ORIGINAL ARTICLE

University Students' Reasons When Deciding on Genetically Modified Agricultural Products

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***Abstract**: Socio-scientific issues (SSI) are contentious social issues that relate to science and technology. Despite the fact that socio-scientific issues are typically seen as a single entity, they possess multifaceted characteristics. All university students, regardless of their major, should be prepared to analyze complex socio-scientific issues and educated as scientifically literate individuals. This study examined the reasons affecting university students' decision-making regarding the production and use of genetically modified agricultural products. The survey, which included five positive and five negative reasons for the production and use of GMOs, was developed with consideration of the key dimensions of the SEE-SEP model (science, environment, economy, ethics and policy), which is developed for comprehensive understanding of the factors influencing individuals' decision-making. The data were collected from 110 university students. The findings indicated that while 65% university students do not support GMOs 35 % support, regardless of their major. With respect to reasons, similarities and the differences are observed between supporters and non-supporters as well as between science and non-science majors. For both comparisons, science- and environment-based reasons were found to be the most effective in shaping university students' decisions, followed by other reasons in differing orders. The implications are discussed for addressing SSI in college classes.*

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Introduction

SOCIO-SCIENTIFIC issues (SSIs) refer to complex, controversial, and often value-laden topics involving science and technology, as well as social, ethical, and environmental considerations (Zeidler & Nichols, 2009). Example of these topics includes cloning, gene therapy, genetically modified organisms, nuclear power plants, water consumption, and global climate change. Even though these issues are generally open-ended and do not have a single "right" answer, it helps people to engage in critical thinking and informed decision-making. Due to their interdisciplinary nature, they require individuals to consider scientific evidence, social impact, values, cultural norms, and personal beliefs. Close to people's lives, socio-scientific issues offer a personal engagement with these issues. In this way, they can be encouraged to engage more in thinking critically and making informed decisions on those issues (Rundgren & Rundgren, 2010). When addressing these socio-scientific issues, individuals must engage in multi-faceted thinking and analysis (Fowler & Zeidler, 2016; Sadler, 2004; Zeidler & Keefer, 2003).

Cassidy and Kurfman (1977) define decision making as the process of selecting personal or public judgments by considering alternatives. When making a decision on a socio-scientific issue, one must engage in various reasoning and discussion processes to produce and evaluate different options, judge them, and compare existing options with each other before deciding on a socio-scientific issue (Demiral & Türkmenoğlu, 2018). Due to their complex nature, decision-making about SSIs are particularly challenging (Gresch et al., 2013). An example of such a complication is in the production and consumption of genetically modified organisms, which has become one of the most controversial issues of our time (Legge Jr. & Durant, 2010). Dealing with socio-scientific issues, such as genetically modified organisms, presents individuals with complex decision-making situations regarding scientific, economic, policy, environmental, and ethical considerations. Even though consideration of these perspectives changes based on a case, it is crucial to understand how various perspectives influence the decision-making of individuals with different backgrounds.

The study by Rundgren and Rundgren (2010) suggests that value, personal experience, and knowledge are some of the key factors that influence individuals' reasoning about SSIs. To gain a comprehensive understanding of the factors influencing individuals' decision-making, a holistic approach is proposed by Rundgren and Rundgren (2010). The SSI Model was developed, consisting of six areas: Sociology/culture, Environment, Economy, Science, Ethics/morality, and Policy (SEE-SEP). It is suggested that the combination of value, personal experience, and

knowledge influence how these six areas of reasons are interpreted and decisions are made by individuals.

The purpose of this study is to analyze the decisions university students make regarding production and use of GMOs from a holistic viewpoint. The implementation of this model allows for a more in-depth examination of the issue. University classes for students majoring in science and non-science differ in their content and nature, emphasis and discussions on socio-scientific issues. Hence, this study focuses on the college students' reasoning patterns concerning socio-scientific issues based on their majors.

Awareness of the prioritization of factors influencing the choices made can inform suggestions to develop educational interventions for a comprehensive understanding of science and technology related issues in society. Furthermore, the research findings present opportunities for further discourse and suggestions for implementation within interdisciplinary education. These recommendations are aimed at improving the competence of students and the public to engage in dialogue and make informed decisions about socio-scientific issues. Using the SEE-SEP model to analyze college students' decision-making patterns can aid in the discussion and development of a systematic framework for educating individuals on complex social and environmental problems.

SEE-SEP Model in the Context of Socio-scientific Issues

Sadler (2011) emphasizes that socio-scientific problems have more than one perspective beyond their relationship with science. Information obtained from disciplines such as economy, policy and environment have an important effect on understanding socio-scientific issues. "SEE-SEP model" developed by Chang Rundgren and Rundgren (2010) emphasizes the multidisciplinary nature of SSI. The SEE-SEP model has been applied in numerous studies to analyze individuals' reasoning about SSI situated in various domains. It is predominantly used in research with high school students (Almarlind & Sullivan Hellgren, 2021; Chang Rundgren et al., 2011; Christenson et al., 2012; Christenson et al., 2014; Eriksson & Rundgren, 2012; Garrecht et al., 2021). When reviewing the studies conducted with university students, it is found that the participants are generally limited to pre-service science teachers (Cebesoy, 2014; Karisan & Cebesoy, 2021; Menke et al., 2022; Türköz & Öztürk, 2020).

Cebesoy (2014) explored the decision-making abilities of science teachers within the context of SSI related to genetics. It has been discovered that several factors influence science teachers' decisions on SSI. Moral considerations were identified as the most influential factor for teacher candidates' decisions. Additionally, economic, legal, technological, and

religious concerns were also deemed significant. Moreover, Karisan and Cebesoy (2021) investigated justifications for socio-scientific issues by pre-service science teachers. In this study, two SSI scenarios related to genetics were presented, and written reports of participants were analyzed using the SEE-SEP model. The study's findings suggested that pre-service teachers' arguments are mainly centered on the science and ethics/morals dimensions. Conversely, policy, sociology/culture were rarely used as justifications and economics had the least amount of mention. Menke et al. (2022) investigated the knowledge domains utilized by pre-service science teachers during deliberation on a socio-scientific issue. Participants were presented an article and asked to articulate their thoughts using the think-aloud protocol. This methodology allowed for a more authentic representation of their thinking processes, rather than limiting it to the SEE-SEP framework. In addition to the subject areas defined by SEE-SEP, this study also included knowledge areas of media literacy and the nature of technology. The study concluded that pre-service teachers benefited the most from media literacy and the nature of technology fields. In contrast to previous studies, Türkoz and Öztürk (2020) examined the decisions and justifications of prospective science teachers on three distinct scenarios involving sugar intake during pregnancy, processed milk, and nuclear power plants based on the SEE-SEP model. The study showed that pre-service teachers take different dimensions into account in different SSI issues, but in the end they make decisions about SSIs by thinking about the issue in a holistic way and taking all dimensions into account.

There are several studies conducted with pre-service, in-service science teachers and secondary school students (Almarlind & Sullivan Hellgren, 2021; Chang Rundgren et al., 2011; Karisan & Cebesoy, 2021; Menke et al., 2022). However, studies that have been conducted with university students of different majors are very limited. It is crucial for not only educators but also individuals from various fields to be scientifically literate citizens. Therefore, it is important to examine the reasoning patterns of university students from different majors to see the broader picture of their decision-making about specific SSI. The following subsection reports on studies conducted with students from both science and non-science majors to explore university students' decision on socio-scientific issues.

Science Major and Non-Science Major Students' Decision-Making on Socio-scientific Issues

The literature reveals limited research on the decision-making processes of university students regarding socio-scientific issues, with the exception of science teacher candidates (Chang & Chiu, 2008; Eş & Türkoğlu, 2021). Although few studies compare science majors and non-science majors, the

findings of these studies point to important issues. For instance, Eş and Türkoğlu (2021) included theology students as non-science majors, and science teacher education students as science majors in their study. They analyzed the mental model drawings of nuclear power plants from both groups. Firstly, all participants gave their decision on the construction of a nuclear power plant in their respective regions, followed by drawing what comes to their mind when thinking of nuclear power plants. Data were analyzed using the SEE-SEP model detailed earlier. Results show that theology students viewed constructing nuclear power plants positively, while science majors viewed it negatively. The drawings of theology students emphasized economic impacts, whereas the science majors focused on environmental effects. Irrespective of their majors, the drawings of both student groups exhibited the most emphasis on the subject of the environment, with subsequent mentions on technology, economy, and science (Eş & Türkoğlu, 2021).

Christenson and colleagues (2014) compared students in social sciences and science programs with respect to the supporting reasons they used when discussing global warming, genetically modified organisms, nuclear energy and consumer behavior issues. The analysis revealed that social science majors produce more justifications than science majors. Furthermore, irrespective of their major, students primarily relied on values in their arguments.

Since previous studies suggest a difference in reasoning between science majors and non-science majors, it may be valuable to examine which factors students in both fields prioritize when making decisions about a specific socioscientific issue. This is particularly significant since both groups of graduates will have a say in many socio-scientific issues as citizens. Investigating how the decision-making of science majors and non-science majors are influenced by variety of reasons may provide valuable insights with respect to what educational experiences can be provided to the students in an era where science and technology dominated dichotomic societal issues are frequently present.

Focus of the Research

The study aimed to analyze the factors that influence university students' decision-making regarding the development and use of genetically modified agricultural products. Two research questions were formulated to examine the patterns of reasoning behind their choices.

- What is the priority of reasons affecting the university students' decisions for the production and use of genetically modified agricultural products?

Table 1. The Number of the Participants in Terms of Gender, Major and Year the University.

	Gender			Major		Year					
	Female	Male	Other	Science	Non-science	Freshman	Sophomore	Junior	Senior	Master'	PhD
	75	32	3	55	55	9	12	12	41	30	6
Total	110										

- Is there a difference between major and non-science major university students' reasons for the production and use of genetically modified agricultural products?

Methodology

Research Design

Descriptive research (Baker, 2017) was conducted to examine the factors influencing the decisions made by the university students, both science and non-science majors, regarding SSI. The study aimed to provide an overview of the reasons that influence their decision-making. The data was collected through a written questionnaire completed by 110 university students. The data were analyzed to investigate the prioritization of the factors considered in the students' decision-making on SSI depending on their major.

Participants

One hundred and ten university students, consisting of 55 non-science majors and 55 science majors, volunteered to take part in this study. The group comprised students at all levels, from freshmen to PhD students, from a university in Istanbul, Türkiye. For the purposes of the study, psychology, philosophy, linguistics, economics, business and sociology students were grouped as non-science majors and all other science, engineering and technology majors were grouped as science majors.

The study's primary objective is to examine students' majors, not to compare them based on their gender or year in the university. Nonetheless, we collected information on the students' gender and year in the university to ensure variability. The study included 75 female students, 32 male students, and 3 students who opted not to disclose their gender. In addition, the participants included 9 freshmen, 12 sophomores, 12 juniors, and 41 seniors, 30 masters' and 6 PhD students at the same university (**Table 1**).

Table 2. The Reasons Offered to Students from Science, Economy, Environment, Ethics, and Policy Viewpoints to Support or not to Support Using and Producing Gmos.

Domain of Viewpoints	Reasons supporting production and use of GMOs	Reasons Not supporting production and use of GMOs
Science	Some studies indicate that due to the high nutritional value of genetically modified agricultural products, it contributes to a healthy and balanced diet, especially for people living in low socio-economic areas.	Some studies state that consuming genetically modified foods may cause unexpected health problems and allergic reactions.
Economy	Producing GMOs contributes to the economic development of the country because GMOs can be produced at less cost.	Since genetically modified seeds are of foreign origin and are sterile, they cause economic foreign dependency in agriculture.
Environment	Since genetically modified agricultural products are produced in a smaller area and using much less pesticides, they have less negative impact on the environment than conventional agricultural production.	There is always a possibility that genetically modified products may become the dominant species by genetically infecting other natural species and disrupt the ecological balance by damaging biodiversity.
Ethics	Genetically modified products are a method that could provide a solution to the problem of hunger in the world.	The use of genetically modified products as animal feed violates animal rights.
Policy	The use of genetically modified products as animal feed has been allowed since 2011 with the decision taken by the Biosafety Board in our country.	In 2010, the use of genetically modified products in baby food and supplementary foods for young children was prohibited in our country.

Data Collection Tool

Although interviews are commonly used as a data collection method in many studies on socio-scientific issues, recent research indicates that written formats can also be employed to analyze individuals' decision-making regarding SSI (Capkinoglu et al., 2019; Ladachart & Ladachart, 2021). In this study, researchers distributed an anonymous survey to collect data that included informed consent. Students were requested to prioritize the reasons for their decision on a socio-scientific issue; production and use of genetically modified agricultural products. This topic involves economic, ecological, social, biotechnological and ethical dilemmas that help students develop a balanced understanding of risk and benefit (Cinici, 2016). This multidimensional nature of GMOs can allow students to evaluate this SSI from a multiple perspective.

The questionnaire was prepared by using Google Forms because online tools are a convenient and faster way to reach the students. The questionnaire was divided into three parts for them. The first part asked about the students' personal information regarding gender, year at the university and their majors. The year at the university and gender information were asked to ensure variability among the students and was not included in the analysis. The second part of the questionnaire includes a figure including five pros and five cons of using and producing genetically

modified agricultural products. The students were asked to read these statements to decide on a position. Each statement was written by considering the key elements of the SEE-SEP model (Rundgren & Rundgren, 2010). The SEE-SEP model includes sociology/culture, environment, economy, science, ethics, and policy perspectives but for this study sociology/culture perspective was left out because relevant opposing reasons were not available for this dimension in this specific context. Two opposite statements which could be the reasons to support or not to support GMOs were written for each viewpoint; environment, economy, science, ethics, and policy (See **Table 2**).

The study is not concerned with whether students support or oppose GMOs, but rather seeks to determine which dimensions (environmental, economic, scientific, ethical, and policy-based) have the greatest impact on their decisions. To this end, all statements were presented to students in a circular figure where opposing statements were in identical color to avoid leading students prioritizing when reading. Subsequently, after reading each statement, students were prompted to indicate their stance on GMOs. This, in turn, resulted in the display of five statements on their screen based on their choice of supporting or not supporting. Finally, the students were asked to re-read each reason carefully and decide on the order based on their priority in making their decision.

The Google Form was first created and then sent to two science education researchers who are experts in socioscientific issues to get feedback to ensure the content of the survey, the corresponding oppositeness of the statements, comprehensibility, and technical functionality. Their feedback indicated that the questions were clear, the instructions were understandable, and the form worked as intended. All questions were set as mandatory to prevent incomplete submissions. No technical issues were encountered during the actual data collection process.

Subsequently, the online survey was administered to a total of 110 student volunteers from the university. Students were informed of the study, their consent received in the first page of the survey and only requested to disclose their gender, year in the university, and majors to maintain anonymity.

Data Analysis

The study aimed to not only determine the differences between groups, but also examine the order of students' reasons for SSI decisions. To achieve this goal, responses were analyzed to find out weighted average for each reason among the order of multiple reasons for each participant group (supporting GMOs-Not Supporting GMOs and, Science and Non-science majors).

Following formula was used for this purpose;

$$\frac{X_1W_1 + X_2W_2 + X_3W_3 \cdots X_NW_N}{Total\ participants}$$

In this formula W is weight of the ranked position and X is a response count for answer choice. Each student's most preferred choice (ranked as #1) has the largest weight, and their least preferred choice has a weight of 1. The reasons given to the students are science, economy, ethics, policy, and environment based. It means that there are 5 choices to order. The #1 choice of the students has a weight 5, the #2 choice has a weight of 4, the #3 choice has a weight of 3, the #4 choice has a weight of 2, and the #5 choice has a weight of 1. For example, the score was calculated for science-based reason of science major students as follows.

[(23*5) + (18*4) + (8*3) + (5*2) + (0*1)] / 55 = 221/55 = 4

The same formula was used to calculate each reason's scores in terms of students' major and their preference for production and use of GMOs. The results of the analysis are displayed using tables.

Results

Comparison of the reasons affecting the university students' decision-making about GMOs

The questionnaire consisted of five statements for two options: supporting or not supporting genetically modified agricultural products (GMOs). The statements, which explored the impact of environment, policy, ethics, economy, and science on students' decision-making related to GMOs, aimed to identify general patterns. The study featured 55 non-science and 55 science majors. **Table 3** shows that 39 students support genetically modified organisms (GMOs) while 71 do not. Of those who support GMOs, 21 are science majors and 18 are non-science majors.

Table 4 shows the general result of students rank multiple reasons in order of preference. According to the results, it can be said that science and environment-based reasons are most effective reasons to shape students' decision on GMOs regardless of their majors and their choice to produce and use GMOs with equal weights. Furthermore, first two reasons are followed by ethics and policy, and economy in descending order to shape the students' decisions. This hierarchy suggests that students prioritize factors they perceive as more directly linked to health, safety, and ecological impact over

Table 3. The Number of the Students Who Support and do not Support Production and Use of Genetically Modified Agricultural Products (Gmos).

	Support GMOs	Non-Support GMOs	Total
Science Major	21	34	55
Non-science major	18	37	55
Total	39	71	110

Table 4. Order of Student's Reasons Regardless of their Position on Production and Use of Genetically Modified Agricultural Products.

Reason Domain	Score
Science	3.9
Environment	3.9
Ethics	2.5
Policy	2.4
Economy	2.3

Table 5. Order of Students' Reasons Based on their Support of Production and Use of Genetically Modified Agricultural Products.

Reason Domain	Support GMOs Score	Non-Support GMOs Score
Environment	4.1	3.8
Science	3.8	3.9
Ethics	3.2	1.9
Economy	2.5	2.6
Policy	1.4	2.8

economic or regulatory concerns when forming opinions about GMOs. Ethics and policy received moderate attention because students may have had limited exposure to societal and regulatory issues as GMOs are highly restricted in Turkish market. The low emphasis on economic factors may reflect less awareness of economic consequences. These insights highlight the need for interdisciplinary approaches in education that integrate scientific facts with ethical, policy, and economic contexts to foster more comprehensive critical thinking and decision-making skills among the students.

Table 5 indicates that the students who support GMOs ranked environment and science-based reasons first and second respectively. On the other hand, the students who do not support GMOs ranked science-based

Table 6. Science and Non-Science Major Students' Ranking Multiple Reasons in Order of Preference.

Reason Domain	Science Major Score	Non-Science Major Score
Science	4	3.6
Environment	3.9	3.9
Economy	2.5	2.7
Ethics	2.3	2.4
Policy	2.3	2.3

reason first and environment-based reason second. Dramatic differences of the importance given to ethics and economy-based reasons between the groups are observed. While policy reasons having the least impact on students' decisions who support GMOs, ethics is the least important reason for the non-supporters. The results indicated that the GMOs supporters gave less importance on policy reasons. This may suggest that the students' decision was driven more by environmental, ethics and scientific reasoning than by existing policies. Although the content of existing policies may align with these views, the participant might have already held these values before encountering the policies. Therefore, while the policies may have reinforced their stance, they may not have been the main driving factor. Additionally, the limited influence of policies in the decision-making process may be due to the students questioning their credibility or authority. Even if the policies supported GMOs in a positive way, the university students' individual value system and independent thinking may have led them to view these policies merely as background information. Non-supporters rated ethics as the least important factor. These results suggest educational programs should emphasize scientific and environmental information while also addressing ethical, economic, and policy aspects to foster well-rounded understanding and critical thinking about GMOs.

Table 6 shows that science major students indicate that science and environment-based reasons is the most effective in their decision to support or not support GMOs. On the other hand, non-science major students' ranked environment- based reason first and science-based reason second. It also shows that policy, ethics, and economy-based reasons are less effective for their decisions than science and environment-based reasons for both groups of students. Additionally, it is observed that students in non-science majors give more weight to economy and ethics reasons compared to science major students. Although there were differences in the scoring, the consistency in the overall ranking suggests that areas such as economy, ethics, and policy should also be considered essential components of the teaching and learning process. This indicates that decision-making on socio-

scientific issues should not be limited solely to science and environmental aspects but rather encompass a broader spectrum of interdisciplinary considerations.

Conclusion & Discussion

This study examined the reasons affecting the science and non-science major students' decision-making for the production and use of genetically modified agricultural products. Five reasons supporting GMO and five reasons not supporting GMO were presented to the students. Reason statements were written in a way that each of them exclusively belonged to specific areas in SEE-SEP framework except social/cultural dimension.

In total, the number of the students who support genetically modified organisms is 39 whereas the number of the students who do not support GMOs is 71. In terms of majors, 21 of science major students support GMO whereas 18 of non-science major students support GMOs. This result is in line with the previous studies that revealed a trend towards negative perceptions about controversial issues (Cinici, 2016; Finucane and Holup, 2005; Klingeman & Hall, 2006; Sönmez & Kılınç, 2012). For example, Cinici (2016) found that teacher candidates generally tend to ignore or distrust positive findings about GMOs. Li and Bautista (2019) also found that preservice science teachers have negative attitude towards GMOs.

Students supporting GMOs decided to support GMO after reading 10 reasons in total. When asked to rank the 5 reasons written in support of GMO according to the effect on their decision, it was seen that the most students chose the environmental concerns reason. This was followed by reasons for scientific, ethical, economic, and policy issues respectively. These results show us that policy related reasons have the least impact on students' support for GMOs. When we look at the students who do not support GMO, it is seen that science and environmental reasons are the most effective in their decision followed by policy, economy and ethical reasons in descending order.

Environmental and science reasons have the most important impact on the students' decisions regardless of their choices to support or not support GMOs. In another study with teachers and students, about 60% of the all participants thought that GMOs would pose a risk to the environment, while more than half of the teachers disagreed, decided that GM organisms do not pose a threat to biodiversity, and it should be encouraged for better food production (Mohapatra et al., 2010). In the current study, we can see that environmental reasons influence the decision of both supporters and non-supporters of GMOs the most. At this point, we see that both groups prioritize environmental reasons, but come to the opposite decisions.

In the current study it was found that while policy reasons having the least impact on students' decisions who support GMOs, it is the third reason for the non-supporters in the order. Recent studies suggest that (Erkan et al. 2021; Pang 2023) suggests that trust in the government, scientists, or media can influence perceptions about GMOs. Gutteling et al. (2006) found that people with a high level of trust in government have a more positive attitude towards GM foods. However, in this study, policy-related reasons had the least influence on university students' decisions to support the production of GM crops. Aerni (2011) stated that the idea that consumers will not accept GM crops only for policy reasons is not accurate. For this reason, the university students may have prioritized environmental and scientific reasons over policy in their decision-making process. Also, ethics is the least important reason for the non-supporters whereas it is third reason for students supporting GMOs in the current study. Wu (2013) also found that moral or ethical issues were not expressed by the students about the genetically modified foods in the eastern context.

Some of the studies indicated differences in the reasoning performance and priorities of major and non-science major students (Christenson et al., 2014; Zeidler & Schafer, 1984). However, in the current study there is no noticeable difference among the pattern of the reasons for science and non-science major students. For both groups, science and environment-based reasons are most effective to shape their decisions and policy-based reasons are less effective. In contrast, Eş and Türkoğlu (2021) found a difference between science and non-science majors who chose theology students as non-science majors. Individuals' reasoning may be context dependent, and therefore a different socio-scientific issue may have led to different results (Topcu et al., 2010).

In this study, the sample consisted of 110 students from a single university in Türkiye. This may limit the generalizability of the findings. Including university students from multiple universities across different regions and socio-cultural contexts could provide a broader understanding of the topic and increase the generalizability for future research. Therefore, it is recommended that future studies expand the sample with respect to quantity of participants and diversity of context.

As tomorrow's workforces, policy makers, or simply citizens, all university students should have the ability to examine complex socio-scientific issues and be educated as scientifically literate individuals who can make decisions about these issues. Although this study shows us that students generally care about environmental and science-based reasons, it should be examined why the belief in other reasons is low.

This study actually lays the groundwork for future studies. Putting the reasons based on policy, economy and ethics at the end, the students stated that these reasons had the least effect on their decisions. However

educational programs need to encourage students to actively participate in problem solving and decision-making, using different subject areas, interdisciplinary thinking on various dimensions. Hence, in various classes experiences should be designed for all students to improve their decision-making skills on socio-scientific issues. In these experiences, scientific data, environmental impacts, policy, ethical and economic aspects can be addressed together in multidimensionally, helping students to critically evaluate controversial topics (Ruth et al., 2016).

Beyond the context in which the study took place, the findings of the study can also provide a framework for international community. The methodological approach used in this study can provide a roadmap for similar studies that can be conducted in different contexts with various SSIs relevant in those contexts.

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