THE RELATIONSHIP BETWEEN EIGHTH GRADE STUDENTS' NATURE OF SCIENCE UNDERSTANDING AND THEIR INFORMAL REASONING ON SOCIOSCIENTIFIC ISSUES

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ABSTRACT

THE RELATIONSHIP BETWEEN EIGHTH GRADE STUDENTS' NATURE OF SCIENCE UNDERSTANDING AND THEIR INFORMAL REASONING ON SOCIOSCIENTIFIC ISSUES

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The purpose of this study was to explore the relationship between eighth grade students' nature of science understanding and their informal reasoning on socioscientific issues. The study was performed with 414 8th grade middle school students in four different public middle schools of Turkey in Ankara, Altındağ. In the present study, correlational research approach was used. Background information about participants was collected by personal information questionnaire. The participants' nature of science (NOS) understanding was determined through Views of Nature of Science Elementary Level (VNOS-E) questionnaire whose open-ended questions assess empirical-based, tentativeness, and subjectivity tenets. The participants' informal reasoning was determined by using the open-ended informal reasoning questionnaire focused on three different socioscientific issues: global warming, acid rain, and genetically modified food. The findings of Pearson correlation analysis revealed that in each of the three different socioscientific issues and in total, there was statistically significant and positive correlation between informal reasoning quality and varieties of informal reasoning modes. The results of multiple regression analysis revealed that all three tenets of NOS made statistically significant unique contributions to the prediction of informal reasoning quality score in global warming issue and genetically modified food issue. Empirical-based and tentativeness tenets made statistically significant unique contributions to the prediction of informal reasoning quality score in acid rain issue. Thus, it was concluded that there was statistically significant relationship between eighth grade students' nature of science understanding and their informal reasoning in global warming, acid rain, and genetically modified food issues.

Keywords: Socioscientific Issues, Informal Reasoning, Nature of Science

ÖZ

SEKİZİNCİ SINIF ÖĞRENCİLERİNİN BİLİMİN DOĞASI ANLAYIŞLARI İLE SOSYOBİLİMSEL KONULARDAKİ İNFORMAL MUHAKEMELERİ ARASINDAKİ İLİŞKİ

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Bu çalışmanın amacı, sekizinci sınıf öğrencilerinin bilimin doğası anlayışları ile sosyobilimsel konulardaki informal muhakemeleri arasındaki ilişkiyi incelemektir. Araştırma, Türkiye'nin Ankara ili Altındağ ilçesindeki dört farklı devlet ortaokulunda öğrenim gören 414 sekizinci sınıf öğrencisi ile gerçekleştirilmiştir. Bu çalışmada ilişkisel araştırma yaklaşımı kullanılmıştır. Katılımcılar ile ilgili bilgiler kişisel bilgi ölçeği ile toplanmıştır. Katılımcıların bilimin doğası anlayışı, açık uçlu soruları deneysel temelli, değişebilirlik ve öznellik ilkelerini değerlendiren Bilimin Doğası İlköğretim Düzeyi anketi (Views of Nature of Science Elementary Level (VNOS-E)) ile belirlendi. Katılımcıların informal muhakemeleri, iklim değişikliği, asit yağmuru ve genetiği değiştirilmiş gıdalar olmak üzere üç farklı sosyobilimsel konuya odaklanan açık uçlu informal muhakeme anketi kullanılarak belirlendi. Pearson korelasyon analizinin bulguları, üç farklı sosyobilimsel konunun her birinde ve toplamda, informal muhakeme kalitesi ile informal muhakeme biçimlerinin çeşitliliği arasında istatistiksel olarak anlamlı ve pozitif bir ilişki olduğunu ortaya koymuştur. Çoklu regresyon analizinin sonuçları, bilimin doğasının üç ilkesinin de iklim değişikliği ve genetiği değiştirilmiş gıda konularında informal muhakeme kalite puanının tahminine istatistiksel olarak anlamlı katkılar yaptığını ortaya koydu. Deneysel temelli ve değişebilirlik ilkeleri, asit yağmuru konusunda informal muhakeme kalite puanının tahminine istatistiksel olarak önemli katkılar sağlamıştır. Böylece, sekizinci sınıf öğrencilerinin bilimin doğası anlayışları ile iklim değişikliği, asit yağmuru ve genetiği değiştirilmiş gıda konularındaki informal muhakemeleri arasında istatistiksel olarak anlamlı bir ilişki olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Sosyobilimsel Konular, Informal Muhakeme, Bilimin Doğası

To my beloved family

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ABBREVIATIONS

AAAS: American Association for Advancement of Science

COST: Conceptions of Scientific Theories Test

IPST: Institute for the Promotion of Teaching Science and Technology

MEST: Ministry of Education Science Technology

NGSS: Next Generation Science Standards

NOS: Nature of Science

NRC: National Research Council

NSTA: National Science Teachers Association

PISA: Programme for International Student Assessment

SSIs: Socioscientific Issues

STSE: Science, Technology, Society, Environment

TAP: Toulmin's Argument Pattern

VNOS-A: Views of Nature of Science A

VNOS-B: Views of Nature of Science B

VNOS-C: Views of Nature of Science C

VNOS-D: Views of Nature of Science D

VNOS-E: Views of Nature of Science E

VOSTS: Views on Science-Technology-Society

CHAPTER 1

INTRODUCTION

1.1 Scientific Literacy and Socioscientific Issues

Scientific literacy basically defines the knowledge students should acquire, and the practices students should learn to perform throughout their science education progress (Sadler & Zeidler, 2009). However, there are different descriptions of scientific literacy in the literature.

Scientific literacy term was firstly published and presented as an aim of science education for the first time in an article of Paul Hurd (Hurd, 1958) in the late of 1950s. Hurd (1958) emphasized the necessity of defining human values, understanding current social, political, and economic problems while modifying educational science objectives. According to Hurd (1998), scientific literacy is an ability which provides citizens to think logically about "science in relation to personal, social, political, economic problems, and issues that one is likely to meet throughout life" (p. 410). As the importance of scientific literacy discussed, various institutions tried to define the features of scientifically literate persons. The earlier definitions broadly focused on the necessity of understanding natural world, being aware of the competencies and limitations of science and technology, and having the ability to think scientifically in order to make decisions (e.g. American Association for Advancement of Science (AAAS), 1989; National Research Council (NRC), 1996). The more recent definition of NRC (2007) described the scientifically literate students is given below. Similar to most of the earlier definitions of scientific literacy, this definition also emphasized understanding science and scientific knowledge.

> "Students who are proficient in science know, use and interpret scientific explanations of the natural world; generate and evaluate scientific evidence and explanations; understand the nature and development of scientific knowledge; and, participate productively in scientific practices and discourse." (NRC, 2007, p. 2)

Holbrook and Rannikmae (2009) mentioned that the definitions of scientific literacy should include socioscientific situations which promote the appearance of responsible citizens. Socioscientific situations are associated with the nature of science (NOS) understanding which provides interacting with different aspects such as environmental, economic, politics, social, and moral during decision-making process about socioscientific situations (Holbrook & Rannikmae, 2009). All in all, according to Holbrook and Rannikmae (2009), scientific literacy is:

> "Developing an ability to creatively utilize appropriate evidence-based scientific knowledge and skills, particularly with relevance for everyday life and a career, in solving personally challenging yet meaningful scientific problems as well as making responsible socioscientific decisions; developing collective interaction skills, personal development and suitable communication approaches as well as the need to exhibit sound and persuasive reasoning in putting forward socioscientific arguments" (p. 286).

In this definition, providing individuals with responsible decision-making process and skilled reasoning on socioscientific issues were seen as critical for scientific literacy. Similarly, Zeidler and Nichols (2009) specified that scientific literacy should be closely related to socioscientific issues and support personal cognitive and moral developments which include the use of cultural, discourse, case-based and nature of science issues (Zeidler & Nichols, 2009). Later on, Programme for International Student Assessment (PISA) (2015) specified the characteristics of scientifically literate person by focusing on the social dimension. According to PISA (2015), understanding and explaining the social extent of scientific information, analyzing how scientific and technological improvement have effects on humans' lives, making decisions on controversial issues involving scientific and social dimensions, and commenting on the latest scientific news reported by the media are some of the most important characteristics of scientifically literate person. More recently, Yacoubian (2018) specified one of the important fragments of scientific literacy as democratic decision-making on science-based social issues. These showed that as time passes by, emphasis on the social dimensions of science has been become clear in scientific literacy definitions.

The approaches emphasizing the social aspect of scientific literacy clearly showed the importance of teaching socioscientific issues in science classrooms to educate scientifically literate citizens. Socioscientific issues (SSIs) are scientific issues having societal and moral dimensions and dilemmas (Zeidler, Sadler, Simmons, & Howes, 2005), and this controversial nature of SSI causes conversation and discussion among students (Zeidler & Nichols, 2009). Kolstø (2001) mentioned that SSIs cause disagreements about practicing these issues because there are some knowledge and claims expressing the harms of these issues for the health or the environment. Since these issues take place in media and students encounter with these issues in their daily lives, giving priority to these issues in science education is very important (Kolstø, 2001). In other words, as science and technology developed, scientific studies which include controversial issues such as genetically modified food and different energy source like nuclear power plant increased; therefore, the students should learn to make decisions about these kinds of issues in science classrooms.

With the understanding of socioscientific issues' importance for scientific literacy and the necessity of these issues in science classes in modern society, countries integrated SSIs into their science curriculums. In 2013, the term of the socioscientific issue was directly located in the Turkish science curriculum for the first time. However, before 2013, these issues were covered under STSE (Science, Technology, Society, Environment) objectives (Topçu, Muğaloğlu, & Güven, 2014). Teaching of SSIs was determined as one of the fundamental ten goals of 2018 Turkish science curriculum (MEB, 2018). Thus, SSIs turn into a more considerable part of science education to improve future generation's scientific literacy.

Socioscientific issues were involved in science education with the target of raising students as qualified decision-makers who able to find various resolutions about these contentious issues, encouraging their moral and intellectual improvement (Zeidler et al., 2005; Zeidler & Nichols, 2009). According to SSI curriculum, students are expected to make analyses and interpretation of evidences some of which are contradictory with their own beliefs, and they are expected to argue on different scientific, social, and moral viewpoints to make decisions about the problems (Zeidler, Sadler, Applebaum, & Callahan, 2009). In this decision-making process, SSIs are negotiated with informal reasoning instead of formal reasoning because these issues involve open-ended and ill-structured problems consisting of societal, moral or ethical contradictions (Sadler & Zeidler, 2005a; Zeidler et al., 2005) and students cannot make formal reasoning or clear-cut solutions for these problems. It is obvious that informal reasoning is necessary for the implementation of SSIs in science classrooms. Therefore, investigating the quality of students' informal reasoning on SSIs was one of the aims in this study. In the following section, SSI and informal reasoning were explained.

1.2 Socioscientific Issues and Informal Reasoning

As mentioned above, SSIs are controversial issues including societal, moral, and ethical dilemmas (Sadler & Zeidler, 2005a; Zeidler et al., 2005). These issues are scientific issues presenting open-ended social problems such as gene therapy, cloning, genetically modified foods which result from biotechnological improvements and such as global climate change, nuclear power plant, pollutions which cause environmental challenges (Presley et al., 2013; Sadler & Zeidler, 2005a). As scientific and technological improvements increased, the controversial issues including social problems have been increasing. Therefore, the citizens attending discussions to make decisions about the issues concerning the whole world were needed by all nations. That's why the citizens should be educated to enable them to attend decision making processes efficiently and make qualified decisions.

In the process of decision making on socioscientific issues, students should use informal reasoning because informal reasoning is proper to use in the complicated issues which do not have definite solutions like contentious SSIs (Sadler & Zeidler, 2005a). To clarify, while formal reasoning represents certain premises based upon experimental assistive outcomes and deductive logic procedures, informal reasoning represents uncertain and alterable premises in consequence of critical thinking of information so arguments can be constructed from both opposite positions in informal reasoning (Perkins, Faraday, & Bushey, 1991). Means and Voss (1996) defined informal reasoning as goal-dependent process, which means while individuals think about a question or issue which are ill-structured in order to answer or make a decision, they consider about the evidences related to the issue and assert reasons to support the claim they want to support. Similarly, Zohar and Nemet (2002) also specified the usage of informal reasoning for ill-structured problems having no clear-cut solutions, but they defined some points of the concept more usefully as follows:

> "Informal reasoning is the reasoning applied outside the formal contexts of mathematics and symbolic logic. It involves reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of particular propositions or decision alternatives" (p. 38).

Since socioscientific issues include ill-structured and open-ended problems, informal reasoning is proper for the process of decision-making on these issues rather than formal reasoning. There are research studies which introduced argumentation as a way of expressing informal reasoning (e.g., Means & Voss, 1996; Sadler, 2004; Sadler & Zeidler 2005a; Zohar & Nemet, 2002). For example, Means and Voss (1996) mentioned the informal reasoning is an ability of generation and evaluation of arguments. Similarly, Zohar and Nemet (2002) explained that argumentation is often examined as the main part of informal reasoning. Toulmin's argumentation framework has been used as the base of argumentation literature (Erduran, 2007). Hitchcock (2005) clearly mentioned that Toulmin's Argument Pattern (TAP) model is most frequently preferred to appraise arguments, and researchers used this model to also evaluate informal reasoning. Most of the researchers studying on informal reasoning about socioscientific issues specified the patterns of informal reasoning as (supportive) arguments, counterarguments, and rebuttals which are among the patterns of the TAP model (e.g. Khishfe, 2012; Means & Voss, 1996; Sadler & Zeidler, 2005a; Wu & Tsai, 2007; Zohar & Nemet, 2002). Therefore, supportive argument, counterargument, and rebuttal were evaluated as patterns of informal reasoning in the present study.

While an argument is a statement supporting the conclusion by justifications or reasons (Angell, 1964; Zohar & Nemet, 2002), counterargument is an argument with a reason supporting the opposite of the conclusion offered by the participant (Means & Voss, 1996; Sadler & Zeidler, 2005a). Zohar and Nemet (2002) defined rebuttals as arguments generated to refute the counterarguments. Kuhn (1993) mentioned rebuttal is a critical part of informal reasoning because it integrates the argument and counterargument. For this reason, rebuttal is utilized as a necessity for highly qualified informal reasoning by some researchers (e.g. Kuhn, 1993; Osborne, Erduran, & Simon, 2004; Wu & Tsai, 2007). Therefore, the construction of rebuttal was accepted as indicative of high quality informal reasoning in the present study.

In recent years, the research studies about informal reasoning on SSIs have been increasing and some of these research studies examined not only informal reasoning quality on SSIs but also informal reasoning modes to comprehend participants' informal reasoning deeply (e.g. Ozturk & Yilmaz-Tuzun, 2017; Sadler & Zeidler, 2005a; Wu, 2013; Wu & Tsai, 2007). Informal reasoning modes identify the perspectives participants looking from when forming arguments like social, ecological, scientific, etc. (Wu & Tsai, 2007). Examining informal reasoning modes is important because there are findings showed the variety of reasoning modes is related to informal reasoning quality. For example, Wu and Tsai (2007) found that the individuals who generated highly qualified informal reasoning benefited from more various reasoning modes in their arguments, so they mentioned the usage of various informal reasoning modes might contribute to the informal reasoning skills. That's why the researcher of the present study investigated not only informal reasoning quality but also informal reasoning modes with the aim of exploring the relationship between informal reasoning quality and informal reasoning modes. Researchers used different classifications for informal reasoning modes in their studies. For example, Patronis, Potari, and Spiliotopoulou (1999) identified four different reasoning modes; social, ecological, economic, and practical while Yang and Anderson (2003) classified students' arguments by two perspectives; scientific-oriented and social-oriented. Different from these classifications, Wu and Tsai (2007) specified four different aspects to analyze informal reasoning modes; social-oriented, economic-oriented, ecological-oriented, and science-oriented or technology-oriented. The informal reasoning modes classification of Wu and Tsai (2007) was preferred in the present study because their classification is more inclusive than others. Social-oriented reasoning refers to the opinions based on the prosperity of the society and human sympathy, while ecology-oriented reasoning describes to the opinions based on ecology (Wu & Tsai, 2007). Also, while economic-oriented reasoning describes the opinions based on economic development, science-or-technology-oriented reasoning refers to opinions based on the limitation and strength of science or technology (Wu & Tsai, 2007).

Since informal reasoning necessitates dilemmas, the socioscientific issues which clearly cause dilemmas in society were chosen in the present study. Also, in this study, the researcher gave importance to contain SSIs, which form concerns in both global and local levels. Therefore, the SSIs included in this study are global warming, acid rain, and genetically modified food which have been discussed among societies in the world for years. In recent years, the discussions on these issues are attracting more attention, and these discussions more extremely taking place on the agenda of many countries including Turkey. That is, these issues were selected because they include essential problems; and enhancing the consciousness of students and encouraging their improvement in the way of constructing qualified informal reasoning on these issues are critical. The reason of including more than one issue was that there are research studies found SSI contexts may affect students' reasoning about the issues. To clarify, students' informal reasoning skills may differ in different SSI contexts (e.g. Khishfe, 2012; Khishfe, Alshaya, BouJaoude, Mansour, & Alrudiyan, 2017; Topcu, Sadler, & Yılmaz-Tuzun, 2010). Thus, the researcher of the present study included three different socioscientific issues global warming, acid rain, and genetically modified food.

In order to raise students as qualified decision-makers about SSIs, students should be educated about forming qualified informal reasoning. Since SSIs comprise of both social dimension and scientific knowledge in their basis, the hypothesis suggesting that understanding scientific knowledge's nature is essential for constructing qualified informal reasoning about SSIs is reasonable. Thus, students' NOS understanding was also examined in the present study in order to find out the association between students' informal reasoning quality and NOS understanding level. In the following section, how NOS understanding and its relation with SSI were operationalized in this study was clarified.

1.3 The Relationship between Nature of Science and Socioscientific Issues

Scientific knowledge has changeable and improvable nature, which has been discussing under the nature of science content in science education literature. Since socioscientific issues are also composed of scientific knowledge, the understanding about nature of scientific knowledge and informal reasoning on SSIs are related to each other. Cerbin (1988) clearly mentioned students' arguments in their informal reasoning can alter in terms of premises when new information is joined or available one alter. Moreover, there are researchers clarified the necessity of nature science understanding for teaching SSI (e.g. Zeidler & Keefer, 2003; Zeidler et al.

2005). That is, two features of scientifically literate person which are having well-developed NOS understanding and being high-qualified decision-makers by constructing qualified informal reasoning were also argued by researchers.

Lederman (1998) discussed that although there is omission for precise agreement, there are sufficient agreements about general aspects of NOS, which provides the integration of NOS into science education. According to these agreements (Lederman, 1998), seven features of scientific knowledge were designated. These are as follows; scientific knowledge is (I) "tentative" signifying scientific knowledge may alter, (II) "empirically based" meaning that scientific knowledge should be based upon empirical evidences, (III) "subjective" standing for that scientists' personal beliefs, ideas, biases, values, former practices, expectations, experiences etc. may impress scientific knowledge, (IV) includes "creativity" which means while making inferences about their observations, scientists benefit from their creativeness, (V) "socially and culturally embedded" implying scientific knowledge is impressed from the conditions of the society where knowledge is generated such as politics, economics, the culture of the society. Moreover, Lederman (1998) also mentioned that individuals should be aware of (VI) "the differences between observation and inference" which is that whereas observation is about comprehending something with senses, inferences cannot be comprehended with senses since they contain more than that, (VII) "the differences between scientific laws and theories" which is that whereas laws demonstrate the connection between phenomena, theories clarify those phenomena. Since the agreements about general aspects of science were gathered, NOS understanding became applicable in the education field. This framework including seven tenets of NOS was used by researchers to develop questionnaires about NOS to examine students' or pre, or in-service teachers' NOS understanding (e.g. Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Lederman & Khishfe, 2002; Lederman & Ko, 2004) and many researchers used these questionnaires to assess participants' NOS understanding (e.g. Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Lederman, & Abd-El-Khalick, 2000; Çetinkaya-

Aydın & Çakıroğlu, 2017; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Yoon, Suh, & Park, 2014).

In the studies investigating the relationship between nature of science understanding and socioscientific issues, there are researchers who focused on certain tenets of NOS instead of all seven tenets of NOS (e.g. Khishfe, 2012; Khishfe et al., 2017; Sadler et al., 2004; Zeidler et al., 2002). For example, Zeidler et al. (2002) included tentativeness, empirically-based, subjectivity, creativity, and cultural-social embeddedness tenets of NOS. In their study, they (Zeidler et al., 2002) highlighted NOS understanding is basically about being aware of the social dimension of science and being aware of how scientists collect, interpret and use data. Therefore, they agreed these five tenets are practicable starting points which might be closely related to SSI. Since the findings of this study (Zeidler et al., 2002) showed that tentativeness, empirically-based, and subjectivity are related with the reasoning on socioscientific issue, some researchers recently focused on these three tenets to examine this possible relationship more deeply (e.g. Khishfe, 2012; Khishfe et al., 2017). The researcher of the present study also focused on tentativeness, empirically-based, and subjectivity tenets of NOS to examine eighth grade students' perspectives on these three tenets more deeply and to find out possible associations of these tenets with informal reasoning on SSIs. As another important point, most of the studies examined the NOS understanding of participants in the context of SSI (e.g. Khishfe, 2012; Khishfe et al., 2017; Sadler et al., 2004). To clarify, the researchers used questions which were coherent with SSI context but prepared to assess NOS understanding of participants. However, in the present study, the researcher used a separate questionnaire including questions independent from the context of SSIs to assess students' NOS understanding to eliminate the threat about the realization of the possible relationship between two variables by the students.

1.4 Purpose of the Study and Research Questions

The purpose of this study is to investigate the relationship between students' nature of science understanding (based on tentativeness, empirical-based, and subjectivity tenets) and their informal reasoning on socioscientific issues global warming, acid rain, and genetically modified food. Specifically, the following research questions will be investigated:

1. What are the eighth grade students' nature of science understanding on empirical-based, subjectivity, and tentativeness tenets?

2. What are the eighth grade students' reasoning modes on socioscientific issues global warming, acid rain, and genetically modified food?

3. What are the eighth grade students' informal reasoning quality on socioscientific issues global warming, acid rain, and genetically modified food?

4. What are the relationship between the eighth grade students' reasoning modes and the quality of their informal reasoning across three different socioscientific issues global warming, acid rain, and genetically modified food?

5. How well do the three tenets of nature of science (empirical-based, subjectivity and tentativeness) predict eighth grade students' informal reasoning quality on socioscientific issues?

1.5 Significance of the Study

Since there are very limited number of studies carried out to explain the relationship between socioscientific issues and nature of science understanding in the literature, the present study is significant (Tezel & Günister, 2018; Topçu et al., 2014). Investigating the relationship between NOS and SSI is essential since some researchers hypothesized NOS understanding enables students to make effective decisions and to construct qualified informal reasoning on SSIs (e.g. Driver et al., 1996, p. 11; Zeidler et al., 2005). The relationship between NOS understanding and informal reasoning quality was generally investigated by conducting Pearson correlation analysis in the literature (e.g. Khishfe, 2012; Khishfe et al., 2017). However, in the present study, multiple regression analysis was performed to investigate the relationship between NOS understanding and informal reasoning quality more deeply. The findings provided empirical evidences for this hypothesis of science education literature. If the findings of the present study support the relationship hypothesis, science curriculum developers and educators can get feedback about how they can use NOS understanding to enable students to construct qualified informal reasoning on SSIs. In addition to the association between nature of science understanding and informal reasoning quality, the researcher of this study investigated the relationship between informal reasoning quality and variety of informal reasoning modes. This is important because there are research studies argued that the variety of reasoning modes is related with informal reasoning quality (e.g. Wu & Tsai, 2007). Thus, the findings of this study provided empirical evidence for this hypothesis. The findings can be feedback showing science educators the importance of criticizing socioscientific issues from multiple perspectives for students' informal reasoning quality.

Moreover, the socioscientific issues genetically modified food, global warming, and acid rain are selected because these issues cause concerns in both global and local levels, and they have been discussing for years. Since these issues include serious problems and has been taking place in the agenda of countries for years, raising awareness of students on these issues is important. Also, most of the studies focused on only one socioscientific issue (Aydın & Kılıç Mocan, 2019) but including more than one issue in a study is important because there are research studies suggested students' informal reasoning skills may differ in different SSI contexts (e.g. Khishfe et al., 2017; Topcu et al., 2010). Thus, including these three issues in the present study is important in order to increase students' awareness about the issues and to empirically find out if students' informal reasoning differs in different SSI contexts.

In addition, the studies on socioscientific issues in Turkey were mostly conducted with pre-service teachers; however, there is incompetent amount of empirical researches conducted with students (Özcan & Kaptan, 2020). The empirical findings attained forthrightly from middle school students is essential since these data can present feedback for the statuses of the students about NOS understanding level and informal reasoning on SSIs, and for socioscientific teaching in classrooms. The feedback about socioscientific teaching is especially essential because teaching of SSIs was determined as one of the main ten goals of 2018 Turkish science curriculum (MEB, 2018). Thanks to this feedback, science teachers and curriculum developers may produce new ideas about the implementation of SSIs in science classrooms in order to support students' scientific literacy.

CHAPTER 2

LITERATURE REVIEW

The main aim of this study was to find out the relationship between eighth grade students' NOS understanding and their informal reasoning on three different SSIs global warming, acid rain, and genetically modified food. In addition to the main aim, the study aimed to find out informal reasoning modes on three different SSIs, and to investigate the relation between the varieties of informal reasoning modes and informal reasoning quality.

In this section, first, in order to comprehend the conception of informal reasoning about SSIs in science education literature and to examine the students' conditions of informal reasoning, several research studies were summarized. Then, to comprehend the place of NOS understanding in science education and to examine students' NOS understanding situations, some research studies were reviewed. Last, the previous research studies examining the relationship between NOS understanding and informal reasoning on SSIs were analyzed in detail to address the research questions.

2.1 Informal Reasoning on Socioscientific Issues

Socioscientific issues are controversial issues including societal, ethical, and moral dilemmas causing discussions among individuals (Sadler & Zeidler, 2005a; Zeidler & Nichols, 2009). SSIs present ill-structured and open-ended problems, which prevents individuals to suggest clear-cut solutions for these problems (Sadler & Zeidler, 2005a). As science and technology improved, the number of controversial issues including societal dilemmas and causing discussions in society has been increasing. Sadler (2004) mentioned that since the medical science, molecular genetics science, and the human population causing various environmental challenges increased, SSIs excessively came forward in the present. Also, it is not surprising these kinds of issues will most probably increase in the future (Sadler, 2004). After all, students were faced with these issues in their daily lives like the issues resulting from biotechnological improvements such as gene therapy, genetically modified foods (Presley et al., 2013; Sadler & Zeidler, 2005a; Walker & Zeidler, 2007); the issues causing environmental challenges such as global climate change, nuclear power plant (Presley et al., 2013; Sadler & Zeidler, 2005a; Wu & Tsai, 2011); and the medical issues such as the effects of smoking, misuse of antibiotics (Lee, 2007; Teodoro & Chambel, 2013). Since students are faced with these socioscientific issues in their daily lives, and it is expected that these kinds of controversial scientific issues will increase in the near future, the necessity of raising students as citizens who are able to make decisions on SSIs is explained by many researchers (e.g. Kolstø, 2001; Miller, 2002).

In order to make decisions about SSIs, the process of informal reasoning was generally preferred because SSIs are complex issues and do not have clear-cut solutions (Sadler & Zeidler, 2005a). Means and Voss (1996) stated that informal reasoning is important for complex and ill-structured problems which necessitate constructing an argument to support a claim. Reasoning was defined by Cerbin (1988) as a process including "many different cognitive activities ranging from making logical inferences, to evaluating syllogisms, to constructing and supporting beliefs" (p. 4). More basically, the reasoning is the progression of generating and evaluating arguments (Shaw, 1996). Actually, only formal reasoning was seen as scientific reasoning for a long time, and constructing formal reasoning was expected from individuals in research studies (Evans, 2002, as cited in Wu & Tsai, 2007). Formal reasoning is the construction of arguments based on deductive systems such as mathematics and logic (Cerbin, 1988; Sadler, 2004). In formal reasoning, arguments are formed based on only certain premises (Cerbin 1988). Therefore, formal reasoning can be used for well-defined problems which have clear answers or solutions. However, formal reasoning is not proper to solve open-ended and ill-structured problems like socioscientific issues. In the literature, many researchers suggested that informal reasoning is proper to construct arguments for open-ended problems (e.g. Cerbin, 1988; Means & Voss, 1996; Perkins et al., 1991; Zohar & Nemet, 2002). In contrast to formal reasoning, informal reasoning includes inaccurate and changeable premises, which provides there can be arguments from both opposite positions after critical consideration of evidences (Means & Voss, 1996; Perkins et al., 1991). Since SSIs are open-ended and ill-structured problems, informal reasoning is proper to make decision on these issues rather than formal reasoning. That's why many researchers preferred to include informal reasoning within the research studies focusing on SSIs (e.g. Sadler & Zeidler, 2005a; Topcu et al., 2010; Wu & Tsai, 2007; Zohar & Nemet, 2002).

The studies made about informal reasoning on socioscientific issues focused on informal reasoning from different perspectives. According to the review of Sadler (2004), the studies focused on the expression of informal reasoning through argumentation, the relationship between NOS understanding and informal reasoning on SSIs, the evaluation of information and evidences about SSIs, and the influence of conceptual understanding on informal reasoning. More recently, the SSI decision-making frameworks used in research studies were illustrated in the review study of Fang, Hsu, and Lin (2019). It was exhibited that the studies about informal reasoning on SSIs used the frameworks which were gathered under four different titles; the modes of informal reasoning on SSIs, the quality of informal reasoning on SSIs, the modes of decision-making on SSIs, and the criteria setting and priority while constructing informal reasoning on SSIs (Fang et al., 2019). It is obvious that while assessing participants' informal reasoning, researchers used different frameworks.

Many researchers focused to evaluate the quality of informal reasoning when dealing with attendants' reasoning on the issues. Kuhn (1991) mentioned that informal reasoning quality is about coherence, internal consistency and the ability to discuss the issue from different perspectives. On the other hand, Sadler and

Zeidler (2005b) specified four specific patterns to assess the quality of informal reasoning. According to this framework (Sadler & Zeidler, 2005b), the quality of informal reasoning was determined with regard to four criteria intrascenario coherence, interscenario noncontradiction, counter-argument construction, and rebuttal construction. While intra-scenario coherence aimed to assess if the arguments support the stated position for any one socioscientific issue, interscenario noncontradiction targeted to assess if the arguments to support a position in one SSI scenario contradict with the arguments constructed in other related SSI scenarios (Sadler & Zeidler, 2005b). As it is understood, counter-argument and rebuttal construction intended to assess if participants could construct these argument structures or not (Sadler & Zeidler, 2005b). Different from these frameworks, most of the researchers specified the patterns of informal reasoning as supportive arguments, counter-arguments and rebuttals to assess informal reasoning quality (e.g. Khishfe, 2012; Khishfe et al., 2017; Wu & Tsai, 2007; Zohar & Nemet 2002). Some researchers especially assigned rebuttal construction as an indicator of high quality of informal reasoning (e.g. Kuhn, 1993; Osborne et al., 2004; Wu & Tsai, 2007) while some assigned counter-argument and rebuttal as an indicator of highly-qualified informal reasoning (e. g. Means & Voss, 1996; Sadler & Zeidler, 2005b).

Some researchers did not focus on the quality of informal reasoning in their studies but they only focused on specifying participants' informal reasoning modes which describe the viewpoints of participants in their arguments like economic, social, scientific, etc. For example, Sadler and Zeidler (2005a) mentioned that they were not interested in the quality of informal reasoning in their study. They aimed to find out 30 college students' informal reasoning patterns on the genetic engineering issues. However, in their study, researchers used the term of "modes" and "patterns" interchangeably (Sadler & Zeidler, 2005a). They established three different types of informal reasoning modes which are rationalistic, emotive, and intuitive informal reasoning modes (Sadler & Zeidler, 2005a). Although they (Sadler & Zeidler, 2005a) used "pattern" and "mode" terms interchangeably and in the same meaning, most of the researchers preferred to use informal reasoning "mode" term to specify participants' point of view in their arguments (e.g. Wu & Tsai, 2007; Yang & Anderson, 2003). Different from the classification of informal reasoning modes used by Sadler and Zeidler (2005a), Patronis et al. (1999) classified the modes of reasoning as social, economic, ecological, and practical modes in their study, which was conducted with 14-year-old students. On the other hand, Yang and Anderson (2003) conducted a study with 12th grade high school students and classified their arguments about nuclear energy use into three types of informal reasoning modes scientifically-oriented, socially-oriented, and equally disposed reasoning modes.

In recent years, researchers investigated not only informal reasoning quality or informal reasoning modes, but they focused on both informal reasoning quality and modes (e.g. Ozturk & Yilmaz-Tuzun, 2017; Topçu, Yılmaz-Tüzün, & Sadler, 2011; Wu, 2013; Wu & Tsai, 2007; Wu & Tsai, 2011). The reason of investigating both of the quality and modes is that the findings of some research studies showed that there is a relationship between variety of informal reasoning modes and informal reasoning quality (e.g. Wu & Tsai, 2007). In order to investigate kinds of informal reasoning outcomes decision-making mode, informal reasoning mode, and informal reasoning quality together, Wu and Tsai (2007) worked up an integrated framework. In the literature, it was observed that there are distinct frameworks to assess informal reasoning on socioscientific issues.

In the present study, the integrated framework worked up by Wu and Tsai (2007) was preferred to use, but the part of decision-making mode of the framework was not included. The reason was that this study aimed to investigate students' informal reasoning quality, informal reasoning modes, and if there is a relationship between these outcomes or not. In addition, since the kinds of reasoning modes in this framework (Wu & Tsai, 2007) is more inclusive than others' classifications (e.g. Patronis et al., 1999; Yang & Anderson, 2003), this framework was preferred. In this framework, the high school students' arguments about nuclear energy usage issue were classified under social-oriented, ecological-oriented, economic-oriented and science-or-technology-oriented informal reasoning modes. The last reason of preferring the framework of Wu and Tsai (2007) was that the quality of informal reasoning was assessed by focusing on supportive arguments, counter-arguments, and rebuttals which are patterns preferred by many researchers in the literature (e.g. Khishfe, 2012; Khishfe et al., 2017; Wu & Tsai, 2007; Zohar & Nemet 2002).

The findings of the research studies investigating participants' informal reasoning quality showed that most of the participants could not form rebuttal in their informal reasoning (e.g. Dawson & Venville, 2009; Topcu et al., 2010; Wu & Tsai, 2007; Wu & Tsai, 2011). For example, Wu and Tsai (2007) carried out a research with 10th grade students in Taiwan and found that the average of rebuttal construction of participants is 0.45 while the average of supportive argument construction is 1.58. Similar findings were also revealed in their other research (Wu & Tsai, 2011) which was conducted with high school students in Taiwan. According to the findings, although the average of participants' supportive argument construction is 1.25, the average of their rebuttal construction is 0.50. Ozturk and Yilmaz-Tuzun (2017) conducted a research by using the framework and questionnaire developed and used by Wu and Tsai (2007, 2011). However, they studied with pre-service science teachers in Turkey. They found that the average of supportive argument construction is 1.86 while their rebuttal construction average is 1.38. Although the average of rebuttal is better in this study than others (Wu & Tsai 2007; Wu & Tsai, 2011), it should be taken into consideration while Wu and Tsai (2007, 2011) studied with students, Ozturk and Yilmaz-Tuzun (2017) studied with pre-service teachers who studied at one of the most academically successful universities of Turkey. That's why for the finding of Ozturk and Yilmaz-Tuzun (2017), it is possible to infer that the pre-service science teachers did not show sufficient abilities to form highly-qualified informal reasoning. Topcu et al. (2010) revealed findings which support this inference about the findings of Ozturk and Yilmaz-Tuzun (2017). Topcu et al. (2010) conducted research with pre-service science teachers and found that 61% of the pre-service teachers could not form well-constructed counter-argument and rebuttal. Since the findings of research studies showed both students and pre-service teachers cannot construct highly-qualified informal reasoning on socioscientific issues, the researchers should continue to conduct research studies to investigate and show the conditions of sufficiency of teachers and students about constructing qualified informal reasoning which is one of the important aims of science curriculum.

The findings of the research studies about informal reasoning modes were mixed and showed difference based on time or country. For example, Wu and Tsai conducted a research to investigate Taiwanese high school students' informal reasoning modes in the arguments about the usage of nuclear power in 2007 and 2011. Also, Ozturk and Yilmaz-Tuzun (2017) implemented the questionnaire about nuclear power usage used by Wu and Tsai (2007, 2011) to pre-service science teachers in Turkey. All these three research studies also used the same framework which specifies four different informal reasoning modes; economic-oriented, ecological-oriented, social-oriented, and science-or-technology-oriented. Although the same SSI and same questionnaire were used in three research studies, the findings about informal reasoning modes were different. Wu and Tsai (2007) found that students mostly constructed ecological-oriented arguments, and then, they respectively constructed economic-oriented arguments and science-or-technology-oriented arguments. Since science-or-technology-oriented mode of informal reasoning came in third place, they argued that students cannot connect the things they learned in science classes with the issues they faced in their daily lives (Wu & Tsai, 2007). However, after four years, Wu and Tsai (2011) conducted a research with high school students by using the same SSI and questions, and they found different results. This time, the most used reasoning mode in students' arguments was science-or-technology-oriented. While ecological-oriented arguments came in the second place, economic-oriented arguments came in the third place (Wu & Tsai, 2011). By using the same questionnaire, Ozturk and Yilmaz-Tuzun (2017) conducted a research with pre-service teachers in Turkey. They found that the arguments about nuclear power usage in Turkey were mostly economic-oriented. The second most used reasoning mode was ecological-oriented, while the third most used was social-oriented reasoning mode (Ozturk & Yilmaz-Tuzun, 2017). These findings showed that the informal reasoning modes participants used in their arguments about the same SSI may differ depend on time, country, or sample. That's why more research studies should be conducted for each socioscientific issue in different countries and with different samples. In order to contribute to the literature, the researcher of the present study found out Turkish students' informal reasoning modes about three different SSIs which are global warming, acid rain, and genetically modified food.

The researchers who studied about informal reasoning on socioscientific issues conducted their studies with different sample profiles. Although there are studies which were conducted with middle school or high school students in the international literature (e.g. Dawson & Venville, 2009; Khishfe, 2012; Khishfe et al., 2017; Patronis et al., 1999; Wu & Tsai, 2007; Yang & Anderson, 2003; Zohar & Nemet, 2002), there are very few studies which were conducted with students in Turkish context (e.g. Ozden, 2020). It is observed that most of the research studies in the national literature were conducted with pre-service science teachers (e.g. Karışan, Yılmaz-Tüzün, & Zeidler, 2017; Ozturk & Yilmaz-Tuzun, 2017; Pehlivanlar, 2019; Topcu et al., 2010; Yapıcıoğlu & Aycan, 2018). To contribute to closing this gap in the literature, the researcher of the present study worked with middle school students.

The researchers investigating informal reasoning on SSIs used different data collection procedures. Video recording or audiotape recording is one of the ways which was preferred very rarely in the literature (e.g. Dawson & Venville, 2010; Karışan et al., 2017). There are also researchers who preferred interviews to collect data (e.g. Topcu et al., 2010; Topçu et al., 2011; Sadler & Zeidler, 2005a). However, the sample sizes of the research studies whose data collected via interview were not large. That's why especially the researchers who studied with a large sample size preferred to collect their data with open-ended questionnaire (e.g. Ozturk & Yilmaz-Tuzun, 2017; Wu, 2013; Wu & Tsai, 2007). Some open-ended questionnaires used in the research studies did not only include questions about SSI content but also included scenarios about SSI content (e.g. Khishfe et al., 2017; Pehlivanlar, 2019). In the present study, since the sample was large and consisted of middle school students, the researcher preferred to use open-ended questionnaire including scenarios and open-ended questions about SSIs in order to collect data about students' informal reasoning.

Socioscientific issues include scientific knowledge, although these issues have social dimensions. That's why it is not surprising that there are researchers who clarified the necessity of nature science understanding for teaching SSI (e.g. Zeidler & Keefer, 2003; Zeidler et al. 2005). Since the main aim of the present study is to find out the relationship between students' NOS understanding and their informal reasoning on SSIs, the research studies which were conducted about nature of science were also reviewed below the following title.

2.2 Nature of Science Understanding in Science Education

Scientific knowledge has some features like improvable, changeable, etc. in their nature, which is discussed under the content of "nature of science understanding" in the literature. There is no single and agreed definition of nature of science term in the literature. However, the lack of consensus among the science researchers about the single definition of NOS is not surprising when the multifaceted and complex nature of scientific knowledge is considered (Lederman, Lederman, & Antink, 2013). One of the most cited definitions of NOS was made by Lederman (1992), and he defined NOS as "the epistemology of science", "science as a way of knowing" and "the values and beliefs inherent to scientific knowledge and its development". McComas, Clough, and Almazroa (1998) defined NOS as a domain identifying "what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (p. 4). Similarly, Clough and Olson (2008) mentioned that science educators use the nature of science term to explain "the issues such as what science is, how it works, the epistemological and ontological foundations of science, how scientists function as a social group and how society influences and reacts to scientific endeavors" (p. 143). As science and scientific thinking improved, conceptions of researchers about NOS changed and these changes reflected on the definitions and place of NOS in science education during the past 100 years (Lederman et al., 2013).

Even though there is no consensus about the description of nature of science, science researchers agreed that there is an acceptable level of generality regarding NOS which should be explained to students (Lederman et al., 2013). Lederman (2002) mentioned that they believe there cannot be a singular NOS or absolute agreement about the meaning of NOS term. Abd-El-Khalick and Lederman (2000) clearly examined the changes of NOS conceptions throughout the development of science and scientific thinking. Although the researchers all agreed about multifaceted, complex, and changeable nature of NOS conceptions, many researchers also agreed about there are aspects of NOS which cannot be rejected, and these agreed aspects of NOS should be transferred to students through education (e.g. Lederman, 2002; Lederman et al., 2013). Forming a framework based on the consensus of researchers about the aspects of NOS is important because educators need a framework to teach about NOS and develop students' NOS understanding. Lederman (1998) mentioned the characteristics of scientific knowledge based on consensus views. According to this framework, there are seven aspects of NOS; (I) empirically based, (II) tentativeness, (III) subjectivity, (IV) creativity, (V) socially and culturally embedded, (VI) the differences between observation and inference and lastly, (VII) the differences between scientific laws and theories. Empirically based aspect infers that scientific knowledge should be based on empirical evidences. Tentative nature of science means that scientific knowledge is not certain and it can change when new evidences are found or existing evidences change. Subjective aspect of NOS stands for scientists' prior experiences, practices, expectations, personal beliefs, ideas, values, biases, etc. form a mind-set which affects their investigation, observation, and interpretation of scientific knowledge. Creativity aspect infers that scientists benefit from their creativity while making inferences about their observations. The meaning of the socially and culturally embedded nature of science is that the culture, politics, and economics of society where scientific knowledge is generated have effects on scientific knowledge. Students also should be aware of the distinctions between observation and inferences which is another aspect of NOS. According to this aspect, while observation is about comprehending something with senses, inferences cannot be comprehended with senses since inferences contain more than that. Lastly, students should notice the distinctions between scientific laws and theories. While laws demonstrate the relation between phenomena, theories clarify those phenomena.

Thanks to these agreements about the general characteristics of scientific knowledge, NOS became applicable in the education field. Thus, researchers developed questionnaires based on this framework including seven tenets of NOS in order to examine students' and pre or in-service teachers' NOS understanding. In the beginning, standardized instruments including multiple-choice or Likert-type questions were developed and used such as Conceptions of Scientific Theories Test (COST) (Cotham & Smith, 1981), Views on Science-Technology-Society (VOSTS) (Aikenhead, Fleming, & Ryan,1989). However, the standardized instruments were criticized by some researchers (e.g. Aikenhead, Fleming, & Ryan, 1989; Lederman & O'Malley, 1990; Lederman, Wade, & Bell, 1998). Lederman and O'Malley (1990) argued that the participants perceive and interpret the items of the standardized instruments in a similar way with instrument developers. This situation causes a threat for the validity of the instrument, according to researchers. Also, Lederman et al. (1998) criticized that the standardized instruments generally reflected their developers' views of NOS and their biases about NOS. That's why Lederman and O'Malley (1990) developed Views of Nature of Science A (VNOS-A) questionnaire including open-ended questions to assess seven tenets of NOS. Later on, Views of Nature of Science B (VNOS-B) (Abd-El-Khalick et al., 1998) and Views of Nature of Science C (VNOS-C) (Abd-El-Khalick & Lederman, 2000) questionnaires were developed by making some differences and adding some context-specific questions to the questions of VNOS-A. Since these two versions of questionnaires VNOS-B and VNOS-C are too long and take a long time for a class period, Lederman and Khishfe (2002) developed the Views of Nature of Science D (VNOS-D) version of questionnaire by shortening. Lastly, Lederman and Ko (2004) also simplified the VNOS-D version and developed Views of Nature of Science E (VNOS-E) to apply with younger elementary students. Since in the present study, the researcher studied with middle school students, the VNOS-E questionnaire was preferred to investigate students' NOS understanding level.

During the last century, science researchers and science research institutions have been mainly focusing on the content of nature of science understanding in science education literature (e.g. AAAS, 1990; Klopfer & Watson, 1957; McComas, Clough, & Almazroa, 1998; National Science Teachers Association (NSTA), 1982; PISA, 2015). The reason of giving importance to NOS understanding in science education is that understanding the nature of scientific knowledge and its developmental process supports the scientific literacy of students (Lederman, 2014). Lederman (2007) mentioned that NOS understanding was seen as an important component for scientific literacy, so teaching NOS understanding was emphasized in recent science curriculum reforms (e.g. AAAS, 1990; Next Generation Science Standards (NGSS), 2013; NRC, 1996; NSTA, 1982; NSTA, 2000). NSTA (2000) clearly mentioned that students should have a complete, accurate, and working NOS understanding to become scientifically literate persons. Nature of science is not only seen as a necessity of scientific literacy, but also it is suggested that nature of science understanding supports making qualified decision-making on socioscientific issues which is also the necessity of scientific literacy (Holbrook & Rannikmae, 2009). Since the present study focused both nature of science understanding and informal reasoning on SSIs, and aimed to find out if there is relationship between them or not, the findings of present study provided empirical evidences for this hypothesis.

Since the importance of nature of science understanding has been increased in science education, many researchers studied to investigate the nature of science understanding from different perspectives. Lederman (1992) made a review about the research studies made in the content of NOS and stated that the research studies were conducted in four different perspectives; the assessment of students' NOS conceptions, the assessment of curricula developed to improve students' NOS conceptions, the attempts to improve teachers' NOS conceptions and the relationship between teachers' NOS conception, classroom practice and students' NOS conceptions. Later on, Abd-El-Khalick and Lederman (2000) specifically examined the research studies aiming to improve teachers' NOS conceptions in their review. They mentioned that in the research studies they reviewed, there were two approaches to improve teachers' NOS conceptions which are implicit and explicit. The researchers who used implicit approach in their studies benefited from science process skills instructions or science based-inquiry activities to improve NOS conceptions. On the other hand, in order to improve teachers' NOS conceptions, the researchers who used explicit approach in their studies benefited from the instruction geared towards the aspects of NOS and/or the elements from history and philosophy of science. More recently, Azevedo and Scarpa (2017) made a review study and classified the articles about nature of science understanding into groups. It was found that more than half of the articles (57.8%) focused on investigating NOS conceptions of participants. According to this review (Azevedo & Scarpa, 2017), the second most studied area (35%) was named as "theoretical positioning" where authors explained their positions about (I) approaches that improve NOS conceptions, (II) the inclusion of certain aspects of NOS in curriculum, (III) criticisms on methods used to find out NOS conceptions or (IV) the information previously shared. There are few review articles about NOS concept (4.8%) and few articles aiming to create an instrument for the assessment of NOS understanding (2.3%) in the literature (Azevedo & Scarpa, 2017). It was clearly observed that one of the most common study subjects in the NOS research area is the investigation of participants' NOS understandings which was also one of the aims of the present study.

Although the investigation of NOS conceptions of participants is the most studied title among the research studies about NOS, the findings showed that both students (e.g. Bektas & Geban, 2010; Dogan & Abd-El-Khalick, 2008; Seçkin, 2013; Sutherland & Dennick, 2002) and teachers have naïve understanding of NOS (e.g. Dogan & Abd-El-Khalick, 2008; Irez, 2006; Liu & Lederman, 2007). For example, Sutherland and Dennick (2002) investigated the NOS understanding levels of 7th grade students from different cultures. It was found that irrespective of cultures, most of the students have insufficient NOS understanding. Similar findings were also revealed by Seçkin (2013) in the Turkish context. Seçkin (2013) conducted a research to find out 8th grade students' NOS understanding levels about five tenets. The findings showed that almost half or more than half of the students have naïve understanding about three NOS tenets. Similarly, Ebren-Kuyumcu (2019) conducted a research in the Turkish context with 7th grade and 8th grade students to investigate their NOS understanding levels. The results showed that although the students do not have naïve understanding, they also do not have sophisticated understanding of NOS. Additionally, Dogan and Abd-El-Khalick (2008) conducted a research with both 10th grade students and their science teachers to investigate their NOS understanding levels. The results showed that the majority of both students and their teachers have naïve NOS understanding. Liu and Lederman (2007) found a similar result for the Taiwanese pre-service teachers. They found that some pre-service science teachers hold naïve views on all aspects of NOS, and the rest of the pre-service teachers hold naïve views on at least one aspect of NOS. As opposed to these findings, Çetinkaya-Aydın and Çakıroğlu (2017) found that almost half of the Turkish pre-service science teachers who participated in the research have adequate NOS understanding. Although there are many research studies investigating both teachers' and students' NOS understanding, investigation of NOS understanding level is still important in order to understand if the goal of providing students with sophisticated NOS understanding is achieved or not.

The studies aiming to investigate individuals' NOS understandings were conducted with participants who have different profiles. While some research studies were conducted with teachers and pre-service teachers (e.g. Abell, Martini, & George, 2001; Iii, Hand, & Prain, 2002; Liu & Lederman, 2007; Murcia & Schibeci, 1999), there are also research studies which were conducted with students (e.g. Moss, 2001; Sutherland & Dennick, 2002; Urhahne, Kremer, & Mayer, 2011; Park, Nielsen, & Woodruff, 2014). There is no obvious difference between the amount of studies conducted with teachers (including pre-service teachers) and the amount of studies conducted with students (including primary, secondary, and high school students). This observation is supported by the findings of the review of Azevedo and Scarpa (2017). According to the findings of this review (Azevedo & Scarpa, 2017), approximately 37% of the research studies were conducted with teachers and pre-service teachers. On the other hand, approximately 32% of the research studies were conducted with primary and secondary school students. However, although there are research studies conducted to investigate students' NOS understandings (e.g. Ebren-Kuyumcu, 2019; Köksal & Sormunen, 2014; Küçük & Çepni, 2015), it is obvious that most of the research studies aimed to investigate teachers' and especially pre-service teachers' NOS understanding in Turkish context of the literature (e.g. Çetinkaya-Aydın & Çakıroğlu, 2017; Erdogan, Cakiroğlu, & Tekkaya, 2006; Irez, 2006; İrez, Çakır, & Şeker, 2011; Macaroglu, Tasar, & Cataloglu, 1998). The present study was conducted with middle school students which contributed to closing this gap in the literature.

As mentioned before, since socioscientific issues include not only social dimensions but also include scientific knowledge in their basis, some researchers suggested that understanding nature of scientific knowledge is related with learning and making decisions on SSIs (e.g. Zeidler & Keefer, 2003; Zeidler et al. 2005). That's why this research aimed to find out the relationship between students' NOS understanding and their informal reasoning on SSIs. In the following title, the research studies examining the relationship between NOS understanding and informal reasoning on SSIs were reviewed and analyzed.

2.3 The Relationship between Nature of Science Understanding and Informal Reasoning on Socioscientific Issues

There are researchers who mentioned that the nature of science understanding is related with socioscientific issues (e.g. Bell & Lederman, 2003; Bell, Matkins, & Gansneder, 2011; Driver, Leach, Millar, & Scott, 1996; Zeidler & Keefer, 2003; Zeidler et al. 2005). In the literature, the relationship between nature of science understanding and socioscientific issues was examined from two different perspectives. While some researchers regarded socioscientific issues as effective contexts to develop individuals' nature of science understanding, other researchers regarded nature of science understanding as a necessity for individuals to make effective decisions on socioscientific issues.

As aforementioned, it was suggested by some researchers that these controversial issues involving both social and scientific extents are favorable contexts to enable students to acquire sophisticated NOS understanding (e.g. Bell, Matkins, & Gansneder, 2011; Lederman, Antink, & Bartos, 2014). For example, Eastwood, Sadler, Zeidler, Lewis, Amiri, and Applebaum (2012) investigated the effects of SSI-based and content-based instructions on high school students' NOS conceptions. NOS questionnaires were implemented at the beginning and end of the semester in both SSI-based and content-based groups. The findings revealed the effectiveness of SSI contexts on gaining NOS understanding. Similarly, Callahan, Zeidler and Orasky (2011) conducted a study to find out the influence of the SSI curriculum on high school students' NOS understanding. The findings showed that although the influence was not statistically significant, some students enhanced their NOS understanding after SSI-based instructions. Additionally, Khishfe and Lederman (2006) conducted a research to find out the influence of integrated NOS instruction within SSI content and nonintegrated NOS instruction on ninth grade students' NOS understanding. Before and after instruction, open-ended questionnaires and semi-structured interviews were applied. The findings revealed that the students who have informed NOS views in the integrated group showed slightly, but not significant, improvement in their NOS views. In addition to the research studies conducted with students, there are research studies which found effect of SSI-based instruction on pre-service teachers' NOS understanding (e.g. Cook & Buck, 2013).

Other researchers argued that NOS understanding encourages students to be influential decision-makers on SSIs (e.g. Driver et al., 1996, p. 11). Zeidler et al. (2005) mentioned that understanding nature of science and scientific knowledge is necessary for providing students to make informed decisions about the scientifically based societal issues which students are faced with in their daily lives. It was propounded NOS views may affect students' valuation of knowledge formed by using scientific way and choice of evidence while explaining their positions about SSI context (Zeidler et al., 2005). In the study of Bell et al. (2000) which was conducted to investigate how pre-service teachers translate their NOS understanding into teaching practices, there are pre-service teachers who mentioned the importance of NOS understanding for students to make informed decisions about the scientific issues they faced with in their social lives. Bell and Lederman (2003) clarified the importance of NOS while making decisions about socioscientific issues as following;

> By knowing the characteristics of scientific knowledge and the way it is constructed, the argument proceeds, citizens will be better able to recognize pseudoscientific claims, distinguish good science from bad, and apply scientific knowledge to their everyday lives (p. 353).

To clarify, there are researchers who hypothesized NOS understanding of individuals affect their decision-making process on SSIs. Some researchers conducted studies to examine the relationship between participants' NOS understanding and their informal reasoning on SSIs (e.g. Bell & Lederman, 2003; Herman, Owens, Oertli, Zangori, & Newton, 2019; Khishfe, 2012; Khishfe et al., 2017; Liu, Lin, & Tsai, 2010; Sadler, Chambers, & Zeidler, 2004; Yu, 2010; Zeidler, Walker, Ackett, & Simmons, 2002). However, it is clear that in the literature, there are limited amount of research studies which directly focused on investigating the relationship between NOS understanding and informal reasoning on SSIs.

First, Zeidler, Walker, Ackett, and Simmons (2002) conducted a research to find out how students' NOS understanding affects their response against evidences clashing with their opinions about animal testing SSI. The research conducted with 248 students who studied in the science field; however, the students were from separate schools and grade levels. Tentativeness, empirically-based, subjectivity, creativity, and cultural-social embeddedness tenets of NOS were contained in the study. The research design of the study was specified as mixed-method design. The data were collected in three steps. As a first step, the students answered open-ended questions evaluating their understandings about NOS. Secondly, the students responded to an ordinal scale question and open-ended questions assessing their opinions about animal testing. Lastly, the researchers selected 41 pairs of students for an interview in accordance with their status of agreement on the animal testing issue and NOS understanding levels. To clarify, two students who have opposite opinions about animal testing, one agreed, and the other one disagreed, were paired, and each pair participated in the interview. NOS understanding level was also taken into consideration by the researchers while selecting pairs. The pairs argued about animal testing in this interview. An investigator observed the participants, and it was provided for the participants to defy each other's reasoning throughout argumentation. According to the results, the NOS understanding of students was reflected in their reasoning about SSI but not much. More specifically, the students accepted the certainty of scientific knowledge concretely which they faced with and which conflict with their opinions. However, they interestingly did not utilize and think of the scientific knowledge while arguing about SSI, and they did not try to persuade their pairs while supporting their own opinions. To clarify, students did not use certain scientific knowledge in their discussion since they believe that scientific knowledge is definitely accurate while opinions are personal. On the other hand, it was revealed that most of the students were aware that scientific knowledge is affected by society, and this understanding was reflected in their reasoning throughout the interview. Moreover, the results showed that the students considering empirical evidences are essential for scientific knowledge altered their decisions when new evidence was represented. In brief, it was found out that NOS views, involving tentativeness, empirical-based, subjectivity, and social and cultural embeddedness tenets, affected and reflected to students' reasoning on SSI. This effect is significant, but it is not a wide effect.

Similar to Zeidler, et al. (2002), Sadler, Chambers, and Zeidler (2004) conducted similar research and found similar results. Eighty-four high school students who took advance biology course participated in the study. The sample comprised of students from the science field similar to the study of Zeidler et al. (2002). In addition, the researchers used open-ended questions and interview in a resembling way it was implemented in the study of Zeidler et al. (2002). Firstly, open-ended questionnaire was utilized to determine NOS understanding of the students, and the considerations affect their decision- making on global warming SSI. Then, 30 students were chosen for the interview. The qualitative analysis was conducted. According to the results, particularly social embeddedness tenet affected students' appraisal of the evidences clashing with their opinions. On the other hand, although many of the students noticed that they are awake to the value of empirical data, they chose the article promoting their own opinions as more persuasive when two articles including equivalent quality and quantity of evidence were represented. In brief, similar with Zeidler, et al. (2002), it was found that the students gave value to the evidence which promote their own opinions while making personal decisions.

Differently, Bell and Lederman (2003) carried out a research with 21 research scientists and professors, some of whom were studying in the science field while some were studying in different fields. The researchers aimed to investigate the effect of NOS understanding on decision-making about SSIs, fetal tissue implantation, global warming, the relationship between diet and cancer, and the relationship between cigarette smoking and cancer. Both questionnaire and interview were used to evaluate participants' NOS understanding and decision-making about SSIs. After specifying participants' NOS understanding based on data, the participants were separated into two groups in accordance with the resemblance of their NOS understanding. After that, the researchers contrasted their decision-making. According to the findings, NOS views did not cause significant distinction in participants' decision-making on SSI. For instance, similar with the finding of Sadler et al. (2004), although participants talked about the importance of empirical evidences, they made decisions based on their moral, social, and personal beliefs and concerns. Briefly, unlike the findings of Zeidler et al. (2002) and Sadler et al. (2004), NOS views of participants did not reflect to their reasoning about the issues significantly. However, there is an essential point which should be emphasized. While Zeidler et al. (2002) and Sadler et al. (2004) studied with students from the science field, the researchers of this study studied with the professors from not only science fields but also different fields in this study. This situation may have an influence on the observed distinctions in the findings.

Recently, Khishfe (2012) carried out research similarly to investigate the relationship between NOS understanding and argumentation skills on SSI. Genetically modified foods and water fluoridation issues were included in this study. The researcher focused on three NOS tenets subjectivity, tentativeness, and empirically based. Also, the researcher focused on generating argument, counterargument, and rebuttal as argumentation skills. The sample comprised of 219 high school students from Lebanon. In order to collect data, the researcher used questionnaire and interview. Data were analyzed both quantitatively and qualitatively. The questionnaire was formed to evaluate students' NOS understanding and argumentation skills. Pearson correlation analyses were conducted to examine the possible relationship. The results showed that there is a strong correlation between generating counterargument performance of students and their NOS understanding on three tenets. Also, some students attended to interview and their responses were analyzed qualitatively. The qualitative findings corroborated the quantitative findings. The researcher also looked for if there is a distinction in the responses of students across two different SSIs. According to the findings, the contextual factors influence students' NOS understanding reflected on their responses and argumentation skills. That's why the researchers should include more than one SSI in their studies to look for possible contextual factors.

Khishfe, Alshaya, BouJaoude, Mansour, and Alrudiyan (2017) carried out a similar research with 74 Saudi Arabian high school students. The findings were in contradiction with the findings of Khishfe (2012). Different from the previous study, four different SSIs were included in the research. The SSIs were global warming, genetically modified food, acid rain and human cloning. Both qualitative and quantitative analyses were conducted. It was discovered that while quantitative analyses showed there is no significant relationship between NOS understanding and argumentation skills, qualitative analyses revealed that the students who constructed qualified arguments also have the sophisticated level of NOS understanding. Similar findings attained from the qualitative analysis were also found for counterarguments in the study of Khishfe (2012). Therefore, there is still probability of the effect of NOS understanding on argumentation about SSIs. Moreover, even though the quantitative analyses contradicted with the previous finding (Khishfe, 2012), the researchers mentioned that most of the students did not construct well-developed arguments and sophisticated NOS understanding, which may influence the correlation analyses. Similar to the research of Khishfe (2012), the researchers looked for if there is a distinction in the responses of students across four different SSIs. However, different from previous findings (Khishfe, 2012), the results of quantitative analyses showed that there is no significant distinction in terms of contextual factors. On the other hand, the qualitative analysis showed some distinctions. For example, more students exhibited empirical and tentative understanding when answering the acid rain scenario. More students showed informed subjective understanding of science when responding to cloning scenario. These findings emphasize the importance of focusing contextual factors in the research studies made in the field of SSIs.

All in all, although there are empirical findings supported the hypothesis about the relationship between NOS understanding and informal reasoning on SSIs, there are research studies which found out no significant relationship between students' NOS understanding aspects and argument components (e.g. Khishfe et al., 2017). Since the amount of study investigating this relationship is insufficient and the findings are mixed, more research studies aiming to search this relationship are needed. That's why the present study aimed to find out the relationship between NOS understanding and informal reasoning quality on SSIs. In order to find out this relationship more deeply, the researcher of the present study conducted analysis to find out if nature of science tenets predict informal reasoning quality on SSIs because some previous research studies already revealed that there were some significant relationship between nature of science understanding and informal reasoning quality based on Pearson correlation coefficient (e.g. Khishfe, 2012). Also, while some research studies focused on only one SSI context (e.g. Zeidler et al., 2002; Sadler et al., 2004), some research studies focused on more than one SSI contexts (e.g. Bell & Lederman, 2003; Khishfe, 2012; Khishfe et al., 2017). Since there are findings showed contextual factors cause a significant difference on students' informal reasoning on the issues (e.g. Khishfe, 2012), this research focused on three different SSI contexts global warming, acid rain and genetically modified food. Moreover, most of the studies examined the NOS understanding of participants in the context of SSI (e.g. Khishfe, 2012; Khishfe et al., 2017; Sadler et al., 2004). In other words, in most research studies, the questions which were prepared to assess NOS understanding were coherent with the SSI context. However, this assessment may cause the students to realize the possible relationship between NOS understanding tenets and informal reasoning components variables. In order to assess students' NOS understanding by eliminating this threat, the researcher of the present study used a separate questionnaire VNOS-E including questions independent from the context of SSIs. Lastly, as seen in the review of the studies, some research studies focused on certain tenets of NOS instead of all seven tenets of NOS (e.g. Khishfe, 2012;

Khishfe et al., 2017; Sadler et al., 2004; Zeidler et al., 2002). After the study of Zeidler et al. (2002) found that tentativeness, empirically-based, and subjectivity tenets are obviously related with the reasoning on SSI, some researchers recently focused on these three tenets to examine the possible relationship of these tenets with informal reasoning on SSI more deeply (e.g. Khishfe, 2012; Khishfe et al., 2017). The researcher of the present study also focused on tentativeness, empirically-based, and subjectivity tenets of NOS in order to understand students' understanding about these three tenets more deeply and to find out the association between these three tenets of NOS and informal reasoning on SSIs.

CHAPTER 3

METHODOLOGY

In this part, information about the research design, sample, instruments, data collection procedure, reliability, and validity of the study were given.

3.1 Research Design

The purpose of the study was basically to investigate the relationship between 8th grade students' nature of science understanding and informal reasoning on socioscientific issues. Therefore, correlational research approach was utilized to find out relations between two or more variables without affecting these variables (Fraenkel, Wallen, & Hyun, 2011). More specifically, the researcher used correlational analyses to understand if there is a relationship between 8th grade students' informal reasoning modes variety and informal reasoning quality, and multiple regression analyses if there is/are predictor/s of informal reasoning quality regarding NOS understanding tenets.

The qualitative data obtained with open-ended questions were scored and transformed into quantitative data, which is named as quantitizing (Sandelowski, Voils, &Knafl, 2009). Thus, the researcher found out if there is a relationship between these variables with Pearson correlation analysis and multiple regression analysis. Since the researcher assessed the data both qualitatively and quantitatively, this research included mixed research analysis.

3.2 Sample and Sampling Procedure

The sample of the study was composed of 414 8th grade students from four different public middle schools in Altındağ district of Ankara. While the target population of this study included all 8th grade students in all public middle schools in Ankara, the accessible population included all 8th grade students in all public middle schools in Altındağ. There are totally 41 public middle schools in Altındağ. However, four different public middle schools were included in the present study, which is approximately 10 % of the accessible population.

In the present study, convenience sampling was utilized while determining the district Altındağ for choosing schools. The researcher chose Altındağ district conveniently because of easy transportation, money restrictions, and time limitation of the master program (Merriam & Tisdell, 2016, p.98). While selecting the four middle schools in Altındağ district, the researcher gave attention to select the schools spread over a wide area of Altındağ in order to form a sample reflecting the accessible population most. The researcher also used purposeful sampling while including only 8th grade students in the present research. The reason is that since 8th grade is the last level of middle school education, these students are expected to have already achieved most of the objectives and goals of the science curriculum for middle schools. Raising students as qualified decision-makers in SSIs is one of the goals of the 2018 Turkish science curriculum (MEB,2018). That's why investigating 8th grade students' informal reasoning abilities in the context of SSI might give feedback about the teaching of SSI goal of the curriculum.

The researcher obtained some information about the sample in order to define the sample in more detail. As represented in Table 3.1., about 45% of the participants were male, and 55% of them were female. Most of the students (about 80% of them) were born in 2005-2006. The students born in 2004 (8 students) were immigrants who can speak and write Turkish fluently. They willingly participated in the present study. The students born in 2007 started school at the age of 5. In the 2012-2013 education year, the school starting age was reduced to 5 years by the Turkish Ministry of National Education, subject to parent demand. Students' science lesson achievement was also reported. According to results, most of the students performed success over the average in middle school grades. Specifically, 95% of the students scored over 50 in 5th grade, 94% of them scored over 50 in 6th grade, and 92% of them scored over 50 in 7th grade. In order to give an idea about the economic conditions of the participants, the researcher got information about parents' work status. While 92% of the fathers have a job, only 24% of the mothers have a job. In addition, the researcher got information about students' knowledge level about each SSI and the source of their knowledge. While only 8% of the students mentioned they have no knowledge about global warming, 33% of them mentioned they have no knowledge about acid rain issue. 18% of the students have no knowledge about genetically modified food issue. Students who have knowledge about global warming specified the sources of their knowledge. It was found that students mostly got their prior knowledge from the Internet and textbook. More specifically, students got their knowledge about global warming mostly from the textbook (about 64% of the students) and the Internet (about 55%). Students mostly used the Internet (about 38%) and textbook (about 27%) to get knowledge about the acid rain issue. Similarly, in order to get knowledge about genetically modified food, students mostly used the Internet (about 50%) and textbook (about 37%).

Table 3.1. Characteristics of the Sample

Variables	N	%
Gender		
Male	185	44.7
Female	229	55.3
Year of Birth		
2004	8	1.9
2005-2006	332	80.2
2007	74	17.9
5th Grade Science Lesson Grade		
0-49	20	5.1
50-69	123	31.0
70-100	253	63.9

Table 3.1. (cont'd)

6th Grade Science Lesson Grade		
0-49	24	6.1
50-69	141	35.6
70-100	231	58.3
7th Grade Science Lesson Grade		
0-49	30	7.6
50-69	129	32.5
70-100	238	59.9
Work Status of Father		
Yes	371	91.6
No	34	8.4
Work Status of Mother		
Yes	100	24.4
No	309	75.6
Knowledge Level about Climate Change		
Rather Much	39	9.4
Much	158	38.3
Poor	184	44.6
Never	32	7.7
Knowledge Source about Climate Change		
Course Book	266	64.3
The Internet	227	54.8
Radio and TV	86	20.8
Journal and Newspaper	60	14.5
Social Environment	75	18.1

Table 3.1. (cont'd)

Knowledge Level about Acid Rain		
Rather Much	11	2.7
Much	64	15.5
Poor	203	49.2
Never	135	32.7
Knowledge Source about Acid Rain		
Course Book	110	26.6
The Internet	158	38.2
Radio and TV	61	14.7
Journal and Newspaper	39	9.4
Social Environment	67	16.2
Knowledge Level about Genetically Modified Food		
Rather Much	34	8.2
Much	131	31.7
Poor	174	42.1
Never	74	17.9
Knowledge Source about Genetically Modified Food		
Course Book	155	37.4
The Internet	208	50.2
Radio and TV	84	20.3
Journal and Newspaper	44	10.6
Social Environment	93	22.5

3.3 Instrumentation

In the present study, three different questionnaires were used. These are (1) Demographic Information, (2) Views of Nature of Science Elementary Level (VNOS-E) Questionnaire developed by Lederman and Ko (2004), and (3) Informal Reasoning on Socio-scientific Issues Questionnaire, which consisted of three scenarios taken from the study of Khishfe and her colleagues (2017) along with open-ended questions taken from the study of Wu and Tsai (2007).

3.3.1 Demographic Information

Demographic information questions were directed to the participants to get information about gender, age, their past years' grades on science lesson, socio-economic status of their parents, the knowledge level about socioscientific issues (global warming, acid rain, genetically modified food), and the sources of their background knowledge about these SSIs.

3.3.2 Views of Nature of Science Elementary Level (VNOS-E) Questionnaire

In order to examine students' nature of science understanding level, Views of Nature of Science Elementary Level (VNOS-E) questionnaire which was worked up by Lederman and Ko (2004) and translated into Turkish by Doğan, Çakıroğlu, Çavuş, Bilican and Arslan (2010) was preferred to use.

This questionnaire originally consists of seven open-ended questions, and these questions are obliged to assess the understanding of students on specific nature of science tenets which are tentativeness, empirical-based, subjectivity, creativity, and the difference between observation and inference. However, in the present study, only three tenets, tentativeness, empirical-based, and subjectivity were included because it was argued that these three tenets were more closely related to socioscientific issues than other tenets (Khishfe, 2012; Zeidler et al., 2002). The following Table 3.2. shows which question in the VNOS-E questionnaire assesses which NOS tenets.

Table 3.2. The Questions and the Tenets the Questions Measure in the Present Study

	The Questions in the Questionnaire					
Nature of Science Tenets	**1**	**2**	**3**	**4**	**5**	**6**
Scientific knowledge is reliable but can change. (Tentativeness)	X		X	X		X
Scientific knowledge includes logical, mathematical and empirical inferences. (Empirical-based)	X	X				
Scientific knowledge is subjective. (Subjectivity)	X				X	

As seen in Table 3.2., the answer of the first question can contain explanation about all three tenets so the evaluation of this question was made in the below of the tenet which student's answer focused on. Since the other questions are obliged to measure one tenet, the answers of other (second, third, fourth, fifth, and sixth) questions were evaluated in the below of this tenet.

In order to assess nature of science understanding, Lederman (2007) stated VNOS-E questionnaire is proper for elementary level students in terms of its appropriateness of development and language. It is observed that this instrument has been using in both national and international research studies (e.g. Lederman & Ko, 2004; Lederman & Lederman, 2004; Çil, 2004; Demirbaş & Balcı, 2012; Cansız, 2014) and the findings of these previous studies showed that VNOS-E questionnaire is valid to assess elementary students' NOS views.

3.3.3 Informal Reasoning on Socioscientific Issues Questionnaire

The Informal Reasoning on Socioscientific Issues questionnaire was adapted by the researcher of this study and included three controversial issues (global warming, acid rain, and genetically modified food). The global warming, acid rain, and genetically modified food scenarios were taken from the study of Khishfe and her colleagues (2017) and translated into Turkish. These scenarios were chosen because all scenarios had the same structure where a brief definition or explanation about the socio-scientific issue is given, and then, the examples about the justifications of both pros and cons sides are given. For each scenario, open-ended questions were asked. Wu and Tsai (2007) developed an open-ended questionnaire to assess high school students' informal reasoning on the manufacture of the additional nuclear power plant in their country Taiwan. Ozturk and Yilmaz-Tuzun (2017) translated and adapted this questionnaire and used it in their study. In this questionnaire, there are four questions to assess the participants' decisions about the issue, ability of constructing supportive arguments, counter-arguments, and rebuttals to justify their decisions. For this study, the researcher made some modifications in the questions in order to assess informal reasoning on global warming, acid rain, and genetically modified food issues.

For the translation and adaptation of the scenarios and the open-ended questionnaires, first, their translation into Turkish was done by the researcher of this study. Then, expert opinion was taken from three experts. One of them was an experienced science teacher, and two of them were science education researchers. These experts were provided their comments regarding both the language and content appropriateness of the scenarios and the questions provided for each scenario. Based on experts' comments, necessary revisions were made.

Since the earlier studies were conducted with high school students (Khishfe et al., 2017; Wu & Tsai, 2007) and pre-service science teachers (Ozturk & Yilmaz-Tuzun, 2017), the scenarios and open-ended questionnaire were piloted with 34 8th grade students in a school in Altındağ. During the application of the instrument, the researcher permitted the students to ask questions about the points they do not understand in the scenarios and questions. All of the students' feedbacks were written at the application site and then used to make necessary modifications in the instrument. At this stage, feedbacks on the changes were taken from experts.

3.4 Data Collection Procedure

After taking ethics permission from both the Ethical Committee and the Ministry of Education, data collection was done both for the pilot study and real study.

The actual data collection was done with the students who were volunteers to participate in the research, and the data were collected in the fall semester of the 2019-2020 education year from four different public middle schools in Altındağ. Before the application of instruments, a consent form was signed by the parents of each student to confirm the parents and the students participated in this research voluntarily. Even so, verbal consent was taken from each student before the implementation of the questionnaires. All of the data were collected by the researcher to standardize the data collection procedure. Before the participants took the instruments, the researcher informed them about the purpose of the study briefly and mentioned that they do not get any harm or difficulty because of this study. The researcher also reminded that their answers would not be shared or graded, and they can write anonymous names instead of their own names. The students completed the questionnaires in their own classrooms during their regular class hours. The implementation of three questionnaires approximately took 40-50 minutes.

3.5 Data Analysis

Data obtained from the questionnaires were analyzed qualitatively first. After qualitative analyses of each questionnaire, the researcher conducted Pearson correlation analysis to examine the relationship between the varieties of informal reasoning modes and informal reasoning quality, and multiple regression analyses to examine how well tenets of nature of science predict informal reasoning quality.

In order to conduct these statistical analyses, the researcher converted these qualitative data into quantitative by using the framework developed by Wu and Tsai (2007) and rubric developed by Akerson and Donnelly (2010). This procedure is named as quantitizing (Sandelowski, Voils, & Knafl, 2009). Detailed information about the analysis procedures was given below.

3.5.1 Views of Nature of Science Elementary Level (VNOS-E) Questionnaire Analysis

In order to analyze students' nature of science understanding level, the researcher used the rubric presented in Figure 3.1. This rubric was developed and used in the study of Akerson and Donnelly (2010) to assess each question of the VNOS-D questionnaire. Since the questions of VNOS-D and VNOS-E are the same, this rubric was used in the present study.

VNOS-E question	Coding rubric
What is science?	Inadequate: Science is everything Adequate: Science is exploring and studying topics, such as chemistry, insects, batteries, etc. Informed: Science is a way of knowing about the world
What other subjects are you learning? How is science different from other subjects? *(Empirical NOS)*	Inadequate: Science is in everything, science follows one method Adequate: Science investigates things Informed: Science uses data to make claims and create ideas
Scientists are always trying to learn about our world. Do you think what scientists know might change in the future? *(Tentative NOS)*	Inadequate: Science does not change Adequate: As we learn more or have new technology science changes Informed: Science changes as we learn more or as scientists reinterpret existing data
How do scientists know that dinosaurs really existed? How certain are scientists about the way dinosaurs looked? *(Tentative NOS)*	Inadequate: Scientists saw dinosaurs. Scientists read about dinosaurs. They are sure Adequate: Scientists have collected evidence of dinosaurs (bones, fossils, etc.). They are pretty sure Informed: Scientists have made observations of evidence (bones, fossils, etc.) and inferred that dinosaurs must have existed. They are pretty sure, but could change their minds with new evidence, or looking at the existing evidence in a different way to create an idea of what dinosaurs must have looked like
A long time ago all the dinosaurs died. Scientists have different ideas about how and why they died. If scientists all have the same facts about dinosaurs, why do you think they disagree about this? *(Subjective NOS)*	Inadequate: If they had more information they would all agree Adequate: Scientists have different interpretations of the facts Informed: Scientists have different interpretations of the facts because of their background knowledge and experiences
TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help them make these pictures. How certain do you think the weather people are about these pictures? Why? *(Tentative NOS)*	Inadequate: They are certain because they have the data Adequate: They are not certain; they might get new data to interpret through inferences Informed: They are not certain; they might get new information or reinterpret the existing data that would change their prediction

Figure 3.1. The Rubric Used to Analyze Nature of Science Understanding

Based on this rubric, the researcher classified the participants' views as inadequate (pointing out student held a misconception), adequate (pointing out a developing view), or informed (pointing out a fully developed view) understanding for each NOS tenet (Akerson, Buzzelli & Donnelly, 2010). Similar to Morrison, Raab, and Ingram's (2009) and Çetinkaya and Çakıroğlu's (2012) method, the researcher firstly classified the views of students as inadequate, adequate, or informed. Then, the researcher scored their answers based on the classification in order to specify students' NOS understanding levels clearly. Based on this method, inadequate views scored as 1, adequate views scored as 2, and informed views scored as 3 for each NOS tenet. After specifying the understanding level of students for each tenet, the researcher summed up their scores for three tenets in order to find out the total score presenting their general NOS understanding level. Thus, the total score ranged between 3 and 9. The students scored with 3 or 4 totally classified as inadequate view, the students scored between 5 and 7 labeled as adequate view, and the students scored with 8 or 9 classified as informed view.

Reliability is about if the data obtained via instruments are consistent over time, location, or conditions (Fraenkel, Wallen, & Hyun, 2012, p. 147). In the data analysis procedure, in order to ensure the reliability for VNOS-E Questionnaire, the researcher used the intra-coder reliability method. The reason of using intra-coder reliability method instead of inter-coder reliability method is that the restrictions came with the outbreak of the Covid-19 pandemic during the coding period. A total of 30 % of the data collected with this questionnaire was analyzed by the researcher of this study in two different time periods. To clarify, the researcher made the categorization of the answers for the first time. After some time passed, the researcher secondly made categorization. Then, the researcher recorded her coding made in two different times on SPSS and conducted reliability analysis to find intra-coder correlation coefficient. Intra-coder reliability was found as 0.90. Then, the researcher shared about 18% of the codes with the expert to take expert opinions. The expert agreed with the researcher for 94% of the shared codes. Inconsistencies were resolved by discussing with an expert to reach consensus. After discussion conducted for the differences and consensus for each participant satisfied, the researcher of this study analyzed the rest of the data by following the same procedure which was achieved a consensus.

3.5.2 Informal Reasoning on Socioscientific Issues Questionnaire Analysis

In order to analyze students' informal reasoning quality and modes about global warming, acid rain, and genetically modified food, the researcher used a modified version of the integrated framework developed by Wu and Tsai (2007). This framework (Wu & Tsai, 2007) is one of the first approaches developed to examine participants' argumentation and decision-making on socioscientific issues by using both qualitative indicators and quantitative measures.

Originally, the framework of Wu and Tsai (2007) was developed to examine informal reasoning under three main titles "decision-making mode and position change", "reasoning modes" and "reasoning levels (reasoning quality)." Since this study focused on the students' informal reasoning modes and quality, the researcher of this study took the "reasoning modes" and "reasoning level (reasoning quality)" parts of the framework. Thus, the framework given in Figure 3.2. was used in the present study.

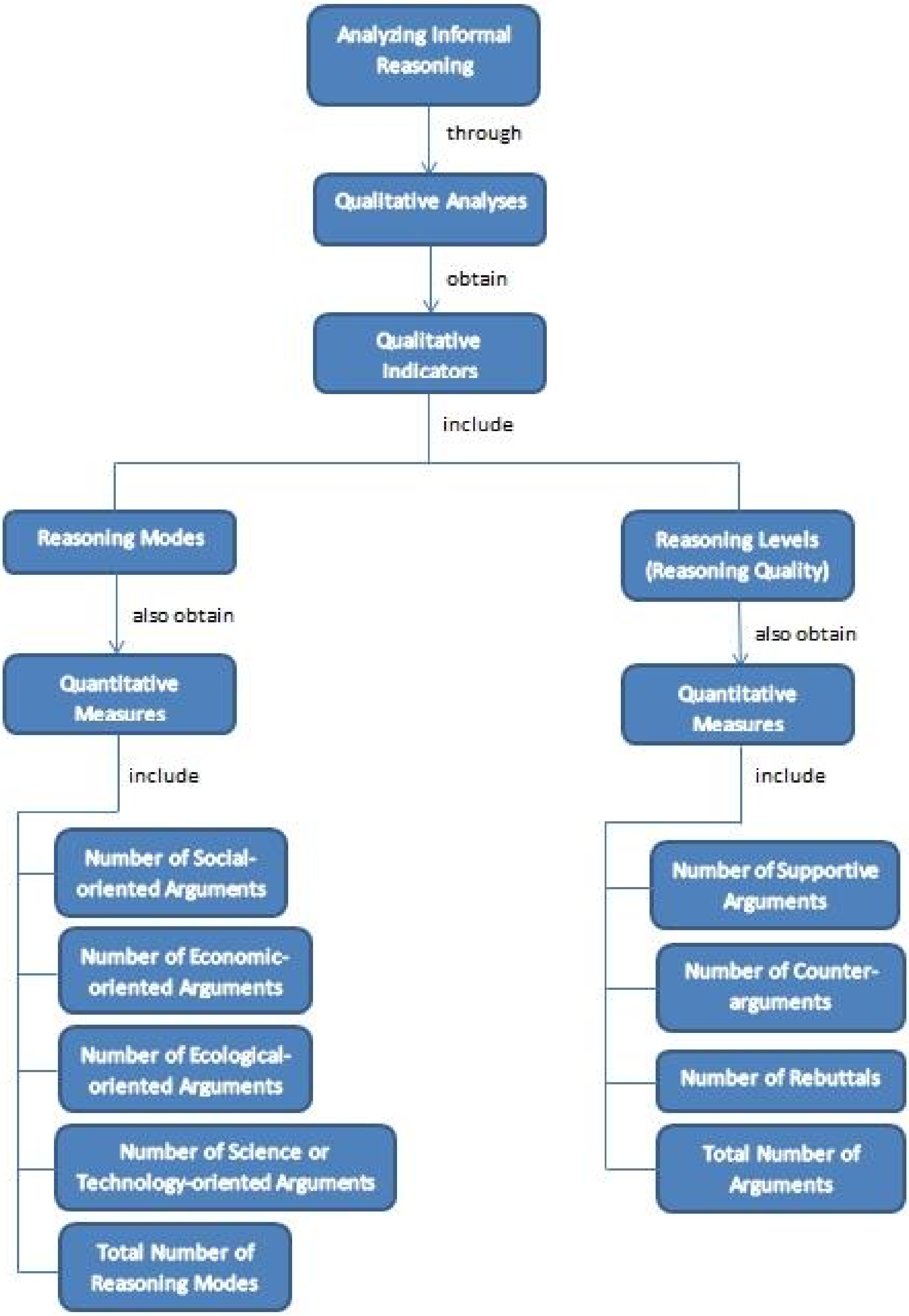

Figure 3.2. The Framework Used to Analyze Informal Reasoning on Socioscientific Issues

This used framework in this study includes two qualitative indicators which are reasoning modes and reasoning quality. The reasoning mode indicator assesses the perspectives that students used while making their arguments on socioscientific issues. These different perspectives were determined as social-oriented, ecological-oriented, economic-oriented, and science-oriented or technology-oriented by studies conducted with high school students. These perspectives were taken into considerations while coding the participants' perspectives in this study. During the analysis procedure, the researcher also looked for emerging codes.

Numbering each reasoning mode enables us to quantify the indicators for informal reasoning modes. The number of social-oriented argument indicators specifies the sum of social-oriented argument a student generated. If a student generated more social-oriented arguments, it means s/he is oriented to reason from social-oriented perspectives. As another quantitative indicator, the number of ecological-oriented argument denotes the amount of ecological-oriented arguments generated by a student. If a participant constructed more ecological-oriented arguments, it means s/he tends to make reasoning based on ecological-oriented attention. In addition, the number of economic-oriented argument remarks how many economic-oriented arguments were constructed by a student. The more economic-oriented arguments generated by a student means that the more s/he tends to consider the issue with economic-oriented aspects. Additionally, the number of science-oriented or technology-oriented argument specifies the sum of science and technology-oriented arguments constructed by a student. It is also thought that the usage of science or technology-oriented arguments by students indicates the ability of using what they learned in science classrooms. If a student generated more science and technology-oriented arguments, it means that s/he tends to think from science or technology-oriented perspectives, and s/he is able to use her/his knowledge obtained in science classrooms. As a last quantitative indicator of reasoning mode, the total number of reasoning modes remarks the total amount of reasoning modes a student benefited in his/her informal reasoning. The more total number of reasoning modes used by a student, the more s/he thinks from multiple perspectives. For example, if a student constructed two ecological-oriented argument and three social-oriented arguments, s/he benefited from two reasoning modes.

Reasoning quality indicators aim to evaluate students' abilities to form three different arguments which are supportive arguments, counter-arguments and rebuttals. In this study, the participants' arguments were categorized by using these argument types. Kuhn (1993) stated that rebuttals are critical for qualified informal reasoning because it integrates argument and counter-argument. Therefore, the construction of rebuttal was accepted as the indicator of high-quality informal reasoning in the present study.

Numbers of each kind of arguments (supportive argument, counter-argument, and rebuttal) are used as the quantitative indicators for reasoning quality. Number of supportive argument indicates the sum of supportive arguments constructed by a student. If a student constructs more supportive arguments, s/he more often supports his/her position with evidences. As other indicator, the number of counter-argument specifies the amount of counter-argument developed by a student. The more counter-argument s/he generates, the more s/he is able to reason from opposite-position. Additionally, the number of rebuttals consists of the sum of rebuttals generated by a student. This indicator measures the ability of a student to justify for his/her position. The total number of arguments indicates the total amount of these three kinds of arguments (i.e. supportive arguments, counter-arguments, and rebuttals).

In order to calculate the reasoning quality of students, the researcher made a modification in the framework. The researcher multiplied the number of supportive argument by one, multiplied the number of counter-argument by two, and multiplied the number of rebuttal by three. The reason is that there are students who constructed 3 supportive arguments but did not construct counter-argument and rebuttal, while there are students who constructed 1 supportive argument, 1 counter-argument, and 1 rebuttal. Although both of the students totally constructed 3 arguments, one of them cannot construct counter-argument and rebuttal. In order to differentiate these students from each other, the researcher scored the type of argument while calculating informal reasoning quality quantitatively.

Similar to VNOS-E Questionnaire, intra-coder reliability for Informal Reasoning on Socioscientific Issues Questionnaire was addressed in the analysis. Similarly, intra-coder reliability method was used instead of inter-coder reliability method because of the outbreak of the Covid-19 pandemic during the coding period. A total of 30 % of the data collected with this questionnaire was analyzed by the researcher of this study in two different time periods. After the independent analysis procedure, the researcher recorded her coding made in two different times on SPSS and conducted reliability analysis to find intra-coder correlation coefficient. Intra-coder reliability was found as 0.95. Then, the researcher shared about 32% of the codes with the expert to take expert opinions. The expert agreed with the researcher for 90% of the shared codes. Inconsistencies were resolved by discussing with an expert to reach a consensus. Then, the researcher of this study analyzed the rest of the data based on the understanding gained during the intra-coder reliability stage.

After all collected data were recorded on SPSS, the researcher conducted some statistical analysis in order to find out the relationships among the three variables. More specifically, the researcher benefited from descriptive statistics involving mean, standard deviation, range, frequencies in order to identify informal reasoning and nature of science understanding of eighth grade students. Also, for each scenario separately and for the total scores calculated by summing the scores in each scenario, Pearson correlation analyses were conducted to find out the relationship between varieties of students' informal reasoning modes and the quality of their informal reasoning. Lastly, multiple regression analyses were conducted to examine the relationship between NOS understanding and informal reasoning quality deeply by finding how well tenets of nature of science are able to predict informal reasoning quality in each scenario and in total.

3.6 Validity

Validity is about if the instruments measure the researcher wants to measure (Fraenkel, Wallen, & Hyun, 2012, p.147). In the following titles, the researcher explained the validity issues.

3.6.1 Internal Validity Threats

In the present study, one of the possible threats is subject characteristic. Different characteristics of subjects like age, success, and gender can cause a threat named as subject characteristic threat (Fraenkel, Wallen, & Hyun, 2012). In order to control this threat, all participants were selected from eighth grade level, and all students were selected from the public middle schools located in Altındağ district of Ankara. Thus, the subject characteristics threat was substantially avoided, but of course, there are some characteristics which cannot be controlled, like intelligence and ability differences of participants.

Other threat for internal validity is location which may cause alternative explanations for the findings (Fraenkel et al., 2012). Since data collection was conducted in four different schools, location threat may occur. However, in order to eliminate this threat, the researcher applied the instruments in students' own classrooms. Also, the schools where the study conducted were selected among the public middle schools located in the same district, Altındağ. Thus, the classrooms of the participant students have almost the same opportunities and atmosphere, which eliminates location threat.

The other possible threat is data collector characteristics (Fraenkel et al., 2012). Since both instruments were applied by the same researcher to all classes from different schools, this threat was controlled by the researcher.

Another threat about the instrument is data collector bias which is the unconscious distortion of the data during the collection or analysis procedure by the data collector to make accurate findings (Fraenkel et al., 2012). The researcher behaved in the same way during the data collection process and in order to control this threat. For controlling this threat, the researcher also refrained from evaluating the two instruments of the same person at the same time. To clarify, the researcher firstly will evaluate the NOS instruments, and after the evaluation of NOS instrument is completed, the researcher will evaluate the informal reasoning instrument at different time.

Lastly, since the content studied has moral, ethical, and social dimensions and it is expected students to make decisions about these controversial issues, they can feel disturbed about expressing their own opinions. Before data collection procedure, the researcher made an explanation about that the answers will not be shared with anyone and they are free to write anonymous names instead of their own names. Thus, this threat was controlled by the researcher.

3.6.2 External Validity of the Analysis

External validity is defined as the generalizability of the findings of a research (Fraenkel, Wallen, & Hyun, 2012). Since purposeful sampling was realized in the present study, the generalizability cannot be done certainly. However, there are some ways to support the external validity of the findings. One of them is a detailed description (Merriam et al., 2016; & Erlandson, Harris, Skipper, & Allen, 1993). The researcher gave detailed information about both the selected purposive sample and data collection and analysis procedure to support the generalizability of the findings.

3.7 Assumptions

The researcher assumes the followings for the present study;

1. During the administration of the questionnaire, the researcher satisfied the same conditions in all classes.
2. All students answered the questions fairly and sincerely.
3. The students did not interact with each other while answering the questions in the questionnaires.

3.8 Limitations

The present study has the following limitations;

1. The findings of the present study were limited to eighth public middle schools located in Altındağ, Ankara. However, the findings could only be generalized to other eighth grade students with similar characteristics.
2. The findings of the study were limited to the reliance on students' written answers on the questionnaires.
3. Students' informal reasoning regarding global warming, acid rain, and genetically modified food was examined by the framework used in the present study. However, distinct conclusions might be found by using distinct frameworks.

CHAPTER 4

RESULTS

In this chapter, descriptive statistics about eighth grade students' nature of science understanding and informal reasoning quality and modes were given. Also, correlational analyses were given to explain the observed relationships between NOS understanding and informal reasoning.

4.1 Descriptive Statistics

4.1.1 Eighth Grade Students' Nature of Science Understanding

Research Question 1: What are the eighth grade students' nature of science understanding on empirical-based, subjectivity, and tentativeness tenets?

VNOS-E questionnaire was used to evaluate the students' NOS understanding on three tenets which were empirical-based, subjectivity, and tentativeness.

As represented in Table 4.1., results about students' NOS understanding on empirical-based tenet revealed that about 57% of the students held inadequate understanding about empirical-based NOS while about 40% of them held adequate understanding about empirical-based NOS. Only about 3% of the students held informed understanding about the empirical-based tenet of NOS.

Results about subjectivity tenet of NOS showed that about 72% of the participants have inadequate, about 27% of them have adequate, and only about 1% of the students have informed understanding about subjective NOS.

Results about students' NOS understanding on tentativeness tenet revealed that about 43% of the students held inadequate understanding on tentativeness aspect of

NOS while about 56% of them held adequate understanding. Only about 1% of the students held informed understanding about tentativeness tenet of NOS.

Inadequate understanding was scored as 1, adequate level scored as 2, and informed scored as 3 for each tenet of NOS by the researcher. In addition to frequencies and percentages, Table 4.1. presents eighth grade students' average scores (means) and standard deviations on the three tenets of NOS and total NOS scores.

The participants' total NOS scores were calculated by summing up the scores of each tenet. The students scored with 3 or 4 totally were classified as inadequate view, the students scored between 5 and 7 were labeled as adequate view, and the students scored with 8 or 9 were classified as informed view. The results about total NOS understanding showed that about 58% of the students have inadequate views on NOS understanding while about 42% of them have adequate views NOS understanding. According to the results, only 1 participant has informed views on NOS understanding.

Table 4.1. Eighth Grade Students' Nature of Science Understanding

	N	%	Mean	SD	Range
Empirical-based			1.46	0.55	1-3
Inadequate	235	56.8			
Adequate	168	40.6			
Informed	11	2.7			
Subjectivity			1.30	0.50	1-3
Inadequate	297	71.7			
Adequate	111	26.8			
Informed	6	1.4			
Tentativeness			1.59	0.52	1-3
Inadequate	176	42.5			
Adequate	232	56.0			
Informed	6	1.4			
Total NOS			4.35	1.07	3-8
Inadequate	239	57.7			
Adequate	174	42.0			
Informed	1	0.2			

Some examples from the students' answers revealing their understanding about empirical-based, subjectivity, and tentativeness tenet of NOS were represented in the Table 4.2.

Table 4.2. Eighth Grade Students' Understanding about Empirical-based, Subjective, and Tentative Nature of Science

Tenets of NOS	Inadequate	Adequate	Informed
Empirical-based	*"Science is the idea we get through reading books, searching, and communicating with our families." (ÖAB13)* *"Science emerges from experiments. The other issues are the result of thinking." (MAB21)* *"Everything that contains information is science." (HSB9)*	*"Science is the inventions based on experiments and observations." (ÖAA1)* *"Science is researching to find out the unknown." (MMC13)*	*"Science is that scientists make useful discoveries to the world. Science is based on knowledge, data, evidence, and invention. Other branches do not use data and evidence." (MMA10)*
Subjectivity	*"Since there is no exact information about the extinction of dinosaurs, everyone may think differently." (ÖAC18)* *"Scientists expressed different views on the extinction of dinosaurs to become famous." (MAC5)* *"Since each scientist does different tests and different researches, they have different opinions."(HSA16)*	*"Although they all have the same evidence, they may have different opinions due to the difference in interpretations" (ÖAE17)* *"Every person's point of view is different. Scientists have also found different results based on different opinions." (MAB21)*	*"For example, according to the information scientists obtained from their own field of science, while a scientist may say that the bones were crushed due to the meteorite, the others may say that these were broken under the ground due to earthquake. Thus, they have different views." (HSA21)*

Table 4.2. (cont'd)

Tentativeness	*"I don't think scientific knowledge will change. For example, the scientist who said the earth was round was executed, but this idea was later proven and has not changed." (ÖAA4)* *"I think scientific knowledge does not change because the information is permanent." (MMC1)*	*"Yes, I think it will change. For example, in the past, people thought the earth was flat. However, this theory changed with the advancement of technology and science." (ÖAB1)* *"Scientific knowledge will change because the things developed today will be developed more technology in the future." (MAC5)* *"It can change because new information emerges as technology develops." (HSB11)*	*"Scientific knowledge will change because as technology improves, we can discover new things. We may even discover that there are things we do wrong." (HSE9)*

4.1.2 Eighth Grade Students' Informal Reasoning Quality and Modes

The participants constructed informal reasoning on three different socioscientific issues which are global warming, acid rain, and genetically modified food. For each socioscientific issue, the students were expected to construct supportive arguments, counter-arguments, and rebuttals. Also, for each SSI, informal reasoning quality was calculated by multiplying the number of supportive argument by one, multiplying the number of counter-argument by two, and multiplying the number of rebuttal by three. The results about informal reasoning for each SSI were given in the next sections.

Research Question 2: What are the eighth grade students' reasoning modes on socioscientific issues global warming, acid rain, and genetically modified food?

Research Question 3: What are the eighth grade students' informal reasoning quality on socioscientific issues global warming, acid rain, and genetically modified food?

4.1.2.1 Informal Reasoning about Global Warming

The results presented in Table 4.3. showed that the students, on average, constructed less than one supportive argument (*M*=0.84), counter-argument (*M*=0.40), and rebuttal (*M*=0.16) about global warming. The average score of students for informal reasoning quality on global warming is 2.13, as shown in Table 4.3.

In Table 4.3., the results also revealed that the number of social-oriented arguments constructed by students is 0.36, the number of economic-oriented arguments is 0.16, the number of ecological-oriented is 0.63, and the number of science and technology-oriented arguments is 0.25 on average. The varieties of students' reasoning modes used in their arguments about global warming were represented as a total number of reasoning modes in Table 4.3. The total number of reasoning modes was found as 1.16 on average which showed that the eighth grade students, on average, used more than one reasoning mode in their arguments about global warming.

Table 4.3. Eighth Grade Students' Informal Reasoning Quality and Modes about Global Warming

	Mean	SD	Range
Number of supportive argument	0.84	0.70	0-5
Number of counter-argument	0.40	0.60	0-2
Number of rebuttals	0.16	0.41	0-2
Informal reasoning quality score	2.13	2.41	0-11
Number of social-oriented arguments	0.36	0.62	0-3
Number of economic-oriented arguments	0.16	0.43	0-2
Number of ecological-oriented arguments	0.63	0.67	0-4
Number of science or technology-oriented arguments	0.25	0.54	0-2
Total number of reasoning modes	1.16	0.98	0-4

Table 4.4. presents the frequencies and percentages of students' arguments for the global warming socioscientific issue. According to the results, about 30% of the students did not construct supportive argument about global warming. While about 59% of the students constructed one supportive argument, about 11% of them constructed more than one supportive argument about global warming issue. About 65% of the participants did not generate counter-argument, while about 30% of them generated one counter-argument, and about 5% of the students generated more than one counter-argument about global warming. Results about the construction of rebuttal showed that about 85% of the students did not construct

rebuttal. About 14% of them constructed one rebuttal about global warming, and only about 1% of the participants generated more than one rebuttal.

Students mostly generated ecological-oriented arguments (about 54% of the students) about global warming SSI. About 29% of the students constructed social-oriented arguments, and about 20% of the students constructed science or technology-oriented arguments, while only about 13% of them constructed economic-oriented arguments.

Table 4.4. Frequencies of Argument Components on Global Warming

	N	%	Range
Number of supportive argument			0-5
No argument	123	29.7	
One argument	244	58.9	
More than one argument	47	11.3	
Number of counter-argument			0-2
No argument	270	65.2	
One argument	124	30.0	
More than one argument	20	4.8	
Number of rebuttals			0-2
No argument	352	85.0	
One argument	56	13.5	
More than one argument	6	1.4	
Number of social-oriented arguments			0-3
No argument	293	70.8	
One argument	95	22.9	
More than one argument	26	6.3	

Table 4.4. (cont'd)

Number of economic-oriented arguments			0-2
No argument	360	87.0	
One argument	43	10.4	
More than one argument	11	2.7	
Number of ecological-oriented arguments			0-4
No argument	191	46.1	
One argument	191	46.1	
More than one argument	32	7.7	
Number of science or technology-oriented arguments			0-2
No argument	331	80.0	
One argument	61	14.7	
More than one argument	22	5.3	

Table 4.5. presents the frequencies and percentages of the argument components' distribution within four different informal reasoning modes in global warming SSI. About 23% of the students generated social-oriented supportive arguments, while about 9% of them constructed social-oriented counter-argument, and about 4% of them constructed social-oriented rebuttal. Results about economic-oriented arguments showed that only about 2% of the students constructed economic-oriented supportive argument while about 11% of the students constructed economic-oriented counter-argument. About 3% of them generated economic-oriented rebuttal. With regard to ecological-oriented arguments, about 53% of the students constructed ecological-oriented supportive arguments while only about 1% of the students generated ecological-oriented counter-argument, and about 3% of them constructed ecological-oriented rebuttal. Lastly, results about science or

technology-oriented arguments showed that only 1 student generated science or technology-oriented supportive argument while about 19% of the students constructed science or technology-oriented counter-argument. About 6% of them constructed science or technology-oriented rebuttal.

Table 4.5. Frequencies of the Distribution of Argument Components within Informal Reasoning Modes in Global Warming Issue

	N	%	Range
Social-oriented arguments			
Supportive argument	94	22.7	1-2
Counter-argument	36	8.7	1
Rebuttal	18	4.3	1
Economic-oriented arguments			
Supportive argument	8	1.9	1
Counter-argument	44	10.6	1
Rebuttal	13	3.1	1
Ecological-oriented arguments			
Supportive argument	219	52.9	1-4
Counter-argument	5	1.2	1
Rebuttal	12	2.9	1
Science or technology-oriented arguments			
Supportive argument	1	0.2	1
Counter-argument	80	19.3	1
Rebuttal	24	5.8	1

Some examples from the students' arguments about global warming were represented in the Table 4.6.

Table 4.6. Eighth Grade Students' Arguments about Global Warming Issue

Informal Reasoning Modes	Supportive Argument	Counter Argument	Rebuttal
Social-oriented	*"If the coal is not burned, people will have difficulty in winter." (ÖAB10)* *"The Sun's harmful rays will hurt us, humans." (ÖAC8)* *"If we do not take precautions, we can die from extreme heat." (ÖAD8)*	*"Global warming has no harm to humans, if it was, it would have been noticed." (ÖAC14)* *"Life goes on; global warming does not cause any problems in our lives." (ÖAE15)*	*"We must sacrifice money and defend ourselves. Money can be regained, but human life cannot be regained." (ÖAC5)*
Economic-oriented	*"If no action is taken, the world will get warmer. We can't go out and a lot of businesses could be closed." (ÖAD10)*	*"If precautions are taken, countries will fall into an economic crisis." (ÖAB11)* *"Taking precautions would be too costly." (MMC16)*	*"The countries with the best economic status can help poor countries." (ÖAB15)*
Ecological-oriented	*"The world is increasingly damaged." (ÖAB11)* *"The glaciers will melt, and the animals at the poles will become extinct." (ÖAB2)*	*"If precautions are not taken against global warming, the world temperature increases." (ÖAC13)* *"Maybe the warmer world is better for living beings." (ÖAC17)*	*"But even if global warming is a natural element of earth's climate, people consume more oil, gas, and coal, increasing this warming even more. It causes the temperature rise to be much higher." (ÖAA4)*

Table 4.6. (cont'd)

	"The ozone layer is damaged." (ÖAC8) *"Air pollution will increase, if we do not take precautions." (ÖAC8)*		
Science or technology-oriented	*"Although developing technology causes good results, it can also cause bad effects on nature." (ÖAC12)*	*"Humans have no effect on these temperature increases; it is a natural part of climate." (ÖAA4)* *"Global warming is not different from the world climate, so precautions should not be taken." (MMC10)*	*"But it takes years for the damage to the ozone layer to heal, and we are increasing this damage." (ÖAA11)*

4.1.2.2 Informal Reasoning about Acid Rain

As presented in Table 4.7., the students constructed less than one supportive argument (*M*=0.67), counter-argument (*M*=0.29), and rebuttal (*M*=0.14) on average about acid rain. Also, informal reasoning quality average score on acid rain is 1.68.

The average number of different reasoning modes' usage by students are as following; 0.10 for social-oriented arguments, 0.30 for economic-oriented, 0.44 for ecological-oriented and 0.27 for science or technology-oriented arguments. As shown in Table 4.7., the results revealed that the average score of total reasoning mode is 0.93. This shows that eighth grade students, on average, used almost one kind of reasoning mode in their arguments about acid rain.

Table 4.7. Eighth Grade Students' Informal Reasoning Quality and Modes about Acid Rain

	Mean	SD	Range
Number of supportive argument	0.67	0.70	0-3
Number of counter-argument	0.29	0.53	0-2
Number of rebuttals	0.14	0.39	0-2
Informal reasoning quality score	1.68	2.40	0-11
Number of social-oriented arguments	0.10	0.32	0-2
Number of economic-oriented arguments	0.30	0.57	0-3
Number of ecological-oriented arguments	0.44	0.64	0-3
Number of science or technology-oriented arguments	0.27	0.52	0-3
Total number of reasoning modes	0.93	1.02	0-4

The results about the frequencies and percentages of students' arguments for the acid rain were presented in Table 4.8. About 45% of the students did not construct supportive argument, while about 44% of them constructed one supportive argument and about 11% of them constructed more than one supportive argument. Results about the construction of counter-argument showed that about 75% of the participants did not generate counter-argument about acid rain issue. About 21% of them generated only one counter-argument, and about 4% of them generated more than one counter-argument. While about 87% of the participants did not construct rebuttal about acid rain, about 11% of them constructed one rebuttal, and only about 2% of them generated more than one rebuttal.

About 37% of the students generated ecological-oriented arguments about acid rain socioscientific issue. While 24% of the students constructed economic-oriented arguments and 23% of them generated science or technology-oriented arguments, only 9% of the students constructed social-oriented arguments about acid rain.

Table 4.8. Frequencies of Argument Components on Acid Rain

	N	%	Range
Number of supportive argument			0-3
No argument	186	44.9	
One argument	183	44.2	
More than one argument	45	10.9	
Number of counter-argument			0-2
No argument	309	74.6	
One argument	89	21.5	
More than one argument	16	3.9	
Number of rebuttals			0-2
No argument	361	87.2	
One argument	47	11.4	
More than one argument	6	1.4	
Number of social-oriented arguments			0-2
No argument	376	90.8	
One argument	35	8.5	
More than one argument	3	0.7	

Table 4.8. (cont'd)

Number of economic-oriented arguments			0-3
No argument	313	75.6	
One argument	81	19.6	
More than one argument	20	4.8	
Number of ecological-oriented arguments			0-3
No argument	262	63.3	
One argument	124	30.0	
More than one argument	28	6.7	
Number of science or technology-oriented arguments			0-3
No argument	318	76.8	
One argument	83	20.0	
More than one argument	13	3.1	

Table 4.9. represents the frequencies and percentages of the argument components' distribution within four different informal reasoning modes in acid rain issue. About 6% of the students generated social-oriented supportive argument, while about 3% of them constructed social-oriented counter-argument, and only about 1% of the participants constructed social-oriented rebuttal. With regard to economic-oriented arguments, about 17% of the students constructed economic-oriented supportive arguments while about 8% of the students constructed economic-oriented counter-argument. About 4% of them generated economic-oriented rebuttal. Results about ecological-oriented arguments showed that about 34% of the students constructed ecological-oriented supportive arguments while only about 3% of them generated ecological-oriented counter-argument and about 7% of them constructed ecological-oriented rebuttals. Lastly, results about science

or technology-oriented arguments showed that about 9% of the participants generated science or technology-oriented supportive argument while about 16% of the students constructed science or technology-oriented counter-argument. About 2% of them constructed science or technology-oriented rebuttal.

Table 4.9. Frequencies of the Distribution of Argument Components within Informal Reasoning Modes in Acid Rain Issue

	N	%	Range
Social-oriented arguments			
Supportive argument	24	5.8	1
Counter-argument	11	2.7	1
Rebuttal	6	1.4	1
Economic-oriented arguments			
Supportive argument	71	17.1	1-2
Counter-argument	34	8.2	1
Rebuttal	17	4.1	1
Ecological-oriented arguments			
Supportive argument	142	34.3	1-2
Counter-argument	11	2.7	1
Rebuttal	28	6.7	1-2
Science or technology-oriented arguments			
Supportive argument	38	9.2	1
Counter-argument	65	15.7	1
Rebuttal	7	1.7	1

Some examples from the students' arguments about acid rain were represented in the Table 4.10.

Table 4.10. Eighth Grade Students' Arguments about Acid Rain Issue

Informal Reasoning Modes	Supportive Argument	Counter Argument	Rebuttal
Social-oriented	*"If we follow the second suggestion, we can continue our lives with clean potable water." (MAA3)*	*"Fossil fuel is what we need; we should be able to use it as much as we want." (MAB24)*	*"Let's say you haven't drunk any water for two days. If I hand you money and water, which one would you prefer? Of course, you get the water. That's why we should take action first and not focus too much on the economy for now." (MAA3)*
Economic-oriented	*"The second solution suggestion allows us to save energy." (MAB4)* *"If we can apply the third suggestion, we can save our architectural works." (MAC4)*	*"The first solution is better because it is economically cheaper." (MAC4)*	*"If the first suggestion is implemented, our architectural works will continue to suffer, but the third suggestion is more comprehensive." (MAC4)*
Ecological-oriented	*"The second suggestion provides us to use less fossil fuel." (MAA12)* *"In the second suggestion, the gases that pollute the air can be controlled." (MAB11)*	*"First suggestion is better because the acid in the water will be cleaned." (MAC6)*	*"We may not be able to clean the water completely by using the first suggestion, and this practice can be very dangerous." (MAB24)*

Table 4.10. (cont'd)

Science or Technology-oriented	*"The first suggestion should be implemented because it can be applied easily." (MAA21)* *"The third suggestion allows us to prevent gases from entering the atmosphere even if we use fossil fuels." (MAC6)*	*"The first solution suggestion cleans the water more easily." (MAB4)* *"The first suggestion is sufficient because acid rain is not harmful." (MMC10)*	*"We do not have to use fossil fuels for our needs. We can use renewable energy sources." (MAB24)*

4.1.2.3 Informal Reasoning about Genetically Modified Food

The findings revealed that the students, on average, generated less than one supportive argument (*M*=0.68), counter-argument (*M*=0.41), and rebuttal (*M*=0.16) about genetically modified food. Students' informal reasoning quality score on genetically modified food was found as 1.97 on average.

According to the results presented in Table 4.11., students, on average, used more than one social-oriented arguments (*M*=1.09) while economic-oriented (*M*=0.04), ecological-oriented (*M*=0.04), and science or technology-oriented arguments (*M*=0.08) were used less than one on average. The average score of the total reasoning mode is 0.80, which means students, on average, did not use more than one kind of reasoning mode.

Table 4.11. Eighth Grade Students' Informal Reasoning Quality and Modes about Genetically Modified Food

	Mean	SD	Range
Number of supportive argument	0.68	0.52	0-2
Number of counter-argument	0.41	0.53	0-2
Number of rebuttals	0.16	0.40	0-2
Informal reasoning quality score	1.97	2.26	0-11
Number of social-oriented arguments	1.09	1.00	0-4
Number of economic-oriented arguments	0.04	0.19	0-1
Number of ecological-oriented arguments	0.04	0.19	0-1
Number of science or technology-oriented arguments	0.08	0.32	0-2
Total number of reasoning modes	0.80	0.68	0-3

Table 4.12. presents the frequencies and percentages of students' arguments for the genetically modified food issue. Results showed that about 34% of the students did not construct supportive argument about genetically modified food while about 63% of them generated one supportive argument, and only about 3% of them constructed more than one supportive argument about the issue. While about 61% of the participants did not construct counter-argument, about 37% of them generated one counter-argument, and only about 2% of them generated more than

one counter-argument. Results about the construction of rebuttal revealed that about 85% of the students did not construct rebuttal. About 14% of them generated one rebuttal, and only about 1% of them constructed more than one rebuttal about the issue.

65% of students generated social-oriented arguments about genetically modified food issue while only about 7% of the students generated science or technology-oriented arguments, and only about 4% of them constructed economic-oriented and ecological-oriented arguments about the issue.

Table 4.12 Frequencies of Argument Components on Genetically Modified Food

	N	%	Range
Number of supportive argument			0-2
No argument	142	34.3	
One argument	261	63.0	
More than one argument	11	2.7	
Number of counter-argument			0-2
No argument	253	61.1	
One argument	153	37.0	
More than one argument	8	1.9	
Number of rebuttals			0-2
No argument	353	85.3	
One argument	56	13.5	
More than one argument	5	1.2	
Number of social-oriented arguments			0-4
No argument	145	35.0	
One argument	129	31.2	
More than one argument	140	33.8	

Table 4.12. (cont'd)

Number of economic-oriented arguments			0-1
No argument	398	96.1	
One argument	16	3.9	
More than one argument	-	-	
Number of ecological-oriented arguments			0-1
No argument	399	96.4	
One argument	15	3.6	
More than one argument	-	-	
Number of science or technology-oriented arguments			0-2
No argument	384	92.8	
One argument	25	6.0	
More than one argument	5	1.2	

Table 4.13. represents the frequencies and percentages of the argument components' distribution within four different informal reasoning modes in genetically modified food issue. About 63% of the students generated social-oriented supportive arguments, while about 34% of them constructed social-oriented counter-argument, and about 11% of them constructed social-oriented rebuttals. With regard to economic-oriented arguments, none of the students constructed economic-oriented supportive argument while about 4% of the students constructed economic-oriented counter-argument, and only one student generated economic-oriented rebuttal. Results about ecological-oriented arguments showed that only about 1% of the students constructed ecological-oriented supportive argument and only about 2% of them generated ecological-oriented counter-argument. Only two students constructed ecological-oriented rebuttal. Lastly,

results about science or technology-oriented arguments showed that about 3% of the participants generated science or technology-oriented supportive argument while about 2% of the students constructed science or technology-oriented counter-argument. About 4% of them constructed science or technology-oriented rebuttal.

Table 4.13. Frequencies of the Distribution of Argument Components within Informal Reasoning Modes in Genetically Modified Food

	N	%	Range
Social-oriented arguments			
Supportive argument	260	62.8	1-2
Counter-argument	142	34.3	1
Rebuttal	47	11.3	1-2
Economic-oriented arguments			
Supportive argument	0	0	0
Counter-argument	15	3.6	1
Rebuttal	1	0.2	1
Ecological-oriented arguments			
Supportive argument	6	1.4	1
Counter-argument	7	1.7	1
Rebuttal	2	0.5	1
Science or technology-oriented arguments			
Supportive argument	13	3.1	1
Counter-argument	7	1.7	1
Rebuttal	15	3.6	1

Some examples from the students' arguments about genetically modified food were represented in the Table 4.14.

Table 4.14. Eighth Grade Students' Arguments about Genetically Modified Food Issue

Informal Reasoning Modes	Supportive Argument	Counter Argument	Rebuttal
Social-oriented	*"Consuming an unknown and genetically modified food can cause unexpected problems or mutations in our body." (MMA1)* *"It increases vitamin A and reduces blindness in children." (MMA12)* *"It can be harmful to us because it might have side effects." (MMC7)* *"This rice can cause people to get cancer, or we could get poisoned and die." (HSA13)*	*"This rice is suitable for consumption in order to get vitamin A in our body in a shorter time and to prevent blindness." (MMA1)* *"We can eliminate blindness, but maybe a different disease will arise." (MAA13)* *"If the plants are genetically modified and have a structure that contains more nutrients, we will eat less and get more nutrients. This could be the solution to the food shortage that people suffer." (MMB11)*	*"Vitamin A can be taken from non-genetically modified foods such as carrots and fish that are more beneficial for us." (MMA1)* *"Because we do not know how genetically modified herbs affect our bodies, consuming these foods can pose a great risk for us. And, human life is too valuable to be put at risk for such a reason." (MMB11)*
Economic-oriented		*"It would be economically good to put it on sale." (MMC1)* *"The price of this rice can be cheap." (MMC13)*	*"If people have side effects, it may be necessary to do more costly things to correct the side effects." (HSB11)*

Table 4.14. (cont'd)

Ecological-oriented	*"We do not know if this rice can affect other rice varieties genetically." (MMA2)*	*"Since different rice is grown in the same place, the genetic makeup of other rice may be impaired." (MMB6)*	*"This rice may be cheap but its seeds damage our land." (MAA3)*
Science or Technology-oriented	*"We should eliminate vitamin A deficiency with drug (drops etc.), just like vitamin D." (HSA6)*	*"No problem has yet been found to be caused by this rice." (MMA1)*	*"There were no problems in the experiments yet, but there may be problems in the future. For example, paralyzed patients used to be untreated. Treatment is possible today. Therefore, we must not forget that science is advancing day by day and reaching different results." (MMA1)*

Only one student constructed a religious-oriented argument about genetically modified food. The student stated that *"Genetically modified food is haram and selling so selling it is a sin." (MAA14)*.

4.2 Relationship between Varieties of Informal Reasoning Modes and Informal Reasoning Quality

Research Question 4: Does the relationship between the varieties of eighth grade students' reasoning modes and the quality of their informal reasoning differ across three different socioscientific issues global warming, acid rain, and genetically modified food?

The relationship between varieties of informal reasoning modes and informal reasoning quality was found for each socioscientific issue and for total scores. In order to determine the relationship between informal reasoning mode and quality which are continuous variables, Pearson correlation should be conducted. However, before correlational analyses, preliminary analyses were conducted to check the assumptions of correlational analyses.

1. Normality: Since the sample size is large (N=414), the skewness and kurtosis values, and histograms were examined in order to check normality. The skewness and kurtosis values were in the acceptable range which is between -2 and +2. The histograms also supported that the scores of each variable were distributed almost normally.
2. Linearity: In order to check the linearity assumption, scatterplots of scores were formed. It was seen that the relationship between two variables is linear, so this assumption was not violated.
3. Homoscedasticity: Scatterplot was used in order to check the homoscedasticity assumption. Since the plots showed a fairly ever cigar shape along its length, the assumption was met.
4. Outliers: The scatterplots also provided us to find outliers. There were values exceeding the critical value slightly; however, since there was a reasonable data size, the outliers might not be omitted. Therefore, the researcher of the present study did not delete any case from the data.

After controlling the assumptions, the Pearson correlation coefficients were calculated. Alpha level was .01 (two-tailed) as the significant level, and pairwise deletion was implemented, N=414. The results showed that there were statistically significant correlations between informal reasoning quality and varieties of informal reasoning modes in each socioscientific issue. Also, there was a significant correlation between students' total informal reasoning quality scores and informal reasoning mode scores. All of the correlations were positive, and the effect sizes were large. The results were presented in Table 4.15.

As seen in Table 4.15., the relationship between students' informal reasoning quality and their informal reasoning modes in genetically modified food socioscientific issue was smaller than the relationships observed in global warming and acid rain issues. However, this difference is small. In other words, as mentioned before, all effect sizes of correlations were large, although there are small differences (Cohen, 1988, pp 79-81).

Table 4.15. Correlations between Informal Reasoning Mode and Informal Reasoning Quality

	IR Quality Score	IR Modes Score
Global Warming SSI		
IR Quality Score	-	.87*
IR Modes Score		-
Acid Rain SSI		
IR Quality Score	-	.89*
IR Modes Score		-
Genetically Modified Food SSI		
IR Quality Score	-	.75*
IR Modes Score		-
Total Scores		
IR Quality Score	-	.90*
IR Modes Score		-

*Correlation is significant at the 0.01 level (2-tailed).

4.3 Predictors for Informal Reasoning Quality on Socioscientific Issues

Research Question 5: How well do the three tenets of nature of science (empirical-based, subjectivity, and tentativeness) predict eighth grade students' informal reasoning quality on socioscientific issues?

Multiple regression analyses were used to find out how much of the variance in the students' informal reasoning quality can be explained by the three tenets of nature of science. Multiple regression analyses were conducted for each sociscientific issue and for total scores separately. Nature of science understanding tenets which are empirical-based, subjectivity, and tentativeness were used as the predictors in multiple regression analyses. Firstly, the preliminary analyses were conducted to control the assumptions of multiple regression.

1. Sample Size: Pallant (2011) stated that the results obtained from small samples cannot be generalized to other samples. According to Tabachnick and Fidell (2007, p. 123), the sample size requirement for multiple regression is calculated by the formula $N>50+8m$ (where m is the number of the independent variable). In the present study, there were three independent variables, so the minimum sample size for this study should be 75. This assumption was met because the sample of this study included 414 subjects.
2. Multicollinearity and Singularity: The data must not show multicollinearity, which occurs when there are two or more independent variables that are highly correlated with each other. This assumption was checked by looking at correlation coefficients, Tolerance, and Variance Inflation Factor (VIF) values. The results showed that the correlations between independent variables are all smaller than 0.3 which is smaller than 0.8. In addition, the Tolerance value is almost 1.00 which is greater than 0.10, and VIF value is also almost 1.00 which is lower than 10. All these findings supported that there is no multicollinearity. Thus, this assumption was also met.

3. Normality of Residuals: The residuals should be normally distributed about the predicted dependent variable scores. Normal P-P plots and scatterplots showed that the residuals were almost normally distributed. According to Pallant (2011), there could be at most only 1% of cases which fall outside of the range -3.3 and +3.3 in a normally distributed sample. In the table "Casewise Diagnostics" for each socioscientific issue's informal reasoning quality and total informal reasoning quality, there were at most 4 cases (only 1% of the cases) outside of this range. Thus, the normality assumption was met.
4. Linearity of Residuals: The residuals should have a straight line relationship with predicted dependent variable scores. The normal P-P plots showed that the linearity assumption was not violated.
5. Homoscedasticity of Residuals: The variance of the residuals about the predicted dependent variable scores should be the same for all predicted scores. The scatterplots were checked. Since there was a roughly rectangular shape in scatterplots, the homoscedasticity assumption was also met.
6. Outliers: Standardized residual values should be between -3.3 and 3.3. If this interval is exceeded, this means that there would be outliers. The scatterplot and "Casewise Diagnostics" tables showed that there were some outliers. Also, Mahalanobis Distance was used to check outliers. Since there were three independent variables, the critical value for Mahalanobis Distance is 16.27. In the data of this present study, the maximum value for Mahalanobis Distance was 16.42, which just slightly exceeded the critical value. Only one case exceeded the critical value of Mahalanobis Distance. To check if this case has any undue influence on the results, Cook's Distance was checked. Since the values of Cook's Distance were smaller than 1, there was no need to delete the outlier.
7. Independence of Residuals: The residuals should be independent from each other. That is, each residual should not be influenced by other residuals. In

order to check this assumption, Durbin-Watson value was controlled. Since the values were between 1.5 and 2.5 range, the independence of residuals assumption was not violated.

After checking the assumptions, multiple regression analyses were conducted respectively for informal reasoning quality in global warming SSI, informal reasoning quality in acid rain SSI, informal reasoning quality in genetically modified food, and total informal reasoning quality in three different SSIs.

Firstly, multiple regression analysis was conducted to find out how well three NOS understanding tenets empirical-based, subjectivity, and tentativeness (independent variables) predicted eighth grade students' informal reasoning quality score in global warming socioscientific issue (dependent variable). The results were presented in Table 4.16. According to the results, the combination of predictor variables was significantly related to the dependent variable $F(3, 410)=54.08$, $p<0.05$. In other words, the model including the measures of NOS understanding statistically predicted informal reasoning quality in global warming issue. Approximately 28% of the variance of the dependent variable can be explained by the combination of independent variables. Based on the results, all the independent variables made statistically significant unique contribution to the prediction of the informal reasoning quality score in global warming issue. In more detail, the empirical-based tenet made the strongest unique contribution to the prediction of the dependent variable ($beta= 0.38$, $sr^2= 0.127$, $p<0.05$) by explaining 12.7% of the variance uniquely. The effect size of empirical-based tenet was medium ($f^2=0.145$). Then, the tentativeness tenet made a unique contribution to the prediction of informal reasoning quality score in global warming issue ($beta= 0.22$, $sr^2= 0.043$, $p<0.05$) by explaining 4.3% of the variance uniquely. The effect size of tentativeness tenet was small ($f^2=0.045$). The subjectivity tenet made the least unique contribution to the prediction of dependent variable ($beta= 0.15$, $sr^2= 0.020$, $p<0.05$) by explaining 2.0% of the variance uniquely. Subjectivity tenet had small effect size (f^2=*0.020*). The regression equation for predicting informal reasoning quality of eighth grade students in global warming issue is;

$\hat{Y}$= 1.644 X_1 + 0.729 X_2 + 0.995 X_3 – 2.798 where X_1 is used for empirical-based tenet, X_2 is used for subjectivity tenet and X_3 is used for tentativeness tenet.

Table 4.16. Multiple Regression Analyses Results for Variables Predicting Informal Reasoning Quality in Global Warming SSI (N = 414)

	B	*SE B*	*β*
Empirical-based Tenet	1.64*	0.19	0.38
Subjectivity Tenet	0.73*	0.21	0.15
Tentativeness Tenet	0.99*	0.20	0.22
Constant	-2.80*	0.42	
Adjusted R^2		0.28	
F		54.08*	

*p<.05

Secondly, multiple regression analysis was conducted to find out how well three NOS understanding tenets empirical-based, subjectivity, and tentativeness (independent variables) predicted eighth grade students' informal reasoning quality score in acid rain socioscientific issue (dependent variable). The results were presented in Table 4.17. According to the results, the combination of predictor variables was significantly related to the dependent variable $F(3, 410)=35.54$, $p<0.05$. This means that the model including the measures of NOS understanding statistically predicted informal reasoning quality in acid rain issue. Approximately 21% of the variance of the dependent variable can be explained by the combination of independent variables. According to the results, the empirical-based tenet and tentativeness tenet made statistically significant unique contribution to the prediction of the informal reasoning quality score in acid rain issue. In more detail, the empirical-based tenet made the strongest unique contribution to the prediction of dependent variable (*beta= 0.34,* sr^2*= 0.103, p<0.05*) by explaining 10.3% of the variance uniquely. The effect size of empirical-based tenet was almost medium (f^2*=0.115*). Then, the tentativeness tenet made unique contribution to the prediction of informal reasoning quality score in acid rain issue (*beta= 0.20,* sr^2*= 0.036, p<0.05*) by explaining 3.6% of the variance uniquely. Tentativeness tenet had small effect size (f^2*=0.037*). The regression equation for predicting informal reasoning quality of eighth grade students in acid rain issue is;

$\hat{Y}$= 1.472 X_1 + 0.904 X_3 – 2.386 where X_1 is used for empirical-based tenet and X_3 is used for tentativeness tenet.

Table 4.17. Multiple Regression Analyses Results for Variables Predicting Informal Reasoning Quality in Acid Rain SSI (N = 414)

	B	*SE B*	*β*
Empirical-based Tenet	1.47*	0.20	0.34
Subjectivity Tenet	0.37	0.22	0.08
Tentativeness Tenet	0.90*	0.21	0.20
Constant	-2.39*	0.44	
Adjusted R^2		0.20	
F		35.54*	

*p<.05

Thirdly, multiple regression analysis was conducted to find out how well three NOS understanding tenets empirical-based, subjectivity, and tentativeness (independent variables) predicted eighth grade students' informal reasoning quality score in genetically modified food socioscientific issue (dependent variable). The results were presented in Table 4.18. According to the results, the combination of predictor variables was significantly related to the dependent variable F(3, 410)=43.34, p<0.05. In other words, the model including the measures of NOS understanding statistically predicted informal reasoning quality in genetically modified food issue. Approximately 24% of the variance of the dependent variable can be explained by the combination of independent variables. Based on the results, all the independent variables made statistically significant unique contribution to the prediction of the informal reasoning quality score in genetically modified food issue. In more detail, the empirical-based tenet made the strongest unique contribution to the prediction of dependent variable (*beta= 0.34,* sr^2= *0.104, p<0.05*) by explaining 10.4% of the variance uniquely. The effect size of empirical-based tenet was almost medium (f^2=*0.116*). Then, the tentativeness tenet made unique contribution to the prediction of informal reasoning quality score in genetically modified food issue (*beta= 0.20,* sr^2= *0.035, p<0.05*) by explaining 3.5% of the variance uniquely. The effect size of tentativeness tenet was small (f^2=*0.036*). The subjectivity tenet made the least unique contribution to the prediction of dependent variable (*beta= 0.15,* sr^2= *0.022, p<0.05*) by explaining 2.2% of the variance uniquely. Subjectivity tenet had small effect size (f^2=*0.022*). The regression equation for predicting informal reasoning quality of eighth grade students in genetically modified food issue is;

$\hat{Y}$= 1.397 X_1 + 0.715 X_2 + 0.835 X_3 – 2.324 where X_1 is used for empirical-based tenet, X_2 is used for subjectivity tenet and X_3 is used for tentativeness tenet.

Table 4.18. Multiple Regression Analyses Results for Variables Predicting Informal Reasoning Quality in Genetically Modified Food SSI (N = 414)

	B	*SE B*	*β*
Empirical-based Tenet	1.40*	0.19	0.34
Subjectivity Tenet	0.72*	0.21	0.15
Tentativeness Tenet	0.84*	0.19	0.19
Constant	-2.32*	0.41	
Adjusted R^2		0.24	
F		43.34*	

*p<.05

Lastly, multiple regression analysis was conducted to find out how well three NOS understanding tenets empirical-based, subjectivity, and tentativeness (independent variables) predicted eighth grade students' total informal reasoning quality score (dependent variable). The results were presented in Table 4.19. According to the results, the combination of predictor variables was significantly related to the dependent variable $F(3, 410)=63.35$, $p<0.05$. In other words, the model including the measures of NOS understanding statistically predicted total informal reasoning quality. Approximately 32% of the variance of the dependent variable can be explained by the combination of independent variables. Based on the results, all the independent variables made statistically significant unique contribution to the prediction of the total informal reasoning quality score. In more detail, the empirical-based tenet made the strongest unique contribution to the prediction of the dependent variable ($beta= 0.40$, $sr^2= 0.147$, $p<0.05$) by explaining 14.7% of the variance uniquely. The effect size of empirical-based tenet was medium ($f^2=0.172$). Then, the tentativeness tenet made unique contribution to the prediction of total informal reasoning quality score ($beta= 0.23$, $sr^2= 0.050$, $p<0.05$) by explaining 5.0% of the variance uniquely. The effect size of tentativeness tenet was small ($f^2=0.053$). The subjectivity tenet made the least unique contribution to the prediction of dependent variable ($beta= 0.14$, $sr^2= 0.019$, $p<0.05$) by explaining 1.9% of the variance uniquely. Subjectivity tenet had small effect size ($f^2=0.019$). The regression equation for predicting the total informal reasoning quality of eighth grade students is;

$\hat{Y}= 4.513\ X_1 + 1.817\ X_2 + 2.734\ X_3 - 7.509$ where X_1 is used for empirical-based tenet, X_2 is used for subjectivity tenet and X_3 is used for tentativeness tenet.

Table 4.19. Multiple Regression Analyses Results for Variables Predicting Total Informal Reasoning Quality Score (N = 414)

	B	*SE B*	*β*
Empirical-based Tenet	4.51*	0.48	0.40
Subjectivity Tenet	1.82*	0.53	0.14
Tentativeness Tenet	2.73*	0.50	0.23
Constant	-7.51*	1.06	
Adjusted R^2		0.31	
F		63.35*	

*p<.05

4.4 Summary of the Results

Firstly, the findings of the descriptive statistics were represented. Descriptive statistics about eighth grade students' nature of science understanding revealed that students held adequate understanding mostly about tentativeness tenet of NOS (*M* = 1.59, *SD* = 0.52). Then, respectively, they held adequate understanding about empirical-based tenet (*M* = 1.46, *SD* = 0.55) and subjectivity tenet (*M* = 1.30, *SD* = 0.50). Besides, descriptive statistics about informal reasoning for each socioscientific issue were represented. About 70% of the students constructed at least one supportive argument about global warming issue, and about 66% of them generated at least one supportive argument about genetically modified food issue while about 55% of them constructed at least one supportive argument about acid rain issue. The findings about construction of counter-argument revealed that about 39% of the students generated at least one counter-argument about genetically modified food issue, about 35% of them constructed at least one counter-argument about global warming issue, and about 25% of them generated at least one counter-argument about acid rain issue. The findings about rebuttal construction showed that about 15% of the students constructed at least one rebuttal about global warming issue, about 15% of them generated at least one rebuttal about genetically modified food issue and about 13% of them constructed at least one rebuttal about acid rain issue. Moreover, descriptive findings about informal reasoning revealed the usage amount of informal reasoning modes by students. In global warming issue, students mostly constructed ecological-oriented arguments (M = 0.63, SD = 0.67); and then, respectively, they constructed social-oriented (M = 0.36, SD = 0.62), science-or-technology-oriented (M = 0.25, SD = 0.54) and economic-oriented arguments (M = 0.16, SD = 0.43). Moreover, in global warming issue, most of the students (about 53%) constructed their supportive arguments from ecological-oriented perspective. Most of the students who constructed counter-argument about global warming issue (about 19%) used science-or-technology-oriented perspective in their counter-argument. Most students who constructed rebuttal about global warming issue (about 6%) also used science-or-technology-oriented perspective in their rebuttal. In acid rain issue, students mostly constructed ecological-oriented arguments (M = 0.44, SD = 0.64); and then, respectively, they constructed economic-oriented (M = 0.30, SD = 0.57), science-or-technology-oriented (M = 0.27, SD = 0.52) and social-oriented arguments (M = 0.10, SD = 0.32). Moreover, in acid rain issue, most of the students (about 34%) constructed their supportive arguments from ecological-oriented perspective. Similar with global warming issue, most of the students (about 16%) constructed their counter-argument about acid rain from science-or-technology-oriented perspective. Most students who constructed rebuttal about acid rain issue (about 7%) used ecological-oriented perspective in their rebuttal. In genetically modified food issue, students substantially mostly constructed social-oriented arguments (M = 1.09, SD = 1.00); and then, respectively, they constructed science-or-technology-oriented (M = 0.08, SD = 0.32), economic-oriented (M = 0.04, SD = 0.19) and ecological-oriented arguments (M = 0.04, SD = 0.19). Moreover, in genetically modified food issue, most of the students (about 63%) constructed their supportive arguments from social-oriented perspective. Most students who constructed counter-argument about genetically modified food (about 34%) also used social-oriented perspective in their counter-argument. Similarly, most students who constructed rebuttal about genetically modified food issue (about 11%) used social-oriented perspective in their rebuttals.

In order to find out the relationships between variables, correlational analyses were conducted. According to results, in three different socioscientific issues, there was statistically significant and positive correlation between informal reasoning quality and varieties of informal reasoning modes students used in their arguments. Also, there was a significant and positive correlation between students' total informal reasoning quality score and total informal reasoning mode score. Moreover, in order to examine how well three tenets of nature of science (empirical-based, subjectivity and tentativeness) predict eighth grade students' informal reasoning quality on socioscientific issues, multiple regression analyses were conducted. According to results, all tenets of NOS including empirical-based, subjectivity, and tentativeness made statistically significant unique contributions to the prediction of total informal reasoning quality score, informal reasoning quality score in global warming issue and in genetically modified food issue. However, empirical-based and tentativeness tenets made statistically significant unique contributions to the prediction of informal reasoning quality score in acid rain issue.

CHAPTER 5

DISCUSSION, CONCLUSION, AND IMPLICATIONS

In this chapter, the present study was summarized, the findings presented in the previous chapter were discussed, implications for educational practices and recommendations for further research were presented.

5.1 Summary of the Study

The purpose of the present study was to examine eighth grade students' nature of science understanding and their informal reasoning on three different socioscientific issues, and to find out the relationships between these variables. In order to achieve these purposes, the researcher carried out the present study with 414 8th grade students from four different public schools located in Altındağ, a district of Ankara. Data were collected through Views of Nature of Science Elementary Level (VNOS-E) Questionnaire developed by Lederman and Ko (2004) and Informal Reasoning on Socio-scientific Issues Questionnaire which consisted of three scenarios taken from the study of Khishfe et al. (2017) along with open-ended questions taken from the study of Wu and Tsai (2007). Data were collected in the fall semester of the 2019-2020 education year. The data obtained from the VNOS-E questionnaire were first analyzed qualitatively by classifying the NOS tenets based on the rubric developed by Akerson and Donnelly (2010). By using Akerson and Donnelly's (2010) classification, the students' NOS understandings were scored and analyzed quantitatively. Similarly, the data obtained from the Informal Reasoning on Socio-scientific Issues Questionnaire was first analyzed qualitatively, and then the arguments were scored based on the modified version of the integrated framework developed by Wu and Tsai (2007), and the data were analyzed quantitatively. Statistical analyses were conducted to find out the relationship between students' informal reasoning mode and their informal reasoning quality, and the relationships between students' NOS understanding and their informal reasoning quality. Lastly, statistical analyses were conducted to examine how well NOS tenets are able to predict informal reasoning quality.

5.2 Discussions

In the following first two titles, the findings of descriptive statistics were discussed. Then, in the last three titles, the findings of inferential statistics were discussed.

5.2.1 Eighth Grade Students' Nature of Science Understanding

The results of descriptive statistics about eighth grade students' NOS understanding revealed that more than half of the students (about 58%) held inadequate level of NOS understanding in total. More specifically, descriptive statistics showed that about 72% of the students hold inadequate level understanding for subjectivity tenet, about 57% of them hold inadequate understanding about empirical-based tenet and about 43% of them hold inadequate understanding about tentativeness tenet. In other words, more than half of the students have inadequate understanding about both the empirical-based and subjectivity tenets.

Since science researchers and science research institutions mentioned the importance of NOS understanding for scientific literacy during the last century, teaching NOS understanding was emphasized in recent science curriculum reforms (e.g. AAAS, 1990; Institute for the Promotion of Teaching Science and Technology (IPST), 2002; MEB, 2018; Ministry of Education Science Technology (MEST), 2009; NGSS, 2013; NRC, 1996; NSTA, 1982; NSTA, 2000). Reforms in the Turkish science curriculum gave importance to teaching NOS understanding. In the 2005 Turkish science curriculum, although the nature of science was not described, the expression "the nature of science and technology" was included, and the features of science and scientific knowledge were explained below this title (MEB, 2005). In the 2013 Turkish science curriculum, the expression "nature of science" was included and explained clearly (MEB, 2013). In the 2018 Turkish science curriculum (MEB, 2018), teaching nature of science took place among the ten goals of the curriculum. The goal is to provide students with an understanding of how scientific knowledge is developed by scientists, the processes of the development of the scientific knowledge, and how this knowledge is used in new research (MEB, 2018). Although the curriculum aims to provide students with a well-developed understanding of NOS, findings of the present study revealed that more than half of the students (about 58%) hold inadequate understanding about NOS. This finding corroborated the previous studies which reported students' naïve NOS understanding (e.g. Bektas & Geban, 2010; Dogan & Abd-El-Khalick, 2008; Seçkin, 2013; Sutherland & Dennick, 2002). This result showed that the science curriculum does not sufficiently support the development of students' NOS understanding, although developing NOS understanding is among the ten goals of the curriculum. This might be because there is insufficient emphasis on NOS tenets in the objectives of the curriculum. Also, the primary material to transfer the teachings of the curriculum is science textbooks. The textbooks might not support students' NOS understanding. In the literature, there are studies examining the appropriateness of textbooks to NOS teaching (e.g. Irez, 2009; Izci, 2017). For example, Izci (2017) examined the 7^{th} grade science textbook in terms of NOS tenets inclusion. It was found that the textbook did not portray some NOS tenets enough, and some tenets implicitly took place in the textbook (Izci, 2017).

Another reason of students' inadequate NOS understanding might be the inadequate NOS understanding of science teachers. Previous studies showed that both pre-service and in-service science teachers have inadequate NOS understanding in the Turkish context (e.g. Aydemır, Ugras, Cambay, & Kılıc, 2017; Dogan & Abd-El-Khalick, 2008; Timur & İmer-Çetin, 2018). Since teachers educate students, well-developed NOS understanding is important for teachers to provide next generation with well-developed NOS understanding. The findings of Dogan and Abd-El-Khalick's study (2008) support the importance of teachers' understanding for students. They conducted a research with both 10th grade students and their science teachers to investigate their NOS understanding levels. The results showed that the majority of both students and their teachers have naïve NOS understanding. Dogan and Abd-El-Khalick (2008) mentioned that in order to teach NOS understanding effectively to their students, teachers should firstly understand the NOS content. They highlighted the importance of teacher education programs to eliminate this insufficiency and to reach the goal of science curriculum reforms. On the other hand, the studies showed that teachers' well-developed NOS understanding does not mean that they will teach NOS tenets in science classes to develop their students' NOS understanding (e.g. Akerson & Abd-El-Khalick, 2003; Lederman, 1999). Therefore, reforms to improve teachers' understanding of NOS might not be sufficient. The fact that teachers do not teach NOS understanding in their classrooms, although they know it might be because they do not know how to teach NOS. Also, although the teachers know both NOS understanding and how to integrate it, they might not be addressing NOS due to the examination system and limitations in the classroom environment. Hacıeminoğlu (2014) conducted a study with Turkish in-service science teachers, and these teachers mentioned the problems they faced with in the integration of NOS. Some of the teachers mentioned that even if they have efficacy and motivation for the integration of NOS, the expectation of parents and school administration is different because of the examination system. They also mentioned that since there is a large number of students in the classroom, both controlling the classroom and managing the time became a problem.

In the present study, the findings of each NOS tenets were examined, and it was found that compared to the other two tenets, the students had the most inadequate understanding about subjectivity tenet. Compared to the other two tenets, the students had the most inadequate understanding about subjectivity tenet. This finding contradicted with the finding of Ebren-Kuyumcu (2019). Ebren-Kuyumcu

(2019) conducted a research with 7th and 8th grade students to investigate their understanding levels about NOS tenets. Different from the present study, Ebren-Kuyumcu (2019) used Likert-type questionnaire to collect data. It was mentioned that the students generally do not have inadequate understanding about subjectivity tenet (Ebren-Kuyumcu, 2019). In the present study, most of the students mentioned in their answers that because the scientists still do not have sufficient or precise information, they have reached different results despite having the same information. These answers showed that most of the students believe that there is a precise and absolute truth in science. In other words, it was found that most of them (about 72%) did not give any possibility to the subjective thinking of the scientists. The possible reason of this might be that students believe science is objective. McComas (1998) stated the common misconceptions about science, and one of the misconceptions is about the objectivity of science. Previous studies also showed that this misconception is common among both students and pre-service teachers (e.g. Erdoğan, 2004; Liu & Tsai, 2008).

The findings also showed that among three tenets, the tenet at which students had more developed understanding was tentativeness. Although fewer students (about 43%) have inadequate understanding about tentativeness tenet compared to the other two tenets, there are studies showed that students hold more developed understanding about tentativeness compared to the present study. For example, Seçkin (2013) conducted a research study with 8th grade students from Turkey to investigate their NOS understanding levels by using the VNOS-E questionnaire. According to the findings of Seçkin (2013), only 10% of the students hold inadequate understanding about tentativeness tenet. On the other hand, more than half of the students hold inadequate understanding about empirical-based and subjectivity tenets of NOS (Seçkin, 2013). Compared with the study of Seçkin (2013), more students (about 43%) hold inadequate understanding about tentativeness tenet in the present study. However, similar to the finding of the present study, Seçkin (2013) found that the students have a better understanding of tentativeness tenet than the empirical-based and subjectivity tenets. When the answers of the students in the present study were examined, it was seen that most of the students mentioned that over time, scientific knowledge will change because of the development of the technology, new information could be found. However, really few students (about 1%) mentioned that not only because of finding new information but also reinterpretation of the existing information will change the scientific knowledge. This might be due to the belief that scientists do a lot of experiments and use only experimental data to reach an objective conclusion. As mentioned above, one of the common myths about science is the objectivity of science (McComas, 1998). Thus, it is possible that the students of the present study thought the existing scientific knowledge can be objective because only 1% of the students mentioned about reinterpretation of the existing scientific knowledge.

In the study of Hacıeminoğlu (2014), the in-service science teachers mentioned that misconception is one of the problems in the integration process of NOS. They mentioned that the reason of the misconception might be insufficient explanations about NOS tenets in textbooks, teachers' inadequate knowledge about NOS, and teachers' language used when teaching NOS. On the other hand, the teachers mentioned that teaching all NOS tenets is a problem for them because of both limited time and limited materials. In the present study, why students' understanding about some tenets was more inadequate than others might be that the teachers did not address some tenets enough and appropriately in classrooms.

In summary, the findings of the present study showed that more than half of the 8^{th} grade Turkish students have inadequate level of NOS understanding. The reason might be insufficient NOS emphasis in the science curriculum and the science textbooks, and teachers' insufficient teaching of NOS in the classrooms. Also, it was found the students mostly have inadequate understanding on subjectivity tenet compared to empirical-based and tentativeness tenets. The reason might be that the students have "science is objective" misconception, or teachers did not address subjectivity tenet in the classroom enough.

5.2.2 Eighth Grade Students' Informal Reasoning Quality and Modes

The results of descriptive statistics about eighth grade students' informal reasoning quality scores in three different socioscientific issues revealed that students' informal reasoning quality scores differ across three different SSIs. This finding is consistent with the research studies suggested that students' informal reasoning skills may differ in different SSI contexts (e.g. Khishfe et al., 2017; Topcu et al., 2010). In more detail, the results of descriptive statistics about students' informal reasoning revealed that students showed different argumentation qualities on constructing supportive argument and counter-argument in each SSI while they almost showed similar argumentation qualities on the construction of rebuttal in each SSI. For example, more students (about 70%) constructed supportive argument about global warming issue compared to acid rain issue (about 55% of the students) and genetically modified food issue (about 66%). When the percentages of counter-argument construction were examined, it was observed that the least number of students (about 25%) constructed counter-argument about acid rain issue compared to global warming issue (about 35% of the students) and genetically modified food issue(about 39%). According to the results of informal reasoning quality scores, the students have the least informal reasoning quality scores in acid rain issue (M = 1.68, SD = 2.40) compared to their scores in genetically modified food issue (M = 1.97, SD = 2.26). And, it was revealed that the students have the most qualified informal reasoning about global warming issue (M = 2.13, SD = 2.41). The reason might be that students could be the most familiar with global warming issue and the least familiar with acid rain issue. In the demographic form, it was asked to students, "How well do you think you know about global warming, acid rain, and genetically modified food?". When the answers of the students for this question about each issue were examined, it was revealed that only about 8% of the students mentioned they never know about global warming while about 18% of them mentioned they never know about genetically modified food, and about 33% of them mentioned they never know about acid rain. To clarify, when the informal reasoning quality scores and knowledge level for each SSI were compared, it could be inferred the students were able to construct more qualified informal reasoning about the issue they indicated that they already know something. Sadler (2004) mentioned in his review study that there are studies supported content knowledge affects informal reasoning quality positively (e.g. Hogan, 2002), but more empirical evidences were needed. Thereupon, Sadler and Zeidler (2004) conducted a study to investigate the effect of content knowledge on undergraduate college students' informal reasoning quality. They found that the participants who have more content knowledge about the issue exhibited more qualified reasoning about the issue. More recently, Baytelman, Iordanou, and Constantinou (2020) conducted a research with university students and found that prior content knowledge is a predictor for argument quantity and quality in SSIs. Investigating the relationship between students' content knowledge and informal reasoning quality statistically is not a goal of the present study. Also, in the present study, the students' prior content knowledge was not measured. Only, they were asked how well they think they have knowledge about each SSI. It was observed that the students constructed more supportive and counter arguments, and constructed more qualified informal reasoning about the issue on which they indicated that they already know more. Thus, this result supported the relationships between prior content knowledge and students' informal reasoning (e.g. Baytelman et al., 2020; Hogan, 2002; Sadler & Zeidler, 2005b). Khishfe (2012) also conducted a study with 11th grade students and found that the students showed different argument construction performances across several SSIs. Khishfe (2012) also suggested this difference might be because of students' prior content knowledge about the issue and familiarity of the issue.

In the present study, the data obtained via demographic information form also showed that the students mostly obtained knowledge from the textbook used in the science classes and then from the Internet about global warming issue. About genetically modified food and acid rain issues, the students mostly obtained knowledge from the Internet and then textbook used in the science classes. It is observed that students showed better performance in global warming issue which they obtained their prior knowledge mostly from textbook. On the other hand, the students' reasoning quality scores in genetically modified food and acid rain issues which they obtained their prior knowledge mostly from the Internet is lower than the score of global warming issue. Although the reasoning quality score in global warming is better than the scores in the other two issues, the mean values of scores showed that the quality scores of students in three SSIs are low. The reason of students' low informal reasoning quality might be the Internet usage as a source of knowledge. In the literature, it is argued that the media and the Internet might cause misconceptions and misunderstanding about the issues (e.g. Khalid, 2001; Zhou et al., 2020). For example, Ozturk and Yilmaz-Tuzun (2017) investigated pre-service science teachers' informal reasoning about nuclear power plant. The participants showed low quality in their reasoning and mentioned they mostly obtained knowledge about the issue from media (TV, radio, etc.). Ozturk and Yilmaz-Tuzun (2017) mentioned that the reason of low quality might be the usage of media as a source of knowledge because media might cause misconceptions and misunderstanding by transferring incomplete information. As known, one of the most recent SSI is COVID-19 pandemic and vaccine. There are recent studies investigated the effect of media usage as a knowledge source about the issue (e.g. Lin, Broström, Griffiths, & Pakpour, 2020; Zhou et al., 2020). The findings showed that media including social media cause misunderstanding about the issue (Lin et al., 2020; Zhou et al., 2020). Thus, the reason of low informal reasoning quality might be the usage of the Internet as the source of knowledge.

When the percentages of rebuttal construction were examined, it was observed that almost the same number of students were able to construct rebuttal in all three issues. About 15% of the students constructed rebuttal in global warming issue and genetically modified food issue. About 13% of the students generated rebuttal in acid rain issue. When the percentages compared to the construction of supportive arguments and counter-arguments, really few students were able to construct rebuttal. Thus, it can be mentioned that really few students showed highly-qualified informal reasoning because rebuttal construction was assigned as an indicator of the highest quality of informal reasoning by some researchers (e.g. Kuhn, 1993; Osborne et al., 2004; Wu & Tsai, 2007). This study's finding is consistent with the findings of previous research studies conducted with students (e.g. Dawson & Venville, 2009; Wu & Tsai, 2007; Wu & Tsai, 2011) and pre-service teachers (e.g. Ozturk & Yilmaz-Tuzun, 2017; Topcu et al., 2010). In that, Wu and Tsai (2007, 2011) found that students' rebuttal construction ability was lower than supportive argument construction ability. More recently, Ozden (2020) conducted a study with Turkish elementary school students to investigate their informal reasoning quality. Ozden (2020) used different framework to assess their reasoning. However, similar to the present study, it was reported that students mostly showed low-quality in their reasoning. The reason of students' low performance on rebuttal construction might be inadequate content knowledge about SSIs. In the literature, there are studies showed the importance of content knowledge for qualified informal reasoning (Baytelman et al., 2020; Hogan, 2002; Sadler & Zeidler, 2005b). For example, Sadler and Zeidler (2005b) found that the students who had better content knowledge developed high quality of arguments and rebuttal construction. The other reason of students' low performance on rebuttal construction might be a lack of argumentation experience. In the literature, there are studies showed that the argumentation experience improves students' informal reasoning. For example, Dawson and Venville (2013) conducted a research with high school students to investigate the effects of argumentation experience on students' argumentation skills and informal reasoning. They found that students' argumentation skills and informal reasoning improved after the practice of argumentation about SSI. Although the lack of argumentation might be a reason of the low quality of informal reasoning, the reason of not practicing argumentation about SSIs might be different. One of the possible reasons is that the teachers might not find themselves qualified enough for the argumentation about SSIs in science classes. In the literature, some of the studies conducted with pre-service science teachers from one of the most academically successful universities of Turkey showed that even most of the pre-service teachers also had problems in rebuttal construction (e.g. Ozturk & Yilmaz-Tuzun, 2017; Topcu et al., 2010). To clarify, if teachers cannot construct well-qualified arguments, they might not feel qualified enough to practice argumentation in their classrooms. The other possible reason why argumentation is not practiced in classrooms might be limited teaching time. Genel and Topçu (2016) conducted a research with pre-service science teachers who practiced SSI-based teaching in their field experience courses. Genel and Topçu (2016) found that the teachers had difficulty about time in their SSI-based teaching practices in middle school classrooms. The time limitation problem might distract teachers from practicing argumentation about SSIs in the classrooms.

In the present study, not only informal reasoning argument components but informal reasoning modes were also investigated by using the framework of Wu and Tsai (2007). This framework included ecological-oriented, economic-oriented, social-oriented, and science-or-technology-oriented reasoning modes. According to descriptive findings, students constructed mostly ecological-oriented arguments in global warming issue (about 54% of the students) and acid rain issue (about 37%). They constructed mostly social-oriented arguments in genetically modified food issue (about 65%). Similar with the findings of the present study, Khishfe et al. (2017) also found that students' arguments about global warming issue and acid rain issue were mostly oriented towards environment, and students' arguments about genetically modified food were mostly oriented towards the concerns about consumption of natural foods and health of human. That is, the participants of both Khishfe et al.'s (2017) study and the present study had similar concerns about the SSIs. Khishfe et al. (2017) conducted their research with 11^{th} grade students from Saudi Arabia. It might be thought that the similarity between the findings of Khishfe et al. (2017) and the findings of the present study is due to cultural similarity. However, Dawson and Carson (2017) conducted a research with high school students from Australia to examine their arguments about global warming and climate change. Similar with the present study, Dawson and Carson (2017) found that Australian students mostly concerns about environmental aspects of the issue. The reason why participants from different countries generally constructed environment-oriented arguments about global warming and acid rain might be that these issues are presented as “environmental problems” on the global agenda. Moreover, there is another study conducted by Wu (2013) with university students from Taiwan to examine their informal reasoning modes about genetically modified foods. It was found that students constructed mostly human-benefit-oriented arguments. In other words, similar with the present study and the study of Khishfe et al. (2017), Wu (2013) found that Taiwanese university students mostly concerns about the positive or negative impacts of genetically modified foods on human beings. These similar findings of the studies conducted in different countries showed that some reasoning modes (human-benefit in genetically modified food issue) might be commonly reflected in the arguments of participants from different cultures.

In global warming issue, the students mostly constructed ecological-oriented arguments (M = 0.63, SD = 0.67), and then, they constructed social-oriented arguments (M = 0.36, SD = 0.62). In acid rain issue, ecological-oriented arguments (M = 0.44, SD = 0.64) were mostly constructed by students, and then they mostly constructed economic-oriented arguments (M = 0.30, SD = 0.57). On the other hand, the arguments constructed about genetically modified food issue were mostly social-oriented (M = 1.09, SD = 1.00). The findings about informal reasoning modes showed that the modes were context dependence. In other words, it was found that the students may tend to use different modes in different SSI contexts. Similar with the present study, the study of Khishfe et al. (2017) showed that 11^{th} grade students used different modes in their arguments across four different SSIs global warming, acid rain, genetically modified food, and human cloning. Similarly, Topçu et al. (2011) conducted a study with pre-service science teachers to examine their informal reasoning modes in different SSIs. Different from the present study, Topçu et al. (2011) used the framework of Sadler and Zeidler (2005a), which specifies modes as rationalistic, emotive, and intuitive. Topçu et al. (2011) also found that the modes of informal reasoning varied across different

SSIs. For example, the teachers constructed mostly rationalistic reasoning about gene therapy scenarios and global warming scenario while they generally constructed emotive or intuitive reasoning about cloning scenarios. Thus, it can be concluded that the findings of the present study supported the previous findings which showed that the modes of informal reasoning are context dependence. This might be related with the nature of SSI context. To clarify, environmental issues might firstly direct students to think about the environmental consequences of the issues, while genetic issues might direct students to emotional considerations in their reasoning. The previous studies about genetic engineering SSIs found that the individuals generally showed emotional considerations in their arguments (e.g. Sadler & Zeidler, 2004). Moreover, the other reason why different modes used in different SSIs might be the perception differences of the participants across the issues. Khishfe (2012) conducted a study with 11^{th} grade Lebanese students and found that the students mentioned the harmful effects of water fluoridation issue on their everyday lives and health more frequently than genetically modified food issue. Khishfe (2012) mentioned that individuals might perceive some SSIs as more personal. Due to this perception, the individuals might directly construct arguments about the harms or benefits of the issue on humans (Khishfe, 2012). In the present study, the students mostly focused on the harms and benefits of genetically modified foods for humans while they focused on environmental dimensions of global warming and acid rain in their arguments. The students of the present study might have thought that genetically modified foods affect their personal life and their health more than the other two issues.

Also, religious-oriented reasoning mode emerged as a new reasoning mode. However, only one of the participants constructed an argument religious-oriented about genetically modified food. Kılınç et al. (2013) conducted a research with Turkish pre-service science teachers and found that genetically modified foods issue was seen as related with religious beliefs by some pre-service teachers. However, most of the pre-service teachers mentioned that genetically modified food issue is not related with religion (Kılınç et al., 2013). In the literature, the studies conducted by using genetic engineering scenarios generally found religious-oriented arguments in cloning and gene therapy issues rather than genetically modified food issue (e.g. Khishfe et al., 2017; Sadler & Zeidler, 2004). Mansour (2008) mentioned that personal religious beliefs shape the practices about science and science-related issues. Although religious beliefs might shape the arguments about some genetic engineering practices like cloning and gene therapy, religious beliefs might not influence the arguments about genetically modified food issue that much. Since only one student generated religious-oriented argument about genetically modified food in the present study, it can be mentioned that students mostly argue global warming, acid rain, and genetically modified food issues from ecological, social, economic, and scientific points of view.

Furthermore, according to the findings, it was revealed that while about 20% and about 23% of the students constructed science-or-technology-oriented arguments about global warming issue and acid rain issue respectively, only about 7% of the students constructed science-or-technology-oriented arguments about genetically modified food issue. In other words, compared with the findings of global warming and acid rain issues, a few students constructed science-or-technology-oriented arguments about genetically modified food issue. This might be because genetically modified foods were seen as the direct influence on humans' health by the participants; they did not focus on other perspectives. On the other hand, the usage of science-or-technology-oriented arguments was not ranked first in all three different SSIs. Science-or-technology-oriented arguments are important because construction of these arguments shows that students connect what they learned in science classes with the SSIs they faced with in daily lives (Wu & Tsai, 2007). In contrast with the finding of the present study, Yang and Anderson (2003) found that scientifically-oriented arguments were used most by Taiwanese high school students about nuclear power usage issue. Liu and his colleagues (2010) also found that Taiwanese science-major college students mostly generated science-oriented arguments about local environmental issues. Similarly, Wu and Tsai (2011) found that Taiwanese high school students mostly constructed science-or-technology-oriented arguments about nuclear power plant issue. As mentioned above, Ozturk and Yilmaz-Tuzun (2017) conducted a study by using the same questionnaire with Wu and Tsai (2011) in Turkey. However, they found that science-or-technology-oriented arguments were least common even among Turkish pre-service science teachers. That's why it can be inferred there is a need to provide both teachers and students with scientific perspectives about SSIs. Wu and Tsai (2007) found that the construction of science-or-technology-oriented arguments was highly correlated with rebuttal construction. That's why it was mentioned that the scientific knowledge learned in science classes might be a source to construct more qualified informal reasoning on SSIs (Kolstø, 2001; Wu & Tsai, 2007). This can be succeeded by focusing SSI more on both teacher education programs and science curricula in Turkey. Teachers might give more attention to include the scientific and technological perspectives of SSI contexts in the science classes. They can use materials which can enhance the SSIs discussion by integrating not only ecological or social perspectives but also other perspectives as well.

In summary, it was found that most of the students cannot construct qualified informal reasoning. The reasons might be inadequate content knowledge about SSIs and argumentation experience. Also, the findings of the present study showed that students' informal reasoning quality differs across different SSI contexts. The reasons might be familiarity differences to SSI contexts and prior content knowledge. According to the findings of the present study, students' informal reasoning modes were also different across SSI contexts. Differences in the nature of SSI contexts and differences in the participants' perceptions across SSIs might be the possible reasons for this obtained variety in reasoning modes.

In the following two titles, the results of inferential statistics were discussed. Firstly, the relationship between students' informal reasoning modes and informal reasoning quality was discussed. Secondly, significant predictors for students' informal reasoning quality regarding NOS understanding were discussed.

5.2.3 Relationships between Informal Reasoning Modes and Informal Reasoning Quality

In order to find out the relationship between eighth grade students' informal reasoning modes and informal reasoning quality, Pearson correlation analyses were conducted for the scores in each socioscientific issue and for total scores. Correlational analyses revealed that there were statistically significant, positive correlations with large effect size between varieties of informal reasoning modes and informal reasoning quality for each SSI and in total scores. This means that the number of reasoning modes students used in their arguments was significantly correlated with their informal reasoning quality.

The finding of the present study is consistent with the finding of Wu and Tsai (2007). Wu and Tsai (2007) conducted a study with high school students to examine informal reasoning about nuclear power plant. They found that the number of reasoning modes significantly correlated with the total number of argument which presented informal reasoning quality in their framework (Wu & Tsai, 2007). Also, it was found that students' number of rebuttals significantly correlated with their number of reasoning modes. In the study of Wu and Tsai (2007), constructing rebuttal was seen as an indicator of highly qualified informal reasoning. Thus, Wu and Tsai (2007) concluded that participants who constructed highly qualified informal reasoning benefited from more various reasoning modes in their arguments. Based on their findings, they hypothesized that usage of various reasoning modes may be necessary to develop students' informal reasoning levels, or vice versa. That is, being able to discuss SSI from different perspectives may support students to produce more arguments; or, when students produce more arguments about SSI, they may discuss the issue from different perspectives. The findings of the present study supported the hypothesis of Wu and Tsai (2007). Moreover, although Wu and Tsai (2007) found out this relationship in only one SSI context, three different SSI contexts were included in the present study. It was revealed that the relationship between number of informal reasoning modes and informal reasoning quality was found in each SSI. That is, regardless of the SSI context, a relationship between informal reasoning modes and informal reasoning quality was found. That's why the findings of the present study provided an important contribution to the hypothesis that there is a relationship between informal reasoning modes and informal reasoning quality. Since using multiple reasoning modes and constructing various reasoning components (i.e. supportive argument, counter argument, rebuttal) may strengthen one another, teachers should not only encourage students to construct counter argument or rebuttal but also encourage them to use different perspectives in their arguments. Thus, they might support the improvement of students' informal reasoning quality more effectively.

5.2.4 Predictors of Informal Reasoning Quality Regarding Nature of Science Understanding

In order to find out how well nature of science understanding tenets (empirical-based, subjectivity, and tentativeness) predict eighth grade students' informal reasoning quality on socioscientific issues, multiple regression analyses were conducted for the scores in each SSI and for total scores. The results of the analyses revealed that empirical-based, tentativeness, and subjectivity tenets made statistically significant contribution to the prediction of informal reasoning quality score in global warming issue, genetically modified food issue, and total informal reasoning quality scores. For acid rain issue, empirical-based and tentativeness tenets made statistically significant contribution to the prediction of informal reasoning quality score while subjectivity tenet did not make statistically significant contribution. In the literature, there are similar findings showed that NOS understanding is related with argument construction in SSIs (e.g. Khishfe, 2012; Khishfe et al., 2017; Zeidler et al., 2012).

According to the findings, although three NOS tenets made statistically significant contribution to the prediction of informal reasoning quality in global warming and genetically modified food issues, two NOS tenets made significant contribution to the prediction of reasoning quality in acid rain issue. Multiple regression analyses showed that subjectivity tenet did not make significant contribution to the prediction of reasoning quality in acid rain, though there was a significant correlation between subjectivity and reasoning quality in acid rain issue with a small effect size. Thus, multiple regression analyses showed that this correlation did not present a predictive power of subjectivity on reasoning quality. In the literature, there are studies which investigated the relationship between NOS understanding and informal reasoning quality in SSIs by using different methods (i.e. qualitative, quantitative, mixed method) (e.g. Bell & Lederman, 2003; Khishfe, 2012; Khishfe et al., 2017; Sadler et al., 2004; Zeidler et al., 2002). The studies which conducted quantitative analyses generally used correlational analyses to find out this relationship (e.g. Khishfe, 2012; Khishfe et al., 2017). In the present study, these obtained relationships were further supported with multiple regression analyses to reveal the predictor value among these variables.

The findings showed that the predictors showed variations across different SSIs. Similar results were also found by other researchers. For example, Khishfe (2012) conducted Pearson correlation analyses to find out the relationship between 11th grade students' NOS understanding and arguments about genetically modified food and water fluoridation. The researcher found that there are significant correlations between some argument components (supportive argument, counter argument, and rebuttal) and NOS tenets (empirical-based, subjectivity, and tentativeness). However, significant correlations in water fluoridation issue were more than the correlations in genetically modified food issue. Later, Khishfe et al. (2017) conducted a similar study to find out the relationship between 11th grade students' NOS understanding and arguments about global warming, acid rain, genetically modified food, and human cloning. According to the findings of Khishfe et al. (2017), there were significant relationships between NOS tenets and some argument components about global warming, acid rain, and human cloning. On the other hand, it was found there was no significant correlation between NOS tenets and arguments about genetically modified food (Khishfe et al., 2017). That is, both

Khishfe (2012) and Khishfe et al. (2017) found that the correlations between NOS tenets and arguments differed across different SSI contexts. Although the present study similarly found the predictors differed across different SSIs, only one tenet differed in one SSI among three SSIs. The reason might be that Khishfe (2012) and Khishfe et al. (2017) examined the NOS understanding of participants in the context of SSI while the present study used a separate questionnaire to examine students' NOS understanding. To clarify, in the study of Khishfe (2012) and Khishfe et al. (2017), the correlations more varied across SSI contexts than the predictors of the present study. They mentioned that the reason of the difference of correlations across different SSIs was that the NOS views of individuals could differ in different contexts or topics (e.g. Khishfe & Abd-El-Khalick, 2002). The difference of predictors across different SSI contexts might be less in the present study because NOS understanding was assessed via a separate questionnaire independent from SSI contexts. On the other hand, unlike the other two SSIs, the reason why the subjectivity tenet was not significant predictor in acid rain SSI might be that students had more difficulty in constructing argument about acid rain.

The findings showed that the empirical-based tenet was the predictor for informal reasoning quality in three different SSIs with a medium effect size. Similarly, there are studies found that empirical-based tenet is related with students' performance of argument construction (e.g. Khishfe, 2012). The reason might be that qualified understanding about empirical-based tenet might provide students to be aware of the role and the importance of the evidence to defend their position or to catch the evidences about opposite positions. The students who were aware of the role of the evidences to construct their arguments could construct supportive arguments and rebuttals to defend their positions. They also could use opposite evidences to construct counter-arguments. Thus, the finding of the present study empirically support that the empirical-based understanding might predict students' informal reasoning quality in SSIs.

It was also found that the tentativeness tenet was another predictor for informal reasoning quality in three different SSIs with a small effect size. Khishfe (2012) and Khishfe et al. (2017) similarly found that tentativeness tenet is related with argument construction performance in SSIs. Ozturk and Yilmaz-Tuzun (2017) investigated the relationship between pre-service science teachers' epistemological beliefs and informal reasoning quality. They similarly found that the belief that knowledge is tentative was the significant predictor for informal reasoning quality of pre-service science teachers. Wu and Tsai (2011) mentioned that both beliefs about NOS and scientific epistemological beliefs are the constructs used in science education literature to imply participants' epistemological views toward science and scientific knowledge although there are differences between these two constructs. Thus, the findings of the study focused on epistemological beliefs rather than NOS understanding (e.g. Ozturk & Yilmaz-Tuzun, 2017) could be compared with the findings of the present study. "Certain knowledge" item of epistemological belief refers to the belief that scientific knowledge can change. This item is similar with the tentativeness tenet of NOS. Similar with the present study, Ozturk and Yilmaz-Tuzun (2017) found that 'certain knowledge' item of epistemological belief was the significant predictor for informal reasoning quality. Thus, the present study and the previous studies found that tentativeness understanding could support the construction of counter-argument and rebuttal which are the indicators of qualified informal reasoning (Kuhn, 1993; Means & Voss, 1996). The reason might be that being aware of the tentative nature of scientific knowledge provides students to consider about the opposite evidences which are conflicting with their positions. In other words, since they believe scientific knowledge can change, they could think more flexible about their position while arguing SSI. Thus, they could take into account the opposite positions about SSI and construct counter-argument which is precondition for the construction of rebuttal.

As mentioned above, subjectivity tenet was the predictor for informal reasoning quality in two different SSIs among three SSIs with a small effect size. Khishfe (2012) and Khishfe et al. (2017) also found that subjectivity tenet is related with students' argument construction performance. The reason might be that understanding subjective nature of scientific knowledge provides students with the understanding of that there might be different interpretations of knowledge. This understanding might enable students to handle SSIs from different perspectives by interpreting the knowledge about SSIs.

In summary, it was found that empirical-based and tentativeness tenets significantly predicted the informal reasoning quality in three SSIs. The reason might be that understanding empirical-based and tentativeness tenet provided to think about opposite evidences and alternative views. This might enable students to construct counter-arguments and rebuttals which are the indicators of reasoning quality. It was also found that subjectivity tenet was a significant predictor for informal reasoning quality in global warming and genetically modified food issues. The reason might be that qualified understanding about subjectivity provided students to interpret the SSI from different perspectives. Thus, the students might construct counter-arguments and rebuttals.

5.3 Conclusion of the Study

The goal of the present study was to investigate eighth grade students' NOS understanding, informal reasoning in SSIs, and the relationships between NOS understanding and informal reasoning.

Teaching NOS understanding is an important goal for not only Turkish science curriculum (MEB, 2018) but also goal of other countries' curricula (e.g. IPST, 2002; MEST, 2009; NGSS, 2013; NSTA, 2000) because NOS understanding is an important component for scientific literacy (Holbrook & Rannikmae, 2009). However, the findings of the present study showed that more than half of the eighth grade students had inadequate NOS understanding. Although the goal of the Turkish science curriculum is to provide the students with well-developed NOS understanding since 2005, it is clear that we are still far from reaching this goal.

In addition to well-developed NOS understanding, constructing qualified and persuasive reasoning about SSIs is one of the most important abilities of scientifically literate person (Holbrook & Rannikmae, 2009; PISA, 2015). As technology and science developed, and SSIs increased in modern society, educating students as effective decision-makers about SSIs was seen as necessity (Kolstø, 2001). That's why countries integrated SSIs into their science curricula. The teaching of SSIs became one of the main ten goals of the 2018 Turkish science curriculum (MEB, 2018). However, the findings of the present study showed that most of the students could not construct qualified informal reasoning. Thus, the present study and previous research studies, unfortunately, showed that we are far away from the goal.

Wu and Tsai (2007) hypothesized and found that the quality of informal reasoning is significantly related with the number of reasoning modes used in the arguments. The studies conducted to investigate this possible relationship are insufficient in the literature. The present study examined this relationship in three different SSI contexts and found that there are significant relationships between the number of informal reasoning modes and informal reasoning quality in three different SSIs. Thus, the present study provided important empirical support for the hypothesis. It was concluded that participants who constructed highly qualified informal reasoning benefited from more various reasoning modes in their arguments. In other words, it can be concluded that usage of various informal reasoning modes should be taken into consideration to improve eight grade students' informal reasoning quality on SSIs. Moreover, in the literature, the researchers argued that NOS understanding supports students to become effective decision-makers on SSIs (e.g. Driver et al., 1996, p. 11). Zeidler et al. (2005) mentioned that NOS views may influence students' appraisal of knowledge generated with scientific ways and preference of evidence while expressing their sides about SSI context. That's why they supported the hypothesis that NOS understanding is necessary to provide students to make informed decisions about SSIs which they are faced with in their daily lives. The findings of the present study supported this hypothesis because it was found that students' views about NOS tenets were significant predictors for their informal reasoning quality in SSI. That's why it can be concluded that eighth grade students' NOS understanding levels should be taken into consideration to improve their informal reasoning quality on SSIs.

5.4 Implications of the Study

The present study investigated eighth grade students' nature of science understanding, informal reasoning on socioscientific issues, and the relationship between these two variables. Based on the findings, the present study has several essential implications that should be considered by science curriculum developers, teacher educators, and science teachers.

Scientific literacy is the main goal of science education in most of the countries in order to train individuals as scientifically literate citizens (Dani, 2009); and NOS understanding is an important component for scientific literacy (Holbrook & Rannikmae, 2009). That's why teaching NOS understanding is an important goal in the Turkish science curriculum (MEB, 2018). However, the tenets of NOS did not mention in the curriculum explicitly. In the curriculum, only in objectives of seventh grade, there is an explanation stated that scientific information is not certain and can change and develop. Also, in the objectives of seventh grade and eighth grade, it was emphasized that students are provided the information about theory and principles which are types of scientific knowledge. There is no other explicit expression about the tenets of NOS in the curriculum. That's why the science curriculum should be reviewed by curriculum developers. Emphasizing NOS tenets in the objectives of the curriculum more explicitly may be effective to support students' NOS understanding development. Moreover, in the literature, there are studies argued that the textbooks are not proper to teach NOS effectively because the books implicitly include some tenets and do not include some tenets (e.g. Izci, 2017). Science textbooks should also be reviewed, and all of the NOS tenets should be explicitly included in the books. This also might support the development of students' NOS understanding.

To provide students with well-developed NOS understanding, the teachers should have adequate NOS understanding. In the literature, most of the studies showed that pre-service and in-service science teachers have inadequate NOS understanding in the Turkish context (e.g. Aydemır, Ugras, Cambay, & Kılıc, 2017; Dogan & Abd-El-Khalick, 2008; Timur & İmer-Çetin, 2018). Explicit NOS instructions might be a good way to improve pre-service teachers' NOS understanding levels because there are previous research studies which showed the effectiveness of explicit instruction on the development of NOS understanding (e.g. Ağlarcı, Sarıçayır, & Şahin, 2016; Bell et al., 2011; Ecevit, Yalaki, & Kingir, 2018). Also, explicit NOS instructions might be provided in in-service teacher training programs in order to develop in-service teachers' NOS understanding. Moreover, teachers should also learn how to teach NOS effectively in science classes. Faikhamta (2013) conducted a research to investigate the effect of PCK-based NOS course on in-service science teachers' orientations to teaching NOS. It was found that in-service teachers oriented from implicit discovery approach to explicit inquiry-based approach to teach NOS after taking PCK-based NOS course. As a result, the courses which supported teachers' NOS understanding and their orientations to teaching NOS might be integrated into both teacher education programs and in-service teacher training programs.

The recent definitions of scientific literacy focused on social dimension of the science and emphasizing "science for citizenship" understanding (e.g. Aikenhead, 2002; Bybee, 2008; Holbrook, 2008; Holbrook & Rannikmae, 2009; Miller, 2002; PISA, 2015; Yacoubian, 2018). For example, Miller (2002) clearly mentioned that science has an impact on society, and individuals should be educated as scientifically literate citizens who make decisions about the scientific issues which include social, economic, political dimensions. With the emphasis on raising scientifically literate citizens who are able to make decisions about scientific issues including social aspects, some curriculums were developed for this aim like

Science-Technology-Society (STS), Science-Technology-Society-Environment (STSE) education (Zeidler, et al. 2005). Socioscientific Issue (SSI) took place in the science curriculum with the target of enabling students to be informed decision-makers on these contentious issues, and encouraging their moral and intellectual development (Zeidler et al., 2005). Moreover, as science and technology progressed more and more swiftly, there are more scientific and technological investigations which include dilemmas about ethic, ecologic, moral, health, etc. for all nations of societies, such as genetically modified foods, cloning, stem cells, vaccines, nuclear power plants, etc. In fact, in 2020, with the global pandemic COVID-19, the vaccination issue which is a SSI has been discussing in many countries by the citizens on social media platforms. To clarify, this epidemic process we are in shows us the importance of raising our students who can discuss these issues and make decisions about these issues effectively. The findings of the present study showed that really few students showed highly-qualified informal reasoning. In the demographic information form, it was observed that the students mentioned they usually used the Internet as a source of knowledge. There are studies showed that media including social media cause misunderstanding about the issue (Lin et al., 2020; Zhou et al., 2020). The reason of low informal reasoning quality might be the usage of the Internet as the source of knowledge. Hence, it can be suggested that in the science classes and course materials, current SSIs should be included and explained more. Teachers should transfer reliable knowledge about the SSIs in the classrooms by benefitting from the course materials. They also should direct students to reliable knowledge sources.

Moreover, in the present study, informal reasoning quality scores and supportive and counter argument construction performance showed difference across different SSIs. Based on the information about students' knowledge levels about SSIs in demographic information form, it could be inferred the students were able to construct more qualified informal reasoning about the issue they mentioned they already know something. Khishfe (2012) also found a similar result and mentioned that prior content knowledge and familiarity may support the students' argument construction performance. Sadler and Zeidler (2004) found that the university students who had high level content knowledge constructed more qualified informal reasoning. More recently, Baytelman et al. (2020) found that prior content knowledge is a predictor for argument quantity and quality in SSIs. Hence, in science classrooms, teachers may give more importance to inform students about SSI contexts to provide them with content knowledge about these issues and to make them familiar with these issues. They may use course materials including reliable content knowledge about the issues. Due to prior content knowledge about SSIs, students might construct more qualified informal reasoning.

The other reason of low qualified informal reasoning might be a lack of argumentation experience. There are studies showed that argumentation experience affects students' argumentation skills and informal reasoning quality positively (e.g. Dawson & Venville, 2013; Zohar & Nemet, 2002). Some of these studies found that explicit argumentation instruction improved students' argument construction skills in SSIs which directly affect informal reasoning quality (e.g. Zohar & Nemet, 2002; Khishfe, 2014). That is, findings showed that students improved their skills about constructing counter argument or rebuttal with the support of explicit instructions (Zohar & Nemet, 2002; Khishfe, 2014). That's why teachers should conduct argumentation practices for SSIs more frequently in science classes. Also, explicit argumentation instructions should be integrated into these practices. However, teachers might not find themselves sufficient to practice argumentation in the classroom. If the teachers did not enable to construct qualified informal reasoning about SSIs, they could not teach to construct qualified informal reasoning. Ozturk and YilmazTuzun (2017) found that most of the pre-service teachers from one of the most academically successful universities of Turkey could not construct qualified informal reasoning. To provide pre-service science teachers with the ability of highly-qualified informal reasoning, teacher education programs should include a course directly for SSI. Also, in this course, the teachers should not only be provided with highly-qualified informal reasoning practicing argumentations about SSIs but they should also be provided to manage the argumentation in classrooms. In other words, teachers should also learn how to teach SSIs in the classrooms in the universities. Moreover, for in-service teachers, in-service teacher training programs should include SSI-based courses to provide in-service teachers with the ability of teaching SSIs.

The findings of the present study showed that there was positive correlation with large effect size between students' informal reasoning modes and informal reasoning quality in SSIs. Wu and Tsai (2007) also found that participants constructing highly qualified informal reasoning benefited from more various reasoning modes in their arguments. Thus, it was hypothesized that usage of various reasoning modes may be necessary to develop students' informal reasoning levels, or vice versa (Wu & Tsai, 2007). Since the findings of the present study supported this hypothesis, in order to develop students' informal reasoning quality, they should be encouraged to generate more arguments. This may be ensured by providing them to use multiple perspectives while generating arguments about SSIs. Science teachers and curriculum developers may give importance to construct lesson materials to provide students to realize different perspectives of the SSIs such as economic, ecological, social, scientific, technological, etc. As mentioned before, explicit instructions about the argumentation skills might support students' informal reasoning quality (e.g. Dawson & Venville, 2013; Zohar & Nemet, 2002). Informal reasoning mode framework can be integrated into these explicit instructions. Thus, students can be supported to enrich their perspectives about SSIs, and they can use more various reasoning modes in their arguments.

There are researchers mentioned NOS understanding enables students to become influential decision-makers about SSIs (e.g. Driver et al., 1996, p. 11; Zeidler et al., 2005). For example, Zeidler et al. (2005) mentioned that understanding NOS is necessary for providing students to make informed decisions about SSIs. In the present study, the findings revealed that the students' understanding about the empirical-based, tentativeness, and subjectivity tenets of NOS made statistically significant contribution to their informal reasoning quality in SSIs. Thus, in order to improve the students' informal reasoning quality in SSIs, emphasis may be placed on improving the students' understanding of NOS. Although providing students with well-developed NOS understanding and qualified decision-making in SSIs were goals of Turkish science curriculum for middle school (MEB, 2018), the eighth grade students who are in the last grade of middle school showed naïve NOS understanding and unqualified informal reasoning mostly. Since the relationship between these two variables was found in the present study, the science teachers may focus on improving students' NOS understanding to support their informal reasoning quality. Zeidler et al. (2005) mentioned that NOS views may affect students' appraisement of knowledge formed by using scientific way and choice of evidence while explaining their positions about SSI.

In summary, multiple informal reasoning modes and NOS understanding level may be important factors for improving students' informal reasoning quality in SSIs. Also, students' prior content knowledge about SSI context and argumentation experience about SSIs may influence their performance on argument construction about the issue. Curriculum developers should take into consideration all these factors to improve the science curriculum in terms of SSI education.

5.5 Recommendations for Further Research

The following recommendations can be suggested for further research studies on the basis of the present study and former research studies. Firstly, further research can be replicated with different grade levels and larger samples to investigate the relationship among nature of science understanding, informal reasoning quality, and informal reasoning modes. Moreover, different socioscientific contexts can be used in further research studies such as human cloning, vaccination, nuclear power plant, etc. Moreover, further research studies can conduct follow-up interviews with small part of the sample after open-ended questionnaires to examine how students' NOS understanding reflects on their informal reasoning on SSIs. Also, three NOS tenets were included in the present study, but other NOS tenets (e.g.

cultural-social embeddedness) can be included in further research studies to investigate their relationship with informal reasoning quality in SSI.

Secondly, for further research, intervention studies can be conducted to investigate how middle school students' informal reasoning quality in SSI can be developed. To clarify, intervention studies investigating the factors that might affect students' informal reasoning quality should be conducted. For example, a further research study examining the effect of NOS-based instruction on students' informal reasoning on SSI can be designed. Moreover, further research studies are needed to find out the relationship among not only NOS understanding and informal reasoning on SSI but also prior content knowledge about SSI, attitude toward SSI, etc. The findings of these studies may provide some insights to science curriculum developers to design SSI-based curriculum to raise citizens who make qualified decisions about SSIs.

Lastly, as mentioned above, there is a need for effective course materials to support students' NOS understanding development and informal reasoning about SSIs. Further studies should be conducted with the aim of testing the effectiveness of these designed materials used in science classes to support middle school students' NOS understanding and their SSI teaching. If proper and effective materials are designed based on the findings of research studies, teachers can benefit from these materials to improve their students' NOS understanding, informal reasoning on SSI, and indirectly their scientific literacy.

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APPENDICES

A. Permission Obtained From Ankara Provincial Directorate of National Education

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.10625694 29.05.2019
Konu : Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi a) 20/05/2019 Tarihli ve E.126 sayılı yazınız.
b) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü'nün 2017/25 nolu Genelgesi.

Üniversiteniz Matematik ve Fen Bilimleri Eğitimi Anabilim Dalı, Fen Bilimleri Doktora öğrencisi Nesibe Fatıma Nur IRMAK'ın **"Sekizci Sınıf Öğrencilerinin Bilimin Doğası Anlayışları ve Sosyo-Bilimsel Konular Hakkındaki Muhakemeleri Arasındaki İlişkinin İncelenmesi"** konulu araştırması kapsamında ekteki listede adı geçen okullarda uygulanacak olan veri toplama araçları ilgi (b) Genelge çerçevesinde incelenmiştir.

Yapılan inceleme sonucunda, söz konusu araştırmanın Müdürlüğümüzde muhafaza edilen ölçme araçlarının; Türkiye Cumhuriyeti Anayasası, Milli Eğitim Temel Kanunu ile Türk Milli Eğitiminin genel amaçlarına uygun olarak, ilgili yasal düzenlemelerde belirtilen ilke, esas ve amaçlara aykırılık teşkil etmeyecek, eğitim-öğretim faaliyetlerini aksatmayacak şekilde okul ve kurum yöneticilerinin sorumluluğunda gönüllülük esasına göre uygulanması Müdürlüğümüzce uygun görülmüştür.

Bilgilerinizi ve gereğini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Ek:
1-Uygulama araçları (6 sayfa)
2-Okul listesi (2sayfa)
Dağıtım:
Gereği: Bilgi:
Orta Doğu Teknik Üniversitesi Altındağ İlçe MEM
Rektörlüğü

Adres: Alparslan Türkeş cad. Emniyet Mah.4/A Yenimahalle/ANKARA Bilgi için: Ayşe ARDA
Elektronik Ağ: ankara.meb.gov.tr Tel: 0 (312) 212 36 00
e-posta: istatistik06@meb.gov.tr Faks: 0 (312) 221 02 16

Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden 25e7-bb9e-3d54-b2b1-1074 kodu ile teyit edilebilir.

B. Demographic Information Form

Kişisel Bilgi Ölçeği

1. Okulunuzun Adı:____

2. Doğum tarihiniz (yıl): ________________

3. Cinsiyetiniz: ❑ Kız ❑ Erkek

4. Orta-okul eğitimi boyunca fen bilimleri dersi karne notlarınız;

Beşinci sınıf yılsonu notu: ________________

Altıncı sınıf yılsonu notu: _________________

Yedinci sınıf yılsonu notu: _________________

Sekizinci sınıf birinci dönem sonu notu: ______________

5. Kaç kardeşsiniz? : (............) (sizinle birlikte)

6. Annenizin eğitim durumu: ❑ İlkokul ❑ Ortaokul ❑ Lise ❑ Üniversite

❑Yüksek Lisans/ Doktora ❑ Okuma-yazma bilmiyor

7. Babanızın eğitim durumu: ❑ İlkokul ❑ Ortaokul ❑ Lise ❑ Üniversite

❑ Yüksek Lisans/ Doktora ❑ Okuma-yazma bilmiyor

8. Anneniz çalışıyor mu? : ❑ Evet ❑ Hayır

Yanıtınız "evet" ise çalıştığı kurum : ❑ Devlet dairesi ❑ Özel sektör

❑ Kendi işyeri ❑ Çiftçi ❑ Emekli

9. Babanız çalışıyor mu? : ❑ Evet ❑ Hayır

Yanıtınız "evet" ise çalıştığı kurum : ❑ Devlet dairesi ❑ Özel sektör

❑ Kendi işyeri ❑ Çiftçi ❑ Emekli

10. Küresel ısınma ile ilgili ne kadar bilgilisiniz?

❑ Oldukça fazla ❑ Fazla ❑ Az ❑ Hiç

11. Küresel ısınma ile ilgili bilgilerinizi nereden edindiniz? (Birden fazla seçeneği işaretleyebilirsiniz.)

❑ Ders Kitabı ❑ İnternet ❑ Radyo ve Televizyon ❑ Dergi ve gazete

❑ Sosyal çevre ve arkadaşlar

10. Asit yağmuru ile ilgili ne kadar bilgilisiniz?

❑ Oldukça fazla ❑ Fazla ❑ Az ❑ Hiç

11. Asit yağmuru ile ilgili bilgilerinizi nereden edindiniz? (Birden fazla seçeneği işaretleyebilirsiniz.)

❑ Ders Kitabı ❑ İnternet ❑ Radyo ve Televizyon ❑ Dergi ve gazete

❑ Sosyal çevre ve arkadaşlar

10. Genetiği değiştirilmiş gıdalar ile ilgili ne kadar bilgilisiniz?

❑ Oldukça fazla ❑ Fazla ❑ Az ❑ Hiç

11. Genetiği değiştirilmiş gıdalar ile ilgili bilgilerinizi nereden edindiniz? (Birden fazla seçeneği işaretleyebilirsiniz.)

❑ Ders Kitabı ❑ İnternet ❑ Radyo ve Televizyon ❑ Dergi ve gazete

❑ Sosyal çevre ve arkadaşlar

C. Turkish Version of Views of Nature of Science Elementary Level (VNOS-E) Questionnaire

İlköğretim Düzeyi için Bilimin Doğası Görüş Ölçeği

1. Sizce "bilim" nedir?

2. a) Sizce bilimi diğer konulardan (resim, müzik, din, Türkçe gibi) ayıran özellikler nedir? Örnek vererek açıklayınız.

b) Bilim sizce bu konulardan (resim, müzik, din, Türkçe gibi) hangi açılardan farklıdır? Açıklayınız.

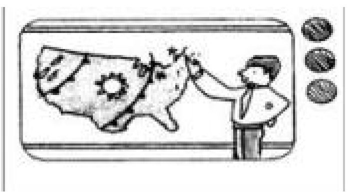
3. Bilim insanları daima dünyamız hakkında daha çok bilgi sahibi olmaya çalışırlar. Bilim insanlarının bugün sahip oldukları bilgilerinin gelecekte değişeceğini düşünür müsünüz? Lütfen örnekler yardımıyla açıklayınız.

4. a) Bilim insanları bir zamanlar dinozorların dünyada yaşadıkları hakkında nasıl bilgi sahibi olmuşlardır?

b) Bilim insanları dinozorların görünüşleri hakkında nasıl bilgi sahibi olmuşlardır? Sizce bu konuda kesin bilgilere sahip midirler? Nedenleriyle açıklayınız.

5. Bilim insanları; dinozorların uzun bir zaman önce, neden ve nasıl yok olduğu konusunda farklı görüşlere sahiptirler. Bilim insanları aynı veri ve kanıtlara sahip olmalarına rağmen dinozorların yok oluşlarıyla ilgili olarak neden farklı görüşlere sahiplerdir?

6. Her gün televizyonda hava durumu spikeri yarın havanın nasıl olacağına dair bilgileri resimlerle bize aktarmaktadır. Bu resimlerin hazırlanmasında birçok bilimsel veriler ve kanıtlar kullanılır. Hava durumu spikeri bu resimlerin verdiği bilgiler hakkında nasıl emin olabilmektedir? Nedenleriyle birlikte açıklayınız.



D. Turkish Version of Informal Reasoning on Socioscientific Issues Questionnaire

Sosyobilimsel Konular ile ilgili Görüşler Ölçeği

Senaryo 1: Küresel Isınma

Küresel ısınma, bütün ülkeleri ilgilendiren önemli bir çevresel durumdur. Bazı bilim insanlarına göre, insan faaliyetleri, özellikle fosil yakıtların (petrol, gaz ve kömür) yakılması, atmosferdeki karbondioksit, ve diğer gaz (karbon monoksit, azot dioksit gibi) seviyelerini önemli ölçüde artırdı. Eğer bu gazlar atmosferde normal seviyede olursa güneş enerjisini hapsederek Dünya'nın sıcaklığını dengede tutar. Fakat atmosferde bu gazların seviyelerinin normalin üzerine çıkması, Dünya'nın sıcaklığını yükseltmektedir ve bu yükseliş de çevresel sorun olan küresel ısınmaya yol açar.

Karşıt görüşe sahip bilim insanlarına göre ise, küresel ısınmada insan faaliyetlerinin etkisi önemsizdir. Dünya sıcaklığındaki artışlar, Dünya ikliminin doğal bir parçasıdır. Dünya'mız geçmişte, insan etkisinin olmadığı zamanlarda, buz çağları ve aşırı sıcak dönemler yaşamıştır. Ayrıca, bu görüşe sahip bilim insanları, küresel ısınmayı engellemek için alınan önlemlerin, ülkeleri ekonomik krize sokacağından endişe duymaktadır.

Paris'te, 2015 yılında düzenlenen iklim değişikliği- küresel ısınma konferansında Paris İklim Anlaşması kabul edilerek atmosferde sıcaklığı artıran gazların miktarının azaltılması hedeflenmiştir. Bütün ülkelerin bu süreçte sorumluluk almaları; fosil yakıtların kullanımını azaltmaları ve yenilenebilir enerji tercih etmeleri kararlaştırılmıştır. Bu anlaşma kapsamında, ekonomik düzeyi iyi olan ülkeler, daha fakir ülkelere finansal destek sağlayacaktır.

Sorular

1. Küresel ısınmaya karşı önlemler alınması ya da alınmaması konusunda sizin görüşünüz nedir?

2. Arkadaşlarınıza kendi görüşünüzü hangi bilgileri kullanarak savunursunuz?

3. Sizin görüşünüze karşıt görüş sahibi olan arkadaşınız hangi bilgileri kullanarak görüşünü savunabilir?

4. Arkadaşınızın görüşü ve verdiği bilgilere karşı kendi görüşünüzü (2. Soruda belirttiğiniz) hangi bilgileri kullanarak savunmaya devam edersiniz?

Senaryo 2: Asit Yağmuru

Fosil yakıt kullanılması (araba motorlarında ve elektrik santrallerinde), kükürt dioksit ve azot dioksit gibi asidik olan kirletici gazların oluşumuna yol açar. Bu gazlar havada yağmur suyuyla reaksiyona girerler ve asit yağmurları oluşur. Asit yağmurları yeryüzüne düştüğünde sudaki hayatı öldürür ve mimari yapılar ve sanat eserleri üzerinde olumsuz Ek olarak, asit yağmuru, mimari yapılar ve sanat eserleri üzerinde olumsuz etkiye neden olur.

Bilim insanlarına göre asit yağmuru sorununu çözmenin üç olası yolu vardır:

1. Bir grup bilim insanı, asit yağmuru probleminin çok önemli olmadığını ve asitleşmiş göllere ve akarsulara bazik bileşikler eklenerek kolayca normale döndürülebileceğini savunmaktadır.
2. Başka bir grup bilim insanı ise, asit yağmurunu azaltmak için havayı kirleten gazların açığa çıkmasının kontrol altına alınmasını önermektedirler. Bu, daha az fosil yakıt yakarak ve daha fazla enerji tasarrufu yaparak sağlanabilir. Ancak, bu çözüm, yeni bir arabanın ortalama maliyetinde artışa ve ayrıca enerji tasarrufunu teşvik eden özel vergilere yol açacaktır.
3. Bir başka grup bilim insanı ise, kirletici gazları atmosfere girmeden önce uzaklaştırmayı savunmaktadır. Bu gazların atmosfere girmeden uzaklaştırılması da çok pahalı olabilir.

Sorular

1. Yukarıdaki çözüm önerilerinden (1,2,3) hangisi sizin için daha uygundur?

2. Arkadaşlarınıza kabul ettiğiniz öneriyi hangi bilgileri kullanarak savunursunuz?

3. Sizden farklı öneriyi kabul eden arkadaşınız hangi bilgileri kullanarak görüşünü savunabilir? (Burada diğer iki seçenekten birisini verebilirsiniz.)

4. Arkadaşınızın görüşü ve verdiği bilgilere karşı kendi görüşünüzü (2. Soruda belirttiğiniz) hangi bilgileri kullanarak savunmaya devam edersiniz?

Senaryo 3: Genetiği Değiştirilmiş Gıdalar

İngiltere'deki bilim insanları, A vitamini eksikliğini gidermek için genetiği değiştirilmiş olan "besin değeri zenginleştirilmiş pirinç" türünü geliştirdiler. Genetiği değiştirilmiş bu pirinç bitkileri normal pirinç bitkisinden iki fazla gen içermektedir.

Bir grup bilim insanı, genetiği değiştirilmiş pirinci yemenin, sindirim sırasında A vitamini alımını arttırarak körlüğün önlenmesine yardımcı olabileceğine inanmaktadır. Sonuç olarak, bu pirincin tüketimi, dünya çapında, 500.000 çocuğu etkileyen çocukluk dönemi körlüğünü azaltabilir. Bu bilim insanları, genetiği değiştirilmiş gıdaların insan ve diğer canlılar için tehlikeli olduğunu belirten herhangi bir bilimsel çalışma olmadığını belirtmektedir.

Diğer bir grup bilim insanı, genetiği değiştirilmiş pirinci (veya genetiği değiştirilmiş herhangi bir yiyeceği) yemenin bizi nasıl etkileyeceğini bilmediğimizi savunmaktadır. İki genin eklenmesinin bitkiyi bir bütün olarak nasıl değiştirdiğini görmek için bu pirincin biyokimyasal analizinin gerekli olduğunu ve bunun yapılmadığını savunmaktadır. Ayrıca, yeni pirinç bitkileri ile diğer pirinçlerin aynı bölgelerde yetişmesinden dolayı diğer pirinçlerin genetik yapısının da bozulabileceğinden endişe duyulmaktadır. Bu yüzden, bu gruptaki bilim insanları, sağlıklı beslenmenin, A vitamini eksikliği ile başa çıkmak için genetiği değiştirilmiş pirinçten daha iyi bir çözüm olabileceğini savunmaktadır.

Sorular

1. Genetiği değiştirilmiş pirincin üretilerek satışa sunulması ya da sunulmaması konusunda sizin görüşünüz nedir?

2. Arkadaşlarınıza kendi görüşünüzü hangi bilgileri kullanarak savunursunuz?

3. Sizin görüşünüze karşıt görüş sahibi olan arkadaşınız hangi bilgileri kullanarak görüşünü savunabilir?

4. Arkadaşınızın görüşü ve verdiği bilgilere karşı kendi görüşünüzü (2. Soruda belirttiğiniz) hangi bilgileri kullanarak savunmaya devam edersiniz?