's scientific knowledge but also one's moral and ethical thoughts and cultural point of view. Zeidler (2005) conclude that students can be more talented on making logical and scientific decisions on SSI by integrating several points of view with their own metacognitive activities (for example, reflective thinking).

In this study the diagram was presented in its original language i.e. English to the participants. The diagram in question is not suitable for students whose level of English is low. Therefore, adaptation of the diagram in Turkish and applying it to other students will greatly contribute to the science education literature. If such adaptation is made by redesigning the models and evidence in accordance with opinions received from specialists, the diagram's validity and reliability will increase and findings to be obtained from it will be evaluated in a better way.

This study focused on some pre-service teachers' level of evaluation of model-evidence links, but it did contain whether the participants managed to evaluate those links right. The MEL diagrams developed by the high school science teachers who attended a workshop organized Lombardi, Sibley and Carroll (2013) was used in this study. The diagrams in question contain evidence texts giving information supporting both models. For example, Evidence 3 explains two studies, one of which proves that Bt corn pollens kill off caterpillars, and the other proves otherwise. In this case it is impossible to establish correct links between the models and evidences. To remove this limitation, it is suggested that evidences containing texts in Turkish should be given to students before using the MEL diagrams in the class, and correct links (supports/strongly supports/contradicts/has nothing to do with the model) should be established. The use of diagrams developed this way will help researchers to review deeper the evaluations made by students on such links.

Pre-service teachers are unable to evaluate the model-evidence links about an issue as controversial as GMO at the critical evaluation level enough, but is this inability limited with GMO or exists in other issues too? This question can be answered and students' level of evaluation of model-evidence links can be reviewed deeper by using the MEL diagrams for other science disciplines and IIS in addition to GMO.

References

Bilen, K., & Özel, M. (2012). Üstün yetenekli öğrencilerin biyoteknolojiye yönelik bilgileri ve tutumları. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED). 6*(2), 135-152.

Braund M, Lubben F, Scholtz Z, Sadeck, M., & Hodges M (2007) Comparing the effect of scientific and socio-scientific argumentation tasks: lessons from South Africa. *School Science Review*, *88*(324), 67-76.

Bruniges, M. (2005). An evidence-based approach to teaching and learning. http://research.acer.edu.au/research_conference_2005/15

Chinn, C. A., & Buckland, L. A. (2012). Model-based instruction: Fostering change in evolutionary conceptions and in epistemic practices. In K. S. Rosengren, E. M. Evans, S. Brem, & G. M. Sinatra (Eds.), *Evolution challenges: Integrating research and practice in teaching and learning about evolution* (pp. 211–232). New York, NY: Oxford University Press.

Christenson, N., & Rundgren, S-N. C. (2015). A Framework for Teachers' Evaluation of Socio-scientific Argumentation: An example using the GMO issue. *Journal of Biological Education, 49*(2), 204-212.

Costa-Font, J., & Mossialos, E. (2007). Are perceptions of risk and benefits of genetically modified food in dependent? *Food quality and preference, 18*(2), 173-82.

Dawson, V., & Venville, G. J. (2009). High-school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy? *International Journal of Science Education, 31*(11), 1421-1445.

Demir, B. & Düzleyen, E. (2012). İlköğretim 8. sınıf öğrencilerinin GDO bilgi düzeylerinin incelenmesi, X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi (X. UFBMEK), 27-30 Haziran, Niğde. Retrieved from http://kongre.nigde.edu.tr/xufbmek/dosyalar/tam_metin/pdf/2334-29_05_2012-23_42_48.pdf.

Erduran, S., Simon, S., & Osborne. J. (2004). TAPping into Argumentation: Developments in the Application of Toulmin's Argument Pattern for Studying Science Discourse. *Science Education, 88*(6), 915–933.

Gürbüzoğlu Yalmancı, S. (2016). Lise öğrencilerinin genetiği değiştirilmiş organizmalara yönelik algılarının belirlenmesi. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 37*, 89-111.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2006). Scaffolding and achievement in problem-based and ınquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educatıonal Psychologıst, 42*(2), 99–107.

İnce, H. Ö., Bahadıroğlu, C., Toroğlu, S., & Bozdoğan, H. (2013). Genetiği Değiştirilmiş Mısır Bitkisinin Bazı Böcek Türlerine Karşı Direnci Üzerine Değerlendirmeler. *Nevşehir Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2*(1), 78-89.

Khishife, R., & Lederman. N (2007). Relationship between Instructional Context and Views of Nature of Science. *International Journal of Science Education, 29*(8), 939–961.

Kılıç, S., Koçak, N., Türker, T., Gürpınar, H., & Gülerik, D. (2010). Kız üniversite öğrencilerinin organ bağışı konusundaki tutumları ve bu tutumlarına etki eden faktörler. *Gülhane Tıp Dergisi, 52*, 36-40.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 8*, 291–310.

Kolsø, S. D. (2006). Science Students' Critical Examination of Scientific Information Related to Socioscientific Issues. *Science Education, 90*(4), 632–655.

Kolstø, S. D., Bungum, B., Arnesen, E., Isnes, A., Kristensen, T., Mathiassen, K., Mestad, I., Quale, A., Tonning, A. S. V., & Ulvık, M. (2006). Science students' critical examination of scientific information related to SSI. *Science Education, 90*, 632-655.

Kulaç, İ., Ağırdil, Y., & Yakın, M. (2006). Sofralarımızdaki tatlı dert, genetiği değiştirilmiş organizmalar ve halk sağlığına etkileri. *Türk Biyokimya Dergisi, 31*(3), 151-155.

Lombardi, D. (2016). Beyond the controversy: ınstructional scaffolds to promote. *The Earth Scientist, 32(*2), 5-10.

Lombardi, D., Bickel, E. S., Brandt, C. B., & Burg, C. (2016). Categorising students' evaluations of evidence and explanations about climate change. *International Journal of Global Warming, 12*(3/4), 313-330.

Lombardi, D., Sibley, B., & Carroll, K. (2013). What's the alternative? Using model-evidence link diagrams to weigh alternative models in argumentation. *The Science Teacher, 80*(5), 36-41.

Lombardi, D., Sinatra, G. M., & Nussbaum, E. M. (2013). Plausibility reappraisals and shifts in middle school students' climate change conceptions. *Learning and Instruction, 27*, 50–62.

MEB (2000). *İlköğretim Okulu Fen Bilgisi Dersi Öğretim Programı*. Ankara: Milli Eğitim Basımevi.

MEB (2013). *İlköğretim Kurumları (İlkokullar ve Ortaokullar) Fen Bilimleri Dersi (3,4,5,6,7 ve 7. Sınıflar) Öğretim Programı.* Milli Eğitim Bakanlığı Talim ve Terbiye Kurulu Başkanlığı, Ankara.

MEB (2017). *Fen bilimleri dersi öğretim programı (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar).* Ankara, Milli Eğitim Bakanlığı.

Merriam, S. B. (1998). Qualitative research and case study applications in education. San Francisco, CA: Jossey-Bass Publishers.

Merriam, S. B. (2002). *Qualitative research in practice: Examples for discussion and analysis.* San Francisco, CA: Jossey-Bass.

Merriam, S. B. (2013). *Nitel araştırma desen ve uygulama için bir rehber* (Çev. Turan, S.). Ankara: Nobel Yayıncılık (Özgün çalışma, 2009).

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*, 994-1020.

Özden, M., Akgün, A., Çinici, A., Gülmez, H., & Demirtaş, F. (2013). 8. Sınıf öğrencilerinin genetiği değiştirilmiş organizmalar (GDO) hakkındaki bilgi düzeyleri ve biyoteknolojiye yönelik tutumlarının incelenmesi. *Adıyaman Üniversitesi Fen Bilimleri Dergisi 3*(2), 94-115.

Pusztai, A., Bardocz, S., & Ewen, S. W. B. (2003). Genetically Modified Foods: Potential Human Health Effects. In: D'Mello, J. P.F. Ed. *Food Safety: Contaminants and Toxin*. UK: CAB International, Wallingford Oxon, 347-372.

Sadler, T. D. (2004). Informal reasoning regarding SSI: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536.

Sadler, T. D. (2011). Situating Socio-scientific Issues in Classrooms as a Means of Achieving Goals of Science Education. In Sadler, T. D. (Eds.) *Socio-scientific Issues in the Classroom* (pp. 1–9). New York: Springer.

Spiris, S. (2012). Archieved Issues of Science Dissected http://rpdp.net/adm /uploads.news/sciencedis/newsletter_322.pdf

Sadler, T. D., & Zeidler, D. L. (2004). The morality of socioscientific ıssues construal and resolution of genetic engineering dilemmas. *Science Education, 88*(1), 4-27.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education, 28*(12), 1463- 1488.

Sinatra, G. M., & Hofer, B. K. (2016). Public understanding of science: Policy and educational implications. *Policy Insights from Behavioral and Brain Sciences, 3*(2), 245-253.

Soysal, Y. (2012). *Sosyobilimsel argümantasyon kalitesine alan bilgisi düzeyinin etkisi: Genetiği değiştirilmiş organizmalar* (Yüksek lisans tezi). Abant İzzet Baysal Üniversitesi, Bolu.

Sönmez, A., & Kılınç, A. (2012). Fen ve teknoloji öğretmen adaylarının GDO 'lu besinler konusunun öğretimine yönelik öz yeterlilikleri: bazı psikometrik faktörlerin muhtemel etkileri. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED), 6*(2), 49- 72.

Türkmen, H., Pekmez, E., & Sağlam, M. (2017). Fen bilgisi öğretmen adaylarının sosyo-bilimsel konular hakkındaki düşünceleri. *Ege Eğitim Dergisi, 2*(18), 448-475.

Topçu, M. S., Muğaloğlu, E. Z., & Güven, D. (2014). Fen eğitiminde sosyobilimsel konular: Türkiye örneği. *Kuram ve Uygulamada Eğitim Bilimleri, 14*(6), 2327-2348.

Zeidler, D. L. (2001). Participating in program development: Standard F. In D. Siebert ve W. McIntosh (Eds.), *College pathways to the science education standards* (pp. 18 – 22). Arlington, VA: National Science Teachers Press.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socio-scientific issues education. *Science Education, 89*(3), 357- 377.