MIDDLE SCHOOL STUDENTS’ INFORMAL REASONING MODES AND ARGUMENTATION QUALITY IN SOCIOSCIENTIFIC ISSUES: EPISTEMOLOGICAL BELIEFS AND ISSUE FAMILIARITY AS PREDICTORS

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ABSTRACT

MIDDLE SCHOOL STUDENTS' INFORMAL REASONING MODES AND ARGUMENTATION QUALITY IN SOCIOSCIENTIFIC ISSUES: EPISTEMOLOGICAL BELIEFS AND ISSUE FAMILIARITY AS PREDICTORS

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The purpose of this study was to examine middle school students' informal reasoning modes, and argumentation quality regarding three different SSI, namely, space explorations (SPE), genetically modified organisms (GMO), and nuclear power plants (NPP); and to investigate how well middle school students' epistemological beliefs (the dimensions of source/certainty, development, and justification) and issue familiarity predict their informal reasoning modes and argumentation quality. For this purpose, correlational research design was used. A total of 465 students (7th and 8th grade) from eight public middle schools in Çankaya constituted the sample through convenient sampling. All data were collected in the Fall Semester of 2020-2021 Academic Year. The middle school students' epistemological beliefs were obtained through *Epistemological Beliefs Questionnaire* adapted into Turkish by Ozkan (2008), whereas issue familiarity was obtained through *Issue Familiarity Form*. The middle school students' informal reasoning modes and argumentation quality were obtained through open-ended questions adapted by Chang and Chiu (2008), and Christenson and colleagues (2012). The data obtained from open-ended questions were analyzed qualitatively first, then transformed into quantitative data. Descriptive statistics showed that middle school students had fairly sophisticated epistemological beliefs, whereas their issue familiarity, informal reasoning modes, and argumentation quality varied across different SSI. Multiple regression analyses indicated that middle school students' epistemological beliefs (except the dimension of justification) predicted their informal reasoning modes and argumentation quality. Moreover, middle school students' issue familiarity made statistically significant contribution to the prediction of their informal reasoning modes and argumentation quality regarding space explorations and nuclear power plants.

Keywords: Socioscientific Issues, Informal Reasoning Modes, Argumentation Quality, Epistemological Beliefs, Issue Familiarity

ÖZ

ORTAOKUL ÖĞRENCİLERİNİN SOSYOBİLİMSEL KONULARDAKİ İNFORMAL MUHAKEME MODLARININ VE ARGÜMANTASYON KALİTELERİNİN YORDAYICISI OLARAK EPİSTEMOLOJİK İNANÇLAR VE KONU AŞİNALIĞI

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Bu çalışmanın amacı öncelikle ortaokul öğrencilerinin uzay araştırmaları, genetiği değiştirilmiş organizmalar ve nükleer güç santralleri olmak üzere üç farklı sosyobilimsel konu ile ilgili informal muhakeme modlarını ve argümantasyon kalitelerini incelemek; sonrasında ise öğrencilerin epistemolojik inançlarının (kaynak/kesinlik, gelişme ve gerekçelendirme boyutlarında) ve konu aşinalıklarının onların informal muhakeme modlarını ve argümantasyon kalitelerini ne ölçüde yordadığını araştırmaktır. Bu amaçla, ilişkisel araştırma deseni kullanılmış, Çankaya ilçesindeki sekiz devlet ortaokulundan toplamda 465 öğrenci (7. ve 8. sınıf) uygun örnekleme yoluyla çalışmanın örneklemini oluşturmuştur. Tüm veriler 2020-2021 Akademik Yılı Güz Döneminde toplanmıştır. Ortaokul öğrencilerinin epistemolojik inançları Özkan (2008) tarafından Türkçe'ye uyarlanan *Epistemolojik İnançlar Ölçeği* ile elde edilirken, öğrencilerin konu aşinalıkları *Konu Aşinalığı Formu* ile elde edilmiştir. Ayrıca, ortaokul öğrencilerinin informal muhakeme modları ve argümantasyon kaliteleri Chang ve Chiu (2008), ve Christenson ve diğerlerinin (2012) çalışmalarından uyarlanan açık uçlu sorularla elde edilmiştir. Açık uçlu sorulardan elde edilen veriler önce nitel olarak analiz edilmiş, sonrasında nicel veriye dönüştürülmüştür. Betimsel istatistik analizleri ortaokul öğrencilerinin gelişmiş epistemolojik inançlara sahip olduğunu; öğrencilerin konu aşinalıklarının, informal muhakeme modlarının ve argümantasyon kalitelerinin ise üç sosyobilimsel konu karşısında farklılaştığını göstermiştir. Çoklu regresyon analizleri ortaokul öğrencilerinin epistemolojik inançlarının (gerekçelendirme boyutu hariç) onların informal muhakeme modlarını ve argümantasyon kalitelerini yordadığını ortaya koymuştur. Ayrıca, öğrencilerin konu aşinalıkları, uzay araştırmaları ve nükleer güç santralleri konuları ile ilgili informal muhakeme modlarının ve argümantasyon kalitelerinin tahminine istatistiksel olarak anlamlı katkı sağlamıştır.

Anahtar Kelimeler: Sosyobilimsel Konular, İnformal Muhakeme Modları, Argümantasyon Kalitesi, Epistemolojik İnançlar, Konu Aşinalığı

To my lovely family

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS

DoC: Degree of Certainty

EBQ: Epistemological Beliefs Questionnaire

FOF: Feelings of Familiarity

GMO: Genetically Modified Organisms

HC: Hard Core

KVP: Knowledge - Value - Personal Experience

MoNE: Ministry of National Education

NH: Negative Heuristics

NPP: Nuclear Power Plants

PB: Protective Belt

PH: Positive Heuristics

SEE-SEP: Sociology/Culture, Environment, Economy, Science, Ethics/Morality, Policy

SEE-STEP: Sociology/Culture, Environment, Economy, Science, Technology, Ethics/Morality, Policy

SPE: Space Explorations

SPSS: Statistical Package for the Social Sciences

SSI: Socioscientific Issues

SSR: Socioscientific Reasoning

STEM: Science - Technology - Engineering - Mathematics

STS: Science - Technology - Society

STS(E): Science - Technology - Society - Environment

WHO: World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Scientific Literacy and Socioscientific Issues

Scientific literacy has been supported by the science education community for a long time (Presley et al., 2013) and raising scientific literate individuals has become one of the major goals in the science education (Sadler, 2004). Although the importance of scientific literacy has remained over many years, its definition has been changed several times. The earlier definitions of scientific literacy were based on the understanding of pure science and the ability to conduct scientific processes, whereas the recent definitions have focused on not only the scientific processes and products, but also the ability to deal with science-related societal issues including both cognitive and affective processes as active citizens (Chang Rundgren & Rundgren, 2010).

According to Miller (1983), who described scientific literacy as a multidimensional construct, there are three indispensable components that constitute scientific literacy: understanding of (a) content knowledge, (b) relationship between science, technology and society, and (c) nature of science. In other words, a scientifically literate person could understand scientific concepts and key terms, the effects of scientific and technological developments on society, and the characteristics of science.

Human experiences with the COVID-19 pandemic have enabled all the people to understand why these dimensions are vital to be scientifically literate. For almost two years, since the World Health Organization (WHO) declared the Coronavirus outbreak as a pandemic (WHO, 2020), COVID-19 has affected nearly all aspects of life including individuals' physical and mental health, education, economy, international relations, societal regulations, travel restrictions and so forth. Every day, lots of new information about the COVID-19 pandemic has appeared on the latest news and some regulations have been announced through the media. All of the people have been exposed to numerous "scientific" terms that dominated daily conversations. Some examples of these terms are *virus*, *pandemic*, *outbreak*, *curve*, *asymptomatic*, *quarantine*, *lockdown*, *social-distance*, *vaccine*, *anti-vaccination*, *online*, *distance education*, *video-conference,* and *virtual environment* (Dillon & Avraamidou, 2020). Making sense of these terms requires good understandings of scientific concepts and principles. Moreover, controversial questions have been discussed such as "Should people be vaccinated or not?", "Should we wear mask or not?", "Is herd immunity or controlled immunity better?" (Evren Yapicioglu, 2020), "Should distance education continue or stop?", "Are we for or against curfew?" (Atabey, 2021), and "If we decide on to be vaccinated, which brand is more protective?". Developing a position and reaching an informed decision regarding all of these questions require to understand not only the aforementioned scientific concepts and terms but also the relations between science, technology, and society.

Similarly, Millar and Osborne (1998) pointed out "a scientifically literate individual could be simply defined as a person who understand the nature of science (NOS), science-technology-society (STS), and scientific concepts/terms" (as cited in Chang Rundgren & Rundgren, 2010, p. 6). Additionally, Thomas and Durant (1987) emphasized that scientific literacy can provide individuals to deal with rapidly increasing scientific and technological developments and accompanying challenges. In other words, a scientifically literate person has the ability to make personal decisions regarding science-related societal issues such as vaccination, smoking, and diet (Chang Rundgren & Rundgren, 2010).

In addition to these definitions, Vision I and Vision II scientific literacy (SL) were proposed by Roberts (2007). Vision I SL can be considered as the literacy "*within science"*, whereas Vision II SL can be considered as the literacy "*about science-related situations"* (p. 730). In other words, Vision I SL focuses on the scientific processes and products that scientists encounter, while Vision II SL focuses on the relation between science and social problems that any citizens can encounter.

To complete the vision of scientific literacy, “functional” scientific literacy was also emphasized by several researchers (Zeidler, 2014; Zeidler & Lewis, 2003; Zeidler et al., 2005). The functional scientific literacy framework also focuses on moral and ethical factors that individuals necessarily evaluate in the process of moral reasoning (Zeidler, 2014), extending Vision II scientific literacy (Roberts, 2007). That means, the functional view of scientific literacy would be incomplete without the consideration of moral and ethical aspects underlying an issue.

All of these given definitions pointed out science-related societal issues including moral and ethical aspects as one of the most important dimensions of scientific literacy and integration of them into the school education is needed to achieve scientific literacy (Dawson & Venville, 2009; Venville & Dawson, 2010). These science-related societal issues are named as socioscientific issues (SSI).

According to Sadler (2004), the ability to make informed decisions regarding complex socioscientific issues plays an important role to achieve scientific literacy. Almost two decades, the researchers have supported the idea that SSI is a vital component of the science education and considerably contributes to scientific literacy (Christenson et al., 2012; Capkinoglu et al., 2020; Driver et al., 2000). SSI are defined as “complex, open-ended, often contentious dilemmas with no definitive answers” (Sadler, 2004, p. 514). They generally tend to be “controversial; multi-faceted; subject to multiple, sometimes, contradictory perspectives; and connected to scientific concepts” (Herman et al, 2018, p. 146).

Besides the international efforts for achieving scientific literacy, Turkey also emphasized on the importance of scientific literacy and integrated SSI with moral and ethical aspects into the science curriculum. With the recent science curriculum changes, “providing students to develop scientific thinking habits, reasoning and decision-making skills through socioscientific issues” was accepted as one of ten goals of the curriculum (Ministry of National Education (MoNE), 2018, p. 9).

Therefore, integrating SSI into science education provides contexts for the students to negotiate and resolve SSI through engaging in practices such as informal reasoning, argumentation, and decision-making.

Considering that SSI is a vital component to achieve scientific literacy, the present study has addressed three different SSI, namely, space explorations (SPE), genetically modified organisms (GMO) and nuclear power plants (NPP) to investigate middle school students' informal reasoning modes and argumentation quality. The reason behind the selection of these particular SSI was that the selected SSI have been discussed from multiple, and contradictory perspectives among the societies in many countries including Turkey. Besides these general common characteristics, there are also specific reasons for each SSI. Regarding SPE, in the last revision of Turkish middle school science curriculum (MoNE, 2018), space-related topics (e.g. Solar System, planets, eclipses, space explorations, etc.) have started to be covered in the first unit of each grade level. The alignment with Turkish middle school science curriculum (MoNE, 2018), the special interest of students toward astronomy-related concepts and having a few studies (Lee & Yang, 2019; Zhang et al., 2017) were the reasons of the selection of space explorations. Therefore, in addition to SSI frequently selected by the researchers (e.g. genetically modified organisms and nuclear power plants), the present study also addressed rarely used space explorations. Regarding GMO and NPP, the related literature showed that most of the studies investigating students' informal reasoning modes and argumentation quality in the context of SSI have addressed topics such as genetic engineering (Georgiou & Mavrikaki, 2013; Sadler & Fowler, 2006; Sadler & Zeidler, 2005a) and nuclear power plants (Demircioglu & Ucar, 2014; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007; Yang & Anderson, 2003).

In the literature, several studies focusing on students' informal reasoning modes and argumentation quality in the context of SSI reported that SSI context may affect students' informal reasoning modes and argumentation quality (Christenson et al., 2012; Christenson et al., 2014; Irmak, 2021). In other words, students' informal reasoning modes and argumentation quality might vary across different SSI. The present study addressed three different SSI from three different disciplines (i.e. Earth Science, Biology and Physics). In Turkish middle school science curriculum (MoNE, 2018), there are mainly four different content areas, namely, The Earth and Universe, Living Things and Life, Physical Events, Matter and its Nature. Thus, in this study, all of these content areas except Matter and its Nature (i.e. SPE from Earth Science, GMO from Biology, and NPP from Physics) were considered.

By selecting different SSI from different disciplines (i.e. content areas in Turkish middle school science curriculum), one of the purposes of the present study was to compare how middle school students' informal reasoning modes and argumentation quality may vary across different SSI. In the following section, the theoretical link between SSI and informal reasoning is introduced.

1.2 Socioscientific Issues, Informal Reasoning and Informal Reasoning Modes

Since socio-scientific issues are ill-structured and lack of clear-cut solutions, they require informal reasoning unlike formal reasoning that has fixed and unchanging structure (Sadler, 2004). In other words, one can solve a problem that requires formal reasoning by only following some logical steps, whereas the same person may not solve a socioscientific issue by following the same steps as SSI have several dimensions to be considered such as political, social, ethical, moral and even economical. According to Sadler (2004), "informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions" (p. 514). Zohar and Nemet (2002) also described informal reasoning as "reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of particular propositions or decision alternatives" (p. 38).

When the literature focusing on how individuals negotiate SSI was examined, it was revealed that several researchers have investigated individuals' informal reasoning modes regarding both local and global contexts. In their study, Sadler and Zeidler (2005a) differentiated college students' informal reasoning regarding biotechnology into three patterns as rationalistic, emotive, and intuitive, and these patterns of informal reasoning have been adopted by several researchers (Atabey & Topcu, 2020; Georgiou & Mavrikaki, 2013; Ozden, 2020) in order to reveal students' informal reasoning patterns both in national and international contexts. Different from this denotation, some researchers investigated individuals' informal reasoning "modes" (Liu et al., 2010; Patronis et al., 1999; Wu & Tsai, 2007; Yang & Anderson, 2003). In their study, Patronis and colleagues (1999) investigated 14 year-old students' informal reasoning modes regarding a new road construction near the school area and revealed four different modes, namely, social, ecological, economic and practical. Similarly, Yang and Anderson (2003) also examined high school students' informal reasoning modes regarding nuclear power plants in Taiwan and proposed three different modes as scientifically-oriented, socially-oriented, and equally-disposed. In another study, Wu and Tsai (2007) investigated high school students' informal reasoning modes regarding nuclear power plants as four different modes, namely, social-oriented, ecological-oriented, economic-oriented, and scientific & technological-oriented. Liu and colleagues (2010) also investigated college students' informal reasoning modes regarding an environmental SSI (i.e. the introduction of an invasive species) and revealed four different modes: ecological, ethical & aesthetic, scientific & technological, and social & economic.

In the present study, informal reasoning modes were adopted to address the multiple perspectives that the participants used to develop their informal reasoning. In order to analyze the middle school students' informal reasoning modes from a holistic perspective, the present study adopted "subject areas" of SEE-SEP Model as an analytical framework (Chang Rundgren & Rundgren, 2010). The reason behind the selection of this analytical framework was that subject areas in the SEE-SEP Model are more diverse and specific than informal reasoning modes proposed by other researchers (Patronis et al., 1999; Yang & Anderson, 2003; Wu & Tsai, 2007) as the related literature showed that most of the studies focusing on the students' informal reasoning have used fewer reasoning modes (Liu et al., 2010; Patronis et al., 1999; Sadler & Zeidler, 2005a; Wu & Tsai, 2007; Yang & Anderson, 2003). Therefore, utilizing a more holistic analytical framework may provide to obtain more detailed information regarding students' informal reasoning modes. The SEE-SEP model consists of six subject areas which are sociology/culture, environment, economy, science, ethics/morality, and policy. Sociology/culture refers to the arguments based on the welfare of the society and development of the country, whereas environment focuses on ecology, nature, and welfare of non-human livings. Also, economy refers to the arguments based on financial conditions, cost, and foreign source (external) dependency, whereas science focuses on the characteristics of science, scientific knowledge, and scientists. Moreover, ethics/morality concerns with the rights of livings and next generations, whereas policy focuses on the governmental issues (e.g. conventions and wars).

In the literature focusing on students' usage of different modes, some of the researchers stated that individuals were able to consider multiple perspectives by using more than one mode or providing combined patterns (Sadler & Zeidler, 2005a; Wu & Tsai, 2007; Yang & Anderson, 2003), whereas some of them reported that students were not successful in considering multiple perspectives while negotiating SSI (Hogan, 2002; Liu et al., 2010). These inconsistent findings of the studies showed that there was a need for further studying regarding to what extent students can consider multiple perspectives while negotiating SSI. Therefore, one of the purposes of the present study was to investigate middle school students' informal reasoning modes in terms of the total number of subject areas. In this sense, the present study focused on the students' ability to negotiate complex SSI from multiple perspectives (i.e. using more than one subject area).

In addition to the aforementioned subject areas, Chang Rundgren and Rundgren (2010) also integrated the aspects of knowledge, value, and personal experience into the extent of SEE-SEP Model to investigate how individuals support their claims and justify their positions while making decisions regarding both local and global issues. Therefore, the SEE-SEP Model consists of not only the subject areas but also accompanying aspects (i.e. knowledge, value, and personal experience) that students' informal reasoning can be derived from. The aspect of knowledge refers to the arguments including concepts and theories regarding a specific subject area, whereas the aspect of value refers to the arguments including value, affection, and attitude regarding a specific subject area. The aspect of personal experience refers to the arguments in which individuals provide personal experiences from their lives.

The literature focusing on individuals' informal reasoning modes indicated that several researchers investigated how individuals use knowledge (Nielsen, 2012b; Sadler & Zeidler, 2005b), value (Albe, 2008; Lee, 2007), and personal experience (Atasoy et al., 2019; Fleming, 1986; Patronis et al., 1999; Sadler & Zeidler, 2004; Zeidler & Schafer, 1984) to justify their positions in the context of SSI (Christenson et al., 2012; Christenson et al., 2014; Rundgren et al., 2016).

In science education, one of the most important goals is providing students to acquire the ability to use knowledge that they have learnt from the school science in different contexts beyond school (Haskell, 2001; Sadler & Donnelly, 2006). For this purpose, several researchers have focused on to what extent students use their content knowledge in SSI contexts. When the related studies were examined, it was revealed that there was no consensus regarding students' usage of content knowledge to justify their positions. Some of the researchers reported that students were able to use the related science content knowledge in different SSI contexts (Nielsen, 2012b; Sadler & Zeidler, 2005b), whereas some of them indicated that students could not adequately use science content knowledge in SSI discussions (Albe, 2008; Zohar & Nemet, 2002). In addition to content knowledge, several researchers asserted that values and personal experiences also frequently used by individuals to support their positions regarding SSI (Albe, 2008; Atasoy et al., 2019; Christenson et al., 2012; Christenson et al., 2014; Patronis et al., 1999; Rundgren et al., 2016).

In the present study, both the middle school students' informal reasoning modes and to what extent they use knowledge, value, and personal experiences were analyzed through SEE-SEP Model (Chang Rundgren & Rundgren, 2010).

1.3 Informal Reasoning and Argumentation on SSI

In addition to the modes of informal reasoning, the quality of informal reasoning has also been investigated in many studies (Irmak, 2021; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007; Wu & Tsai, 2011). Some researchers have taken the structure and complexity of arguments into consideration as a reflection of students' informal reasoning quality (Topcu et al., 2010; Wu & Tsai, 2007). Since informal reasoning and argumentation are theoretically distinct (Means & Voss, 1996) but practically similar (Atabey & Topcu, 2017) constructs, individiuals' quality of informal reasoning has been frequently assessed through their argumentation quality as an indirect measure.

As a pioneer of the argumentation studies, Toulmin's (1958) argumentation model consists of six basic components, namely, claim, data, warrant, backing, qualifier and rebuttal. Although Toulmin's Argumentation Pattern (TAP) has been widely used by the researchers and provides an effective framework to examine the structure of individuals' arguments, it was not enough to assess the students' argumentatioön quality. Therefore, several researchers (Erduran et al., 2004; Osborne et al., 2004) have taken TAP a step further and used some TAP-based levels to assess the students' argumentation quality.

Although TAP has been widely used in the argumentation studies as an analytical framework to identify the components of an argument and assess students' argumentation quality through the TAP-based levels, some limitations were reported by several researchers (Chang & Chiu, 2008; Erduran et al., 2004; Kelly et al., 1998; Sampson & Clark, 2008). The main limitation in applying TAP was reported as the challenge to differentiate the components, especially, data, warrant and backing, from each other (Erduran et al., 2004). According to Kelly and colleagues (1998), another limitation of TAP was the inconsistency with "actual talk" leading that "statements that look like a claim could serve as a warrant given the particular context of a particular segment of the conversation" (p. 857). According to Chang and Chiu (2008), another limitation of TAP was the failure to code some "indirect" points of view that students frequently express in their written arguments to strengthen their positions. Since Toulmin's argument layout includes distinct but related components, these "indirect" points of view were considered as inconsistent with TAP. Therefore, several researchers have developed some alternative analytical frameworks to assess students' argumentation quality (Chang & Chiu, 2008; Kuhn, 1991; Lizotte et al., 2003; Zohar & Nemet, 2002) due to the aforementioned limitations of TAP.

Both the TAP-based levels and other alternative analytical frameworks were developed by considering the components that a high-quality argumentation should contain. Zohar and Nemet (2002) argued that a claim without any justification would not be considered as a valid argument. However, Osborne and colleagues (2004) emphasized that a claim is the simplest step to generate an argument, therefore it should be considered as an important component of a high-quality argument. Moreover, several researchers (Kuhn, 1991; Sadler & Donnelly, 2006; Sadler & Fowler, 2006) have considered justifications and rationale as indicators of high-quality arguments. Although TAP emphasizes the importance of data, warrant and backings for high-quality arguments, some researchers have preferred collapsing these components into one category called as "grounds" due to the unclear distinction between these components. In addition to claim and "grounds", Mason and Scirica (2006) emphasized the importance of counter-arguments as an indicator of high-quality argumentation by emphasizing that individuals should consider and evaluate alternatives as well as their own positions. In the literature, rebuttal has also been considered as an indicator of high-quality argumentation by several researchers (Irmak, 2021; Osborne et al., 2004; Ozturk & Yilmaz-Tuzun, 2017; Sadler & Donnelly, 2006). According to Kuhn (1991), generating rebuttal is "the most complex skill" since an individual generating rebuttal must "integrate an original and alternative theory, arguing that the original theory is more correct." (p. 145). Moreover, Perkins and colleagues (1983) pointed out that the ability to evaluate pros and cons of an argument was another indicator contributing high-quality argumentation.

Considering the criteria used in the studies to assess students' argumentation quality, it was revealed that there are some common components considered as indicators to refer high-quality argumentation, namely, claim (Osborne et al., 2004), justifications and grounds (Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Zohar & Nemet, 2002), counter-arguments (Kuhn, 1991; Voss & Means, 1991), and rebuttals (Kuhn, 1991; Osborne et al., 2004). In parallel to these components, Chang and Chiu (2008) developed Lakatos' Scientific Research Programmes as an alternative analytical framework to assess students' argumentation quality. According to the framework, (1) "making claims", (2) "providing supporting reasons", (3) "presenting counter-arguments", (4) "showing qualifiers" and (5) "evaluating arguments" are the five indicators of high-quality argumentation (p. 1756).

Lakatos' Scientific Research Programmes includes four connected components: Hard-Core (HC), Positive Heuristics (PH), Negative Heuristics (NH) and Protective Belt (PB). According to Chang and Chiu (2008), HC including individuals' claims and supporting reasons are located in the core of Lakatos' Scientific Research Programmes. NH protects the HC (i.e. one's the original theory) by generating counter-arguments or limitations, whereas PH protects the HC by presenting "qualifier showing the alternative line to inquiry". Finally, PB in which PH and NH embedded represents the evaluation skills of individuals. In the literature, several researchers (Chang & Chiu, 2008; Rundgren et al, 2016) adopted Lakatos' Scientific Research Programmes as an alternative analytical framework to assess students' argumentation quality. Since one of the purposes of the present study was to investigate middle school students' argumentation quality regarding different SSI in a more holistic way, the present study also adopted Lakatos' Scientific Research Programmes as an alternative analytical framework. Therefore, HC (claim and supporting reasons), PH (qualifiers), NH (counter-arguments and limitations), and PB (evaluation skills) were considered as indicators of high quality argumentation in the present study. One of the reasons behind the selection of this analytical framework was the ability to handle "indirect" points of view generated by the students to strengthen their arguments. Since this analytical framework considered

PH as a reflection of qualifiers, the indirect points of view generated by the students could be easily coded as “PH” even if they are not directly related to the original supporting reason (Chang & Chiu, 2008; Means & Voss, 1996).

When the literature focusing on the analytical frameworks to assess students’ informal reasoning modes and argumentation quality was examined, it was revealed that some of the analytical frameworks (Chang & Chiu, 2008; Erduran et al., 2004; Osborne et al., 2004) considered structure-based quality (i.e. the components of arguments), while some others (Christenson et al., 2012; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Wu & Tsai, 2007; Zohar & Nemet, 2002) considered content-based quality (i.e. integration of scientific knowledge and evaluating issues from multiple perspectives). Unless the researchers adopt some integrated frameworks such as the work of Wu and Tsai (2007), they are required to use two different analytical frameworks to develop better understanding in terms of both structure (quantity of components and complexity) and content of the argumentation. Therefore, in addition to the studies focusing on informal reasoning modes and argumentation quality separately, there are also some studies (Dawson & Venville, 2009; Dawson & Venville, 2013; Georgiou & Mavrikaki, 2013; Sadler & Zeidler, 2005b; Venville & Dawson, 2010) examining these constructs through the same data-set by using different analytical frameworks; one to investigate informal reasoning modes and another to assess argumentation quality. The reason behind adopting two different analytical frameworks is the effort to develop a good understanding regarding how individuals negotiate SSI in a more holistic way.

Similar to the purpose of researchers utilizing integrated frameworks to investigate individuals’ both the modes and quality of informal reasoning (Irmak, 2021; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007; Wu & Tsai, 2011), the present study also adopted two different analytical frameworks to provide deeper insights regarding students’ informal reasoning modes and argumentation quality across different SSI. Therefore, in the extent of the present study, the middle school students’ informal reasoning modes, in terms of the subject areas and KVP used, was analyzed through the SEE-SEP Model (Chang Rundgren & Rundgren, 2010), whereas their argumentation quality was analyzed through Lakatos' Scientific Research Programmes (Chang & Chiu, 2008). Adopting both of these analytical frameworks to analyze the students' performance was also supported by the literature (Christenson & Chang Rundgren, 2015). In their study to facilitate teachers' assessment of SSI argumentation, the researchers proposed a new assessment tool based on these frameworks focusing on both the structure and content of the students' argumentation. In the literature, both of these analytical frameworks were also used by the researchers (Es & Ozturk, 2021; Es & Varol, 2019), however the researchers selected single SSI (fishing ban a local issue; and nuclear power usage respectively) to examine students' informal reasoning modes and argumentation quality. Different from the aforementioned studies (Es & Ozturk, 2021; Es & Varol, 2019) focusing on single SSI, adopting both of these analytical frameworks to reveal students' informal reasoning modes and argumentation quality regarding multiple SSI is unique to the present study.

Moreover, when the literature focusing on how individuals go through the reasoning process and generate arguments while negotiating SSI was examined, it was revealed that most of the studies were conducted with pre-service teachers (Karisan & Cebesoy, 2021; Ozturk & Yilmaz-Tuzun, 2017; Topcu et al., 2010; Yilmaz-Tuzun & Topcu, 2013) and older students from colleges and undergraduate degrees (Chang & Chiu, 2008; Sadler & Zeidler, 2005b; Wu & Tsai, 2007). Since it was needed to focus on younger students for the further research studies (Topcu et al, 2014), the present study attempts to fill this gap in the literature by conducting the study with 7th and 8th grade middle school students. According to Atabey and Topcu (2020), investigating how younger students go through informal reasoning process provides students to be raised as active citizens who have the ability to negotiate and resolve controversial SSI from the early stages of their lives. Thus, this study may have a potential to achieve scientific literacy from the earlier ages through engaging students with complex dilemmas of SSI (Dawson & Venville, 2009; Venville & Dawson, 2010). The selection of these particular grade levels was also related to

Turkish middle school science curriculum (MoNE, 2018) since the SSI topics selected (SPE, GMO, NPP) for this study are covered in 7th and 8th grades.

1.4 Issue Familiarity, Informal Reasoning Modes and Argumentation Quality

The studies focusing on students' informal reasoning modes and argumentation quality across different SSI indicated that there is no consensus regarding the role of SSI context. In other words, some researchers stated that students' informal reasoning modes and argumentation quality might vary across different SSI (Baytelman et al., 2020; Irmak, 2021), whereas some of them indicated that SSI context had no influence on students' informal reasoning modes and argumentation quality (e.g., Topcu et al., 2010). Since there are some inconsistent findings regarding how SSI context influence students' informal reasoning modes and argumentation quality, the present study also addressed the role of SSI context in middle school students' informal reasoning modes and argumentation quality. Although there is no consensus in the literature regarding the role of SSI context, majority of the researchers in the field of science education agree that basic familiarity regarding an issue is needed for students to engage in argumentation (Garrecht et al., 2021; Lewis & Leach, 2006; Topcu et al., 2010). Therefore, in the present study, students' issue familiarity was also studied to investigate its relationships with informal reasoning modes and argumentation quality.

According to Garrecht and colleagues (2021), issue familiarity was regarded as "the knowledge about an issue, with greater familiarity enabling students to engage with the issue under debate to a greater extent" (p. 5). Moreover, individual factors (e.g. students' motivation to learn the related SSI) also influence students' effort to familiarize themselves regarding the issue under discussion (Garrecht et al., 2021). Similarly, Khishfe (2012b) indicated that prior content knowledge and personal relevance regarding an issue constituted students' issue familiarity. In another definition, Zhang and colleagues (2022) described the feeling of familiarity (FOF) as “FOF arises when the current task is closely tied to previous experiences or when participants attribute the fluency on the current task to prior experiences” (p. 4). In addition to these definitions, several researchers also indicated that individuals' familiarity regarding an issue might come from mass media such as newspaper, the Internet, television (TV), news, and advertisements (Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017). Considering these definitions, students' level of knowledge, level of interest, willingness for further studies (i.e. to learn; to read and research; to do project) and their sources of information (e.g. media, television, the Internet) regarding SSI were operationalized as issue familiarity in the present study.

In the field of science education, several researchers focusing on the role of SSI context indicated that familiarity contributes students' informal reasoning modes and argumentation quality (Capkinoglu et al., 2020; Garrecht et al., 2021; Khishfe, 2012b; Lewis & Leach, 2006). In their study, Garrecht and colleagues (2021) investigated how increased familiarity through an intervention influence students' (n=163) argumentation quality regarding animal testing. As a result of the intervention, it was revealed that increased issue familiarity improved students' diversity of discipline-related arguments although all disciplines were not improved equally. Similar to the findings of the previous study, Lewis and Leach (2006) indicated that when the students were familiar with the issue, they were able to generate more reasoned arguments. Moreover, the researchers also emphasized that students ignored the new issues when they were “outside of their experience and had little relevance to their immediate lives” (p. 1275). Similarly, Khishfe (2012b) also indicated that “students might better connect to the issue especially if it is more familiar and related to their everyday lives” (p. 492). In parallel to these findings, Capkinoglu and colleagues (2020) investigated 7th grade students' (n=36) argumentation quality regarding five local SSI, namely an artificial lake, chicken coops, leather tanneries, base stations, and hydroelectric power plants (HPP). Results showed that HPP topic was the most challenging SSI for all groups. That means, students were not able to generate high quality arguments regarding HPP. According to Capkinoglu and colleagues (2020), a possible reason behind the students' failure to generate high quality argument was that HPP may be the least attractive context among all SSI regardless of the learning group.

1.5 SSI and Epistemological Beliefs

Dealing with ill-structured problems (i.e. SSI) requires developing a position, providing justifications, considering multiple perspectives and evaluating alternatives (Angeli & Valanides, 2012; Voss & Means, 1991). Thus, negotiation and resolution of ill-structured problems require sophisticated epistemic beliefs (Kitchener, 1983; Schraw et al., 1995).

Epistemology is basically the branch of philosophy interested in "the nature and justification of human knowledge" (Hofer & Pintrich, 1997, p. 88). In this manner, personal epistemological beliefs can be defined as individuals' "beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (Hofer, 2002, p. 4). The history of epistemological beliefs mainly started with the longitudinal studies conducted by Perry (1968) and his work shed light on subsequent works focusing on individuals' epistemological beliefs.

The studies regarding the models of epistemological beliefs are categorized into two groups. The first group researchers (Baxter Magolda, 1992; Belenky et al., 1986; King & Kitchener, 1994; Kuhn, 1991; Perry, 1968) proposed developmental models including unidimensional beliefs. These models focusing on individuals' epistemological beliefs started with the work of Perry (1968), and continued with women's ways of knowing (Belenky et al., 1986), argumentative reasoning (Kuhn, 1991), epistemological reflection model (Baxter Magolda, 1992) and reflective judgment model (King & Kitchener, 1994). According to the first group of researchers, the model of epistemological beliefs has a stage-like structure. In other words, epistemological beliefs, as one general dimension, evolve through stages on a continuum (Hofer & Pintrich, 1997). Unlike the first group of researchers asserting that developmental models of unidimensional beliefs, the second group of researchers (Ozturk & Yilmaz-Tuzun, 2017; Schommer, 1990; Yilmaz-Tuzun & Topcu, 2010) proposed multidimensional models of independent beliefs. According to Schommer (1990), the model of epistemological beliefs can be described as "a belief system that is composed of several more or less independent dimensions" (p. 498) rather than one general dimension.

When the earlier studies focusing on individuals' epistemological beliefs were examined, it was revealed that most of them were conducted with late adolescents from undergraduate degrees and adults from different backgrounds. This tendency may be resulted from the assumption that epistemological beliefs of younger students was difficult to define (Kuhn, 1988). By considering the focus groups of these studies, it can be stated that there was a need to study with younger students. For this purpose, several researchers (Conley et al., 2004; Elder, 1999; Ozkan, 2008) investigated younger students' epistemological beliefs. In their study, Conley and colleagues (2004) developed an instrument called as *Epistemological Beliefs Questionnaire* to assess 5th grade students' (n=187) epistemological beliefs regarding four dimensions (i.e. source, certainty, development, and justification). These dimensions were developed based on the beliefs (beliefs about nature of knowledge and beliefs about nature of knowing) proposed by Hofer and Pintrich (1997). The dimensions of certainty and development were compatible with the beliefs about nature of knowledge, whereas the dimensions of source and justification were compatible with the beliefs about nature of knowing.

The studies focusing on younger students' epistemological beliefs in Turkish context revealed that many researchers (Aydin & Gecici, 2017; Boz et al., 2011; Kurt, 2009) used Epistemological Beliefs Questionnaire developed by Conley et al. (2004) and adapted into Turkish by Ozkan (2008) to investigate younger students' epistemological beliefs. Since one of the purposes of the present study was to investigate middle school students' epistemological beliefs, Epistemological Beliefs Questionnaire (EBQ) adapted into Turkish by Ozkan (2008) was also used in the extent of this study. The reason behind the selection of this instrument was that EBQ was more appropriate to be administered to younger students in terms of its structure and number of items. To clarify, since the number of items in the EBQ (n=26) was less than other epistemological beliefs instruments such as Schommer's Epistemological Beliefs Questionnaire (n=63), it was more appropriate to be completed in a limited time by younger students. When the literature focusing on individuals' epistemological beliefs was examined, it was also revealed that most of the studies conducted with pre-service teachers and older students (Saylan et al., 2016; Topkaya, 2015; Ozturk & Yilmaz-Tuzun, 2017; Yilmaz-Tuzun & Topcu, 2013) adopted Schommer's Epistemological Questionnaire (SEQ) to assess epistemological beliefs. Considering this trend, it can be inferred that Epistemological Beliefs Questionnaire (EBQ) developed by Conley et al. (2004) and adapted into Turkish by Ozkan (2008) was considered as more appropriate for younger students.

In the literature, several studies have addressed the relationship between epistemological beliefs, informal reasoning modes and argumentation quality in the context of SSI. When the related literature was examined, it was revealed that there are some conflicting evidences from the fields of psychology, science education, and business, although the existence of relationship was dominantly reported in the findings of the studies. Many of the studies revealed that individuals' epistemological beliefs may contribute their informal reasoning modes and argumentation quality (Baytelman et al., 2018; Baytelman et al., 2020; Bendixen et al., 1994; Bendixen et al., 1998; Liu et al., 2010; Mason & Scirica, 2006; Oztuna Kaplan & Cavus, 2016; Ozturk & Yilmaz-Tuzun, 2017; Schommer & Dunnell, 1997; Wu & Tsai, 2011), whereas some of the studies indicated that there is no systematic link between these constructs (Angeli & Valanides, 2012; Mintchik & Farmer, 2009; Topcu et al., 2011). Therefore, epistemological beliefs were considered as another predictor of middle school students' informal reasoning modes and argumentation quality in the extent of the present study.

1.6 Purpose of the Study

The purpose of the present study was two-fold. The first purpose was to describe the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality across different SSI, namely, space explorations (SPE), genetically modified organisms (GMO) and nuclear power plants (NPP). The second purpose of the present study was to investigate the relationships between the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality regarding three different SSI. More specifically, the present study investigated how well middle school students' epistemological beliefs and issue familiarity predict their informal reasoning modes and argumentation quality regarding the aforementioned SSI.

1.7 Research Questions (RQ)

The present study addressed the following research questions:

1. What are the middle school students' informal reasoning modes regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
2. What are the middle school students' argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
3. What are the middle school students' epistemological beliefs on the dimensions of source/certainty, development, and justification?
4. What are the middle school students' issue familiarity regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
5. What are the relationships between the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes and argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

Rationale:

The rationale for addressing the research questions presented above is the lack of consistent findings in the literature. Although most of the researchers (Baytelman et al., 2020; Christenson et al., 2012; Christenson et al., 2014; Irmak, 2021) emphasized that students' informal reasoning modes and argumentation quality might vary across different SSI, some of the researchers (Topcu et al., 2010) indicated that SSI context had no influence on informal reasoning modes and argumentation quality. Accordingly, the present study provided an empirical evidence regarding the role of SSI context, which is still an unclear matter under discussion (Garrecht et al., 2021).

Also, the role of issue familiarity on students' informal reasoning modes and argumentation quality has not been explicitly tested yet (Garrecht et al., 2021). Correspondingly, the students' issue familiarity was explicitly assessed through Issue Familiarity Form and regarded as one of the predictor of their informal reasoning modes and argumentation quality.

Moreover, many of the researchers in the literature indicated that individuals' epistemological beliefs contribute their informal reasoning modes or argumentation quality (Baytelman et al., 2018; Baytelman et al., 2020; Bendixen et al., 1994; Bendixen et al., 1998; Liu et al., 2010; Mason & Scirica, 2006; Oztuna Kaplan & Cavus, 2016; Ozturk & Yilmaz-Tuzun, 2017; Schommer & Dunnell, 1997; Wu & Tsai, 2011), whereas some of the studies reported that there is no systematic link between these constructs (Angeli & Valanides, 2012; Mintchik & Farmer, 2009; Topcu et al., 2011). Correspondingly, the students' epistemological beliefs were regarded as another predictor of their informal reasoning modes and argumentation quality.

1.8 Significance of the Study

When the literature regarding SSI contexts was examined, it was revealed that most of the studies focusing on individuals' informal reasoning modes and argumentation quality have addressed some limited subjects such as genetic engineering (Georgiou & Mavrikaki, 2013; Sadler & Fowler, 2006; Sadler & Zeidler, 2005a) and nuclear power plants (Demircioglu & Ucar, 2014; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007; Yang & Anderson, 2003). With a few exceptions (Lee & Yang, 2019; Zhang et al., 2017), space explorations topic has not been frequently used as SSI context by the researchers. Therefore, in addition to SSI frequently used by the researchers (e.g. genetically modified organisms and nuclear power plants), the present study also addressed space explorations, which has been rarely used in the studies as SSI context. Moreover, since the last revision of Turkish middle school science curriculum (MoNE, 2018), space-related topics (e.g. Solar System, planets, eclipses, space explorations, etc.) have started to be covered in the first unit of each grade level. Both the alignment with Turkish middle school science curriculum (MoNE, 2018) and the special interest of students stimulated the selection of space explorations as SSI context.

With the addition of space explorations, the present study has addressed three different SSI from three different content areas in Turkish middle school science curriculum (i.e. SPE from Earth Science, GMO from Biology, and NPP from Physics) to reveal middle school students' informal reasoning modes and argumentation quality. Although all of the SSI selected for this study were interdisciplinary and included multiple perspectives, their main disciplines were different from each other.

In the literature, some of the studies focusing on the role of SSI context indicated that students' informal reasoning modes and argumentation quality might vary across different SSI (Baytelman et al., 2020; Irmak, 2021), whereas some of the studies indicated that SSI context had no influence on students' informal reasoning modes and argumentation quality (Topcu et al., 2010). In other words, there is an inconsistency between the findings of the studies regarding whether students' informal reasoning modes and argumentation quality are context-dependent or not. In this manner, the role of SSI context in students' informal reasoning modes and argumentation quality is still an unclear matter under discussion (Garrecht et al., 2021). Therefore, addressing three different SSI from different content areas (i.e. different disciplines) provides a detailed information regarding how the middle school students' informal reasoning modes and argumentation quality vary across different SSI.

Also, selecting space explorations as SSI context has the potential to make a unique contribution to the literature by providing researchers to understand the role of SSI context in students' informal reasoning modes and argumentation quality better. Moreover, selecting SSI contexts that students are more familiar with also provides to obtain detailed information regarding how issue familiarity is related to students' informal reasoning modes and argumentation quality.

Although there is a consensus within majority of the researchers in the field of science education that basic familiarity regarding an issue is needed for students to engage in argumentation (Garrecht et al., 2021; Lewis & Leach, 2006; Topcu et al., 2010), the role of issue familiarity in students' informal reasoning modes and argumentation quality has not been explicitly tested. Also, Garrecht and colleagues (2021) emphasized that "the question of whether increased issue familiarity affects the diversity of discipline-related arguments that are employed remains unanswered" (pp. 5-6). Considering this gap, Garrecht and colleagues (2021) investigated whether 9th and 10th grade students' (n=163) argumentation quality regarding animal testing improved or not with an additional familiarization intervention. As a result of the intervention, it was revealed that increased issue familiarity improved students' diversity of discipline-related arguments although all disciplines were not improved equally. In their study, since the increased number of arguments was considered as increased issue familiarity, students' familiarity regarding animal testing was not explicitly tested. Also, Garrecht and colleagues (2021) studied with one SSI and called the researchers to "examine the effect of issue familiarity on students' multidisciplinary argumentation across varying issues including issues that are cognitively more demanding" (p. 18). Therefore, in order to fill this gap and provide a better understanding regarding the role of SSI contexts, students' issue familiarity was explicitly obtained through Issue Familiarity Form and used as a predictor of middle school students' informal reasoning modes and argumentation quality regarding three different SSI, namely, SPE, GMO, and NPP.

Another significance of the present study is the usage of two different analytical frameworks to develop an understanding regarding how individuals negotiate SSI in a more holistic way. According to Garrecht and colleagues (2021), "the ethical and factual complexity of SSI might become lost when relying solely on such structure-focused schemes" (p. 5). Therefore, similar to the purpose of researchers utilizing integrated frameworks to investigate individuals' both the modes and quality of informal reasoning (Irmak, 2021; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2007; Wu & Tsai, 2011), two different analytical frameworks were used to analyze students' informal reasoning modes and argumentation quality. More specifically, the middle school students' informal reasoning modes, in terms of the subject areas and KVP used, was analyzed through SEE-SEP Model (Chang Rundgren & Rundgren, 2010), whereas their argumentation quality was analyzed through Lakatos' Scientific Research Programmes (Chang & Chiu, 2008). Adopting both of these analytical frameworks to provide deeper insights regarding students' informal reasoning modes and argumentation quality was also supported by the literature (Christenson & Chang Rundgren, 2015; Es & Ozturk, 2021; Es & Varol, 2019). In the literature, both of these analytical frameworks were also used by the researchers (Es & Ozturk, 2021; Es & Varol, 2019), however the researchers selected single SSI (fishing ban a local issue; and nuclear power usage respectively). Different from these studies focusing on single SSI, adopting both of these analytical frameworks to reveal students' informal reasoning modes and argumentation quality regarding multiple SSI is unique to the present study.

Since raising scientific literate individuals is one of the main goals set by Turkish middle school science curriculum (MoNE, 2018), investigating the relationship between epistemological beliefs, informal reasoning modes and argumentation quality regarding different SSI has also potential to provide empirical evidence regarding how the science education provides students to achieve scientific literacy. In the light of the fact that epistemological beliefs, informal reasoning modes and argumentation quality contribute to scientific literacy, the possible relationship between them might be also useful in improving the quality of the science curriculum. Both teachers and curriculum developers may utilize the findings of the present study to improve students' epistemological beliefs as well as informal reasoning modes and argumentation quality. In this sense, science teachers and curriculum developers may comprehend that how epistemological beliefs can be used to enable students to consider multiple perspectives and generate qualified arguments. In this way, the students whose epistemological beliefs are improved may tend to be more competent while negotiating and resolving complex SSI by considering multiple perspectives and generating high-quality arguments.

1.9 Definition of the Important Terms

In this section of the present study, important terms (i.e. scientific literacy, socioscientific issue, informal reasoning, informal reasoning modes, argument, argumentation quality, issue familiarity, and epistemological beliefs) are operationally defined.

1.9.1 Scientific Literacy

Scientific literacy (SL) is one of the most important goals in the science education. Extending Vision II scientific literacy (Roberts, 2007), Zeidler and his colleagues (Zeidler, 2014; Zeidler & Lewis, 2003; Zeidler et al., 2005) proposed the functional scientific literacy framework, which is vital to complete the vision of scientific literacy. According to Zeidler (2014), functional scientific literacy "necessarily includes the evaluation of moral and ethical factors in making judgments about both the validity and viability of situated scientific data and information relevant to the quality of public and environmental health" (p. 697). Therefore, in the extent of the present study, functional scientific literacy, as an extension of Vision II scientific literacy, was adopted in order to ground the theoretical frameworks (i.e.

socioscientific issues, informal reasoning, argumentation and epistemological beliefs) of the present study.

1.9.2 Socioscientific Issue

Socioscientific issues are “complex, open-ended, often contentious dilemmas, with no definitive answers” (Sadler, 2004, p. 514). In the extent of the present study, space explorations (SPE), genetically modified organisms (GMO), and nuclear power plants (NPP) were selected as SSI contexts.

1.9.3 Informal Reasoning

According to Zohar and Nemet (2002), “it [informal reasoning] involves reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of particular propositions or decision alternatives” (p. 38). Additionally, “informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions” (Sadler, 2004, p. 514).

1.9.4 Informal Reasoning Modes

Since the present study adopted SEE-SEP Model as an analytical framework (Chang Rundgren & Rundgren, 2010), middle school students’ informal reasoning modes were analyzed based on the subject areas (sociology/culture, environment, economy, science, ethics/morality, policy) and accompanying aspects, namely, knowledge, value, personal experience (KVP). Moreover, the present study focused on the students’ ability to negotiate complex SSI from multiple perspectives.

1.9.5 Argument

According to Erduran and Jiménez-Aleixandre (2007), an argument can be differentiated into two forms: individualistic and social. While the individualistic form of an argument means the expression or articulation of any reasoned viewpoint by an individual, social form of an argument means a discussion between at least two individuals with a purpose of persuading. Since the participants of the present study were expected to express their arguments in a written way without any discussion environment, the individualistic form of the argument was adopted in the extent of the present study.

1.9.6 Argumentation Quality

Since the present study adopted Lakatos' Scientific Research Programmes as an analytical framework (Chang & Chiu, 2008), middle school students argumentation quality was analyzed based on HC (Hard Core), PH (Positive Heuristics), NH (Negative Heuristics), and PB (Protective Belt). Therefore, the present study focused on the structure and number of components (i.e. claim, supporting reasons, qualifiers, counter-arguments and/or limitations) generated by the middle school students. In other words, argumentation quality for the present study refers to generating more components as the present study focused on structure and complexity of arguments.

1.9.7 Issue Familiarity

In the extent of the present study, issue familiarity was defined as students' level of knowledge, level of interest, willingness to learn; read and research; and do project (Garrecht et al., 2021), and sources of information, namely, family, friends, teacher, textbooks, social media (Facebook, Twitter, Instagram, Youtube, etc.), newpapers and journals, television, students' own observations and experiences (Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017). The middle school students' issue familiarity was based on the scores obtained through Issue Familiarity Form.

1.9.8 Epistemological Beliefs

Epistemological beliefs are "beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs" (Hofer, 2002, p. 4). More specifically, epistemological beliefs are "beliefs about nature of knowledge" (i.e. certainty and development dimensions) and "beliefs about nature of knowing" (i.e. source and justification dimensions) (Hofer & Pintrich; 1997).

CHAPTER 2

LITERATURE REVIEW

In this chapter, theoretical link between scientific literacy and SSI; SSI and informal reasoning; informal reasoning and argumentation; epistemological beliefs and SSI are presented respectively. Also, the studies focusing on the relationships between epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality in the context of SSI are summarized.

2.1 Theoretical Link Between Scientific Literacy and SSI

The term scientific literacy is actually based on the Sputnik 1, the first artificial satellite, launched by the Soviet Union in 1957 (Hurd, 1958). This occurrence stimulated some initiatives including educational plans, projects and movements to enhance the science education in the United States so that students will be able to cope with the modern world where scientific and technological developments rapidly increase (Herold, 1974; Hurd, 1958). In parallel with this purpose, STS (Science-Technology-Society) movement was one of the famous attempts to enhance the science education (Zeidler et al., 2005). Basically, STS approach emphasizes not only science content but also technological and societal contexts where the science content can be integrated. However, it was criticized due to the lack of psychological or developmental aspects such as epistemological beliefs, moral and character development, etc. Although STSE (Science-Technology-Society-Environment) approach was another important attempt to eliminate the limitations of STS, it had still some limitations. STSE approach was also criticized due to the lack of theoretical basis and not directly focusing on students' moral and ethical development. Nevertheless, both STS and STSE approaches have significantly contributed to the science education. In addition to these movements, Project 2061 was also another attempt to enhance the education in the United States. In the extent of Project 2061, Frank (1989) reported that "To ensure the scientific literacy of all students, curricula must be changed …" (p. 248). Although the importance of scientific literacy has remained over many years, its definition has been changed many times. In contrast to earlier definitions focusing on only scientific processes and products, recent definitions of scientific literacy also focus on societal aspects as well as scientific concepts and principles. In parallel to this shift, several researchers and educators (Holbrook & Rannikmae, 2009; Hurd, 1998; Roberts, 2007) presented some basic characteristics of a scientific literate person. For example, a scientifically literate person:

> • knows that science in social contexts often has dimensions in political, judicial, ethical, and sometimes moral interpretations,
>
> • uses science knowledge where appropriate in making life and social decisions, forming judgments, resolving problems, and taking action,
>
> • knows that science problems in personal and social contexts may have more than one 'right' answer, especially problems that involve ethical, judicial, and political actions,
>
> • recognizes when cultural, ethical, and moral issues are involved in resolving science-social problems (Hurd, 1998, pp. 413-414).

Similarly, Holbrook and Rannikmae (2009) stated that the following characteristics are required as well as the intellectual capabilities for a scientific literate person;

> • weighs the benefits/burdens of scientific and technological development,
>
> • engages in responsible personal and civic actions after weighing the possible consequences of alternative options,
>
> • considers the political, economic, moral and ethical aspects of science and technology as they relate to personal and global issues. (Holbrook & Rannikmae, 2009, p. 277).

In addition to these definitions, Roberts (2007) adopted a more holistic approach and differentiated scientific literacy as Vision I and Vision II. While Vision I focuses only the scientific context such as processes and principles, Vision II focuses not only the scientific context but also the authentic context including societal, ethical and political issues (Presley et al., 2013). In parallel with Vision II scientific literacy, Erduran and Jiménez-Aleixandre (2007) expressed that the goal of current science education is providing students to comprehend the societal issues as well as the scientific concepts. When the aforementioned definitions were examined, it was revealed that scientific literacy, contrast to science literacy, is not only having content knowledge but also using this knowledge in the processes regarding personal and societal issues (Lederman et al., 2014). Therefore, creating opportunities for students to comprehend both social issues and underlying scientific and technological principles is essential to achieve scientific literacy.

Extending Vision II scientific literacy, Zeidler and his colleagues (Zeidler, 2014; Zeidler & Lewis, 2003; Zeidler et al., 2005) proposed the functional scientific literacy framework, which is vital to complete the vision of scientific literacy. According to Zeidler (2014), functional scientific literacy "necessarily includes the evaluation of moral and ethical factors in making judgments about both the validity and viability of situated scientific data and information relevant to the quality of public and environmental health" (p. 697). In other words, functional view of scientific literacy would be incomplete without the consideration of moral and ethical aspects underlying the complex socioscientific issues (SSI). For instance, Zeidler and Lewis (2003) indicated that an individual, even who have sufficient content knowledge, understandings of NOS and inquiry, will be inadequate to understand global warming unless he/she considers the underlying moral and ethical aspects of the issue (e.g. intergenerational justice).

Although the components of scientific literacy have been changed over time, one of the main goals for modern science education is providing students to acquire the ability to cope with these SSI including moral and ethical aspects (Sadler, 2004; Wu & Tsai, 2011). Chang Rundgren and Rundgren (2010) also supported the assertion that SSI are vital to achieve scientific literacy by figuring out the relationship between scientific literacy and SSI. Similar to the previous definitions of scientific literacy (Millar & Osborne, 1998; Miller, 1983), Chang Rundgren and Rundgren (2010) also included good understandings of (a) nature of science (NOS), (b) the relationship between science, technology and society (STS), and (c) scientific concepts and terms in the definition of scientific literacy. As it can be seen from the Figure 2.1, since SSI provide an ideal context for students to acquire these components, integration of SSI into school education is vital to achieve scientific literacy.

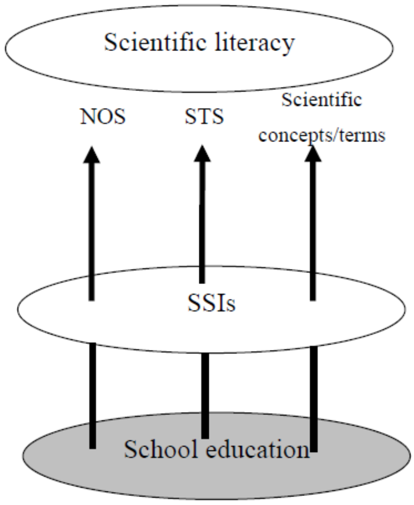

Figure 2.1 The relationship between school education, SSI and scientific literacy. Adopted from "SEE-SEP: From a separate to a holistic view of socioscientific issues" by S. N. Chang-Rundgren and C. J. Rundgren, 2010, Asia-Pacific Forum on Science Learning and Teaching, 11(1), p.7.

SSI are social dilemmas with a conceptual or technological linkage to the science (Sadler, 2002; 2004). Moreover, they are "complex, open-ended, often contentious dilemmas, with no definitive answers" (Sadler, 2004, p. 514), and generally tend to be "controversial; multi-faceted; subject to multiple, sometimes, contradictory perspectives; and connected to scientific concepts" (Herman et al., 2018, p. 146). In the extent of Vision II scientific literacy (Roberts, 2007), using SSI in the science instruction can considerably provide students to acquire understandings and skills regarding the scientific practices such as reasoning, argumentation and decision-making (Presley et al., 2013) on the societal issues including moral, ethical, economic, political aspects and so on. In this manner, the literature generally presents some multidimensional topics that include both scientific-technological and moral-ethical aspects such as biotechnological applications (stem cells, cloning, gene therapy and genetically modified organisms), global warming, climate change, nuclear power plants and some other environmental issues in both local and global contexts (Sadler, 2004; Sadler & Zeidler, 2004; Hou & Wang, 2015; Jho et al., 2014; Liu et al., 2010). Since one of the most fundamental goals for science education is to ensure the scientific literacy for all students; and SSI-based practices (e.g. reasoning, argumentation and decision-making) are the vital parts to achieve this goal, it is important to comprehend how SSI are negotiated and resolved by the individuals (Sadler & Zeidler, 2005a; Topcu et al., 2011).

2.2 Theoretical Link Between SSI and Informal Reasoning

In order to comprehend the link between SSI and informal reasoning better, it is needed to differentiate informal reasoning from formal reasoning. For a very long time, until almost the twentieth century, formal reasoning had been considered as the ideal way of thinking by several philosophers such as Socrates, Plato and Aristotle (Chang & Chiu, 2008). The first difference between formal and informal reasoning is resulted from the bases underlying these two constructs. Formal reasoning is based on some rules of logic and mathematics (Sadler, 2003), whereas informal reasoning is based on individuals' personal knowledge, values, beliefs and attitudes (Means & Voss, 1996) and tends to include premises from multiple sources such as everyday experiences, textbooks, mass-media, television broadcastings, the Internet, newspapers and so on (Chang & Chiu, 2008). Secondly, one of the main differences between formal and informal reasoning is related to the structure of premises. In formal reasoning, the premises constitute fixed and unchanging argument structures like syllogisms in which the modifications of content are not allowed. On the contrary, in informal reasoning, the premises may change when the individuals obtain additional information from the aforementioned different sources. Thirdly, formal reasoning possesses a linear structure by nature, while informal reasoning has tree-like structure including several branches that represent the individuals' everyday life better (Chang & Chiu, 2008). In this respect, informal reasoning requires a thinking process and evaluation regarding the different dimensions of the related issue (Means & Voss, 1996; Sadler & Zeidler, 2005a), and this evaluation may change with respect to the individuals' beliefs about the related context. Considering all of these differences, it can be concluded that one can solve a problem that requires formal reasoning by only following some logical steps, whereas the same person may not solve a complex SSI by doing like that. Zohar and Nemet (2002) also explained the informal reasoning with the following statement: "It [informal reasoning] involves reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of particular propositions or decision alternatives" (p. 38).

When there is no easily accessible information or especially when the related issues are controversial, ill-structured and open to multiple solutions, individuals utilize informal reasoning process to generate a position regarding the complex issues because "informal reasoning involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions" (Sadler, 2004, p. 514).

In the light of this differentiation between formal and informal reasoning, it can be understood that negotiation of socio-scientific issues can be associated with informal reasoning process. Since SSI are complex, open-ended, ill-structured and do not have clear-cut solutions, informal reasoning is more appropriate than formal reasoning while negotiating SSI (Sadler, 2004). In other words, individuals tend to go through informal reasoning process while they are developing a position or deciding on complex and ill-structured issues since SSI provide a good context for individuals to reveal their informal reasoning (Fowler & Zeidler, 2010). By nature, informal reasoning includes both cognitive and affective processes regarding SSI (Dawson & Venville, 2009). Therefore, individuals generally negotiate the related SSI by obtaining information from multiple sources including knowledge, values, beliefs, personal experiences and so on (Chang Rundgren, 2011) and this is consistent with the nature of SSI including several dimensions such as political, social, environmental, economic, ethical and even moral.

During the last two decades, several researchers have studied on how individuals go through informal reasoning process while negotiating SSI (Liu et al., 2010; Patronis et al., 1999; Sadler & Zeidler, 2005a; Wu & Tsai, 2007; Yang & Anderson, 2003). In their study, Sadler & Zeidler (2005a) investigated college students' informal reasoning patterns by using six different SSI regarding biotechnology (i.e. gene therapy and cloning scenarios). After the analyses, they differentiated the college students' informal reasoning into three patterns: rationalistic, emotive and intuitive. The students who exhibited rationalistic pattern in their informal reasoning generated arguments based solely on reasons and logic as a reflection of cognitive considerations (reason-based considerations). In the emotive pattern, students relied on emotions, namely sympathy and empathy, in their informal reasoning to negotiate SSI. In other words, the students who exhibited emotive pattern (care-based considerations) in their informal reasoning consider others (e.g. other people, other livings) that may be affected by the resolution of related SSI. Finally, the students who displayed intuitive informal reasoning pattern generated arguments based on their immediate reactions without providing any ground behind their decisions. As a result of the analyses, it was revealed that students frequently used multiple patterns while negotiating SSI.

Both in national and international contexts, several researchers have adopted the rationalistic, emotive and intuitive patterns in order to reveal the students' informal reasoning (Atabey & Topcu, 2020; Georgiou & Mavrikaki, 2013; Ozden, 2020). In their study, Atabey and Topcu (2020) investigated 8^{th} grade students' (n=104) informal reasoning by utilizing three patterns proposed by Sadler and Zeidler (2005a). After data were collected through an environmental SSI and related questions, it was revealed that students mostly used rationalistic pattern (51.9%) in their informal reasoning; followed by rationalistic-emotive (25.0%); rationalistic-intuitive (9.6%) and emotive (9.6%); and rationalistic-emotive-intuitive (2.9%); while emotive-intuitive (1.0%) was the least used pattern in the students' informal reasoning. In other words, rationalistic pattern mostly dominated the students' informal reasoning regarding the environmental SSI. In contrast to the study conducted by Atabey and Topcu (2020), Georgiou and Mavrikaki (2013) concluded that 10th grade Greek students mostly used intuitive; followed by emotive pattern; and only a few students displayed rationalistic pattern in their informal reasoning regarding biotechnology-related issues. In another study focusing on the elementary students' (n=19) informal reasoning regarding organ transplantation, recycling and use of forest areas, Ozden (2020) collected data through semi-structured interviews and analyzed them adopting logical, emotional and intuitive reasoning patterns developed by the researcher through thematic analysis. In similar to the study conducted by Georgiou and Mavrikaki (2013), it was revealed that the most frequently used pattern by the elementary students was intuitive; followed by emotional; while the least used pattern was logical.

Different from the previous denotation, the patterns proposed by Sadler and Zeidler (2005a), some researchers have preferred using the term "modes" to refer the different viewpoints in students' informal reasoning (Liu et al., 2010; Patronis et al., 1999; Wu & Tsai, 2007; Yang & Anderson, 2003). For instance, Patronis and colleagues (1999) conducted a study with 14 year-old students in order to reveal their informal reasoning modes regarding a new road construction near the school area. After the analyses, it was revealed that there are four different modes, namely social, ecological, economic and practical. These modes generally indicated some pairs of opposite values: "development versus conservation of natural environment, society versus nature, money versus human values, personal happiness versus benefit for all" (p. 748). Especially in the first part of the study, it was revealed that students mostly used these modes that reflect their personal values and general values adopted in the society where they live. Yang and Anderson (2003) were also other researchers who preferred using "modes" to refer the informal reasoning of high school students regarding the nuclear power plants in Taiwan. They differentiated the students' informal reasoning into three modes as socially-oriented, scientifically-oriented and equally disposed. While the socially-oriented students mostly preferred the social type of information, scientifically-oriented students mostly preferred scientific type of information. Besides, the equally disposed students used the combination of both social and scientific types of information. Moreover, the researchers stated that integrated reasoning patterns were considerably appeared on the students' arguments. Similarly, Wu and Tsai (2007) conducted a study with high school students (n=71) in order to reveal their informal reasoning regarding nuclear energy usage. Although they utilized a more holistic way including qualitative and quantitative measures to reveal the students' informal reasoning regarding nuclear energy usage, basically four different modes were revealed as a result of the study: social-oriented, ecological-oriented, economic-oriented, and scientific & technological-oriented. After the analyses, it was revealed that 10^{th} grade students mostly generated ecological oriented arguments (M=1.13, SD=0.91); followed by economic-oriented arguments (M=1.04, SD=0.62) and scientific & technological-oriented arguments (M=0.76, SD=1.09). The least used mode by the students was social-oriented arguments (M=0.21, SD=0.48). When the total number of modes used by the students was examined, it was revealed that students were able to reason from multiple perspectives with a mean score of 2.27 (SD=0.77). In contrast to this finding, Hogan (2002) indicated that eight grade students could not evaluate the issue from multiple perspectives and tended to consider only one aspect of the issue while negotiating an environmental SSI both individually and in small group discussions. The reason behind these inconsistent findings may be based on the difference in the sample studied and complex SSI covered in the extent of these studies.

Like the patterns of informal reasoning offered by Sadler and Zeidler (2005a), the modes of informal reasoning proposed by Wu and Tsai (2007) have been used by several researchers (Demircioglu & Ucar, 2014; Namdar et al., 2020; Ozturk & Yilmaz-Tuzun, 2017; Yapicioglu & Aycan, 2018). In their study, Demircioglu and Ucar (2014) investigated undergraduate students' (n=38) informal reasoning regarding Akkuyu Nuclear Power Plant in Turkey and four informal reasoning modes were used to analyze students' responses: ecological, economic, scientific-technological and social modes. In parallel to the findings of the study conducted by Wu & Tsai (2007), undergraduate students' usage of scientific & technological-oriented and social-oriented modes was not common in their reasoning. Wu and Tsai (2007) explained that the possible reason why the college students mostly use ecologic-oriented mode in their arguments regarding nuclear power usage may be the ecologic-oriented nature of the related SSI.

In another study referring informal reasoning as "modes", Liu and colleagues (2010) investigated the college students' (n=177) informal reasoning about the introduction of an invasive species and revealed four different informal reasoning modes: ecological, ethical & aesthetic, scientific & technological, and social & economic. Analyses showed that the students' informal reasoning is mostly based on ecological mode (53.1%); followed by scientific & technological mode (52.5%) and social & economic mode (31.6%); while the least used mode was ethical & aesthetic (24.9%). In contrast to the study conducted by Wu & Tsai (2007), most of the college students (54.2%) were able to generate only one mode in their reasoning. In other words, college students in this study could not reason from multiple perspectives, therefore it can be concluded that they did not have interdisciplinary approach regarding the related SSI. The informal reasoning modes used in the previous studies were summarized in Table 2.1.

Table 2.1 Informal Reasoning Modes Used in the Previous Studies

Researchers	Informal Reasoning Modes
Patronis et al. (1999)	social, ecological, economic, and practical
Yang & Anderson (2003)	socially-oriented, scientifically-oriented, and equally disposed
Wu & Tsai (2007)	social-oriented, ecological-oriented, economic-oriented, and scientific & technological-oriented
Liu et al. (2010)	ecological, ethical & aesthetic, scientific & technological, and social & economic

2.2.1 SEE-SEP Model

The literature focusing on individuals' informal reasoning modes in the negotiation and resolution of complex SSI showed that several researchers (Liu et al., 2010; Patronis et al., 1999; Wu & Tsai, 2007; Yang & Anderson, 2003) emphasized the cross-disciplinary nature of SSI. In other words, most of the studies indicated that negotiation of SSI includes several perspectives such as ecological, scientific, economic, ethical, political and so on. Moreover, Sadler and his colleagues (2007) presented four important features of socioscientific reasoning (SSR) emerged from individuals' decision making on SSI: complexity, multiple perspectives, ongoing inquiry, and scepticism. In order to integrate these cross-disciplinary findings of several studies and the features of SSR, Chang Rundgren and Rundgren (2010) developed SEE-SEP Model as a holistic viewpoint for the multidimensional nature of SSI. The model includes six subject areas (i.e. sociology/culture, environment, economy, science, ethics/morality and policy) and accompanying three aspects (i.e. knowledge, value and personal experience).

Sociology/culture refers to the arguments based on the welfare of the society and development of the country, whereas environment focuses on ecology, nature, and welfare of non-human livings. Also, economy refers to the arguments based on financial conditions, cost, and foreign source (external) dependency, whereas science focuses on the characteristics of science, scientific knowledge, and scientists. Moreover, ethics/morality concerns with the rights of living things and next generations, whereas policy focuses on the governmental issues (e.g. conventions and wars).

In addition to these subject areas, Chang Rundgren and Rundgren (2010) also integrated the aspects of knowledge, value, and personal experience into the extent of SEE-SEP Model to investigate how individuals support their claims and justify their positions while making decisions regarding both local and global issues. The aspect of knowledge refers to the arguments including concepts and theories regarding a specific subject area, whereas the aspect of value refers to the arguments including value, affection, and attitude regarding a specific subject area. The aspect of personal experience refers to the arguments in which individuals provide personal experiences from their lives.

When the literature focusing on individuals' informal reasoning was examined, it was revealed that several researchers investigated how individuals use knowledge, value, and personal experience to justify their positions in the context of SSI. While some of the researchers (Nielsen, 2012b; Sadler & Zeidler, 2005b) emphasized the importance of content knowledge on students' informal reasoning, some of them (Albe, 2008; Lee, 2007) asserted that values and beliefs were closely related to individuals' decisions on SSI. Another group of researchers (Atasoy et al., 2019; Fleming, 1986; Patronis et al., 1999; Sadler & Zeidler, 2004; Zeidler & Schafer, 1984) indicated that personal experience also frequently used by individuals while making decisions on SSI. In this section, knowledge, value and personal experience, the components of SEE-SEP Model, are presented respectively.

2.2.1.1 Knowledge

From the perspective of science teachers and educational practitioners, enabling students to use content knowledge that they have learnt from the school science in the contexts beyond the classroom is one of the main goals of science education. In other words, students are expected to transfer their learning to new situations and different contexts (Haskell, 2001; Sadler & Donnelly, 2006). For example, students are expected to apply energy concepts while engaging a debate regarding the nuclear power usage. Similarly, they should utilize what they have learnt from the biology courses while generating an argument regarding a biotechnology-related SSI. In parallel to this aim, several studies in the literature have focused on how and to what extent individuals use content knowledge in their informal reasoning and arguments regarding different SSI (Albe, 2008; Nielsen, 2012b; Sadler & Zeidler, 2004; Wu & Tsai, 2007). However, the literature presents some divergent information regarding students' ability to use their content knowledge in the SSI contexts. Some of the studies indicate that students were able to use the related science content knowledge in different SSI contexts (Nielsen, 2012b; Sadler & Zeidler, 2005b), whereas some of them concluded that students could not adequately use the science content knowledge in SSI discussions (Albe, 2008; Zohar & Nemet, 2002). In the extent of the study, Nielsen (2012b) formed eight SSI group discussions regarding gene therapy and the students whose ages vary from 16 to 19 were expected to engage discussions. Analyses revealed that the students were able to use science content knowledge in creative and selective ways in order to emphasize the specific aspects of gene therapy. Similarly, Sadler and Zeidler (2005b) conducted a study with undergraduate students in order to explore the relationship between the students' understandings of genetics concept and their informal reasoning quality. For this purpose, they differentiated two levels of students (n=15 for each group) with respect to their understandings of genetics. Analyses indicated a parallelism between the students' understanding of genetics concepts and their informal reasoning. In other words, the students whose genetics-related understandings were more developed reflected science content knowledge on their informal reasoning more than the students whose genetic-related understandings were less developed did. In contrast to these findings, Zohar and Nemet (2002) examined the effects of explicit argumentation instruction on 9^{th} grade students' (n=99 for the experimental group; n=87 for the comparison group) content knowledge regarding human genetics. Although the students' usage of content knowledge increased after the intervention, their pre-test results showed that they could not use their content knowledge in the human genetics-related SSI context. According to pre-test result, 32.4% of the students did not use biological content knowledge in their arguments. 27.0% of them used non-specific biological content knowledge, whereas 24.3% of them used specific but incorrect biological content knowledge, and only 16.2% of the students were able to use specific and correct biological content knowledge in their arguments (Zohar & Nemet, 2002). From this empirical evidence, it can be inferred that students initially had difficulty to use their content knowledge in the SSI context.

One possible explanation for these divergent findings can be made by "Threshold Model of Content Knowledge Transfer" (Sadler & Donnelly, 2006; Sadler & Fowler, 2006). In their study, Sadler and Fowler (2006) investigated to what extent individuals use scientific content knowledge to justify their positions regarding three genetic engineering scenarios. For this purpose, they interviewed with 45 participants including 15 high school students who have diverse content knowledge on genetics; 15 science-major undergraduate students who have advanced-level content knowledge on genetics; and 15 non-science major undergraduate students who have low-level content knowledge on genetics. After the analyses, it was revealed that science major students who have advanced genetics knowledge displayed high quality of informal reasoning because of the usage of content knowledge, whereas high school students could not reach the threshold and demonstrated low quality of informal reasoning. From this empirical evidence, it is possible that students may not transfer their content knowledge because of their low-level (i.e. under the knowledge threshold) content knowledge.

2.2.1.2 Value

In addition to the researchers emphasizing the importance of content knowledge on students' informal reasoning (Nielsen, 2012b; Sadler & Zeidler, 2005b), another group of researchers asserted that values and beliefs were closely related the individuals' decisions on SSI. When the literature focusing on individuals' informal reasoning was examined, it was also revealed that individuals tend to make their decisions based on their values rather than knowledge alone, especially when the problem is not well-structured (i.e. ill-structured) and evidences are not easily accessible (Albe, 2008). In the study, Albe (2008) investigated the students' opinions regarding whether the mobile phones are harmful or not as SSI context. Related analysis indicated that students' positions were primarily derived from their values and personal experiences while scientific and technological knowledge was rarely used by the students. It was concluded that students mostly use their personal experiences, values and beliefs when there is no scientific consensus on the issue (i.e. the impacts of mobile phones on health). Similarly, Lee (2007) studied on the informal reasoning of the students whose ages vary from 14 to 16 and adopted the smoking issue as SSI. Analyses revealed that values and attitudes considerably appeared on the students' arguments.

When the studies presented so far are examined, it can be seen that both knowledge and value are occasionally used by the students. In the literature, there are also some studies in which the students used both the aspects of knowledge and value together (Grace & Ratcliffe, 2002; Kolstø, 2006; Sadler & Zeidler, 2005a). In their study, Grace and Ratcliffe (2002) conducted a study examining the 15-16 year-old pupils' informal reasoning regarding the biological conservation scenarios. After the audio-taped discussions were analyzed, it was revealed that the pupils utilized several biological concepts as scientific information, but their usage of values was dominant over the usage of content knowledge. In parallel to the co-dominance of knowledge and value aspects, Sadler and Zeidler (2005a) conducted a study with the college students (n=30) in order to investigate their informal reasoning patterns (rationalistic, emotive and intuitive) regarding six different SSI including genetic engineering scenarios. According to the findings, the combinations of these patterns were occasionally appeared on the students' informal reasoning (e.g. combination of rationalistic and emotive patterns). Similarly, twenty-two students in Norway were interviewed regarding a local controversial issue: constructing new power lines and the risk of child leukemia (Kolstø, 2006). After the students' arguments were analyzed, Kolstø found that the students used both knowledge and values together while negotiating the related SSI.

By considering all of these studies, it can be seen that the students are not able to completely differentiate their arguments from their values, beliefs and attitudes. In other words, they tend to incorporate some affective constructs into the SSI-related reasoning processes. The reason behind this tendency can be explained by the notion of *intellectual baggage* (Zeidler, 1997) and *core beliefs* (Kolstø, 2006). According to Zeidler (1997), students bring their cognitive and moral beliefs to the classroom.

In other words, the classrooms cannot be value-free (Zeidler et al., 2005) and these values that students hold can be considered as "deeply rooted, abstract motivations that guide, justify, and explain attitudes, norms, opinions, and actions" (Davidov et al., 2008, p. 421). From this definition, it can be understood that students' intellectual baggage plays an important role in their informal reasoning that includes positions and accompanying justifications. When the students negotiate an SSI closely related to their intellectual baggage, they tend to use their existing knowledge and beliefs to support their stance. If an SSI is not related to the students' intellectual baggage, then they probably use available information and evidences to evaluate the issue (Rundgren et al., 2016) and frequently ignore the conflicting ones (Evagorou et al., 2012).

2.2.1.3 Personal Experience

As an important part of the *intellectual baggage* (Zeidler, 1997), personal experiences that influence the individuals' emotions, feelings and values may cause that their decisions change (Levinson, 2006). For example, a person supporting war may change their attitudes towards war when he/she face people have suffered from the negative impacts of war. Similarly, a student may change his/her decision regarding the consumption of genetically modified food when he/she experiences a real-life situation. In the literature, many studies have focused on the contribution of the individuals' personal experiences to their informal reasoning processes (Atasoy et al., 2019; Fleming, 1986; Patronis et al., 1999; Sadler & Zeidler, 2004; Zeidler & Schafer, 1984). In their study, Atasoy and colleagues (2019) investigated 7th grade students' (n=23) informal reasoning modes and levels regarding different local issues including hydroelectrical power plants (HEPP), organic tea and Green Road project in the Black Sea Region. When the students' informal reasoning was analyzed, it was revealed that students' personal experiences (e.g. their families working on tea industry) appeared on their informal reasoning. Similarly, Patronis and colleagues (1999) examined the 14 year-old students' arguments on the issue regarding a new road construction near the school area. Analyses revealed that students frequently address their experiences including both personal and social lives in their arguments. In another study, Sadler and Zeidler (2004), explored the college students' (n=20) informal reasoning regarding the gene therapy and cloning issues and qualitative analyses showed that the college students took the personal experiences into consideration as well as the moral aspects while making decisions. Family bias, popular culture and personal experiences were considerably appeared on their arguments. In their study, Zeidler and Schafer (1984) investigated college students' informal reasoning regarding environmental dilemmas and explored some mediating factors of their reasoning. Qualitative analyses indicated that the participants frequently took their personal experiences into consideration to interpret the hypothetical scenarios and provide some rationales for their positions regarding the environmental issues provided by the researchers. Similarly, Fleming (1986) investigated the adolescents' (n=38) reasoning regarding the nuclear power plants and genetic engineering issues. It was revealed that their reasoning was mainly based on social cognition that includes moral and personal aspects. While 70% of participants used moral aspect of reasoning, 30% of them used personal aspect of reasoning. In other words, the adolescents' informal reasoning was primarily connected to their experiences.

2.2.2 Informal Reasoning Modes based on SEE-SEP Model

In the literature, several studies adopted SEE-SEP Model to assess students' informal reasoning modes as a holistic way. In their study, Christenson and colleagues (2012) studied with upper secondary students (n=80) in order to investigate their informal reasoning modes regarding four different SSI which are genetically modified organisms (GMO), nuclear power usage, global warming, and consumption. The students' informal reasoning modes was obtained through the written arguments and analyzed by using SEE-SEP model. The most chosen topic by the students was global warming (33%), whereas the least preferred one was GMO (14%). Regardless of the SSI topics, value aspect was mostly used by the students in the percentage of 67%; following by knowledge (27%), and personal experience (6%). In terms of subject areas, it was revealed that students mostly used the subject area of environment/ecology (28%) and science (27%), whereas they rarely used the subject area of policy (3%). More specifically, the subject area of science was mostly used by the students in the topics of GMO and nuclear power usage; environment in global warming, and sociology/culture in consumption topic. In another study that utilized the SEE-SEP model as an analytical framework, Eriksson and Rundgren (2012) investigated the upper secondary students' informal reasoning modes regarding the wolves in Sweden. For this purpose, the upper secondary students (n=352) were given a questionnaire that address their attitudes towards wolves in Sweden first, then an interview process was conducted with 18 students. In parallel to the study conducted by Christenson et al. (2012), the upper secondary students mostly used value aspect (60%) in their arguments regarding the related SSI; followed by knowledge (30%) and personal experience (10%). When the subject areas used by the students were examined, it was revealed that the subject areas of science and environment were mostly used in the students' arguments, whereas the subject areas of economy and policy were not frequently used by the students. In another study, Christenson and colleagues (2014) replicated their study (Christenson et al., 2012) in order to reveal the impacts of discipline background on upper secondary students' (n=208) informal reasoning modes regarding four different SSI (genetically modified organisms, nuclear power usage, global warming and consumption). Similar to Christenson and colleagues (2012), the most chosen topic by the students was global warming (44%), whereas the least preferred one was GMO (13%). The results were no different than the previous study presented: the value aspect was used by the upper secondary students more than the knowledge aspect and personal experiences regardless of the discipline background. In terms of subject areas, it was revealed that students mostly generated justifications from the subject areas of environment/ecology (M=2.7, SD=2.27) and science (M=2.2, SD=2.96), whereas they rarely used the subject areas of economy (M=0.68, SD=1.72) and policy

(M=0.22, SD=0.53). More specifically, the subject area of science was mostly used by the students in the topics of GMO (64%) and nuclear power usage (66%); the subject areas of environment in global warming (43%), and sociology/culture (36%) in consumption topic. In another study that adopted SEE-SEP Model, Karisan and Cebesoy (2021) investigated pre-service teachers' (n=47) supporting reasons in their informal reasoning regarding two different SSI, namely gene therapy and preimplantation genetic diagnosis. After the pre-service teachers' arguments were obtained through written reports regarding both of the issues, the supporting reasons used by the students were analyzed based on SEE-SEP Model. Analyses showed that pre-service teachers mostly generated arguments from the subject areas of ethics/morality (42%) and science (32%), whereas the subject area of economy was the least used by the students. Moreover, the subject area of environment/ecology did not appear on the students' written arguments. Pre-service teachers' usage of KVP (i.e. knowledge, value and personal experience) was similar to the findings of previous studies. Pre-service teachers in the study mostly used value aspect (66%) to support their positions, followed by knowledge (33%) and personal experience (1%). When the subject areas used by the students in this study and in the previous studies were compared, it can be easily understood that informal reasoning modes (subject areas in this study) was context-dependent. That means, a biotechnology-related SSI was convenient to discuss it by considering the subject area of ethics/morality, whereas consumption issue was appropriate to consider the subject area of sociology/culture.

2.3 Theoretical Link Between Informal Reasoning and Argumentation

So far, the literature review has focused on informal reasoning patterns (Sadler & Zeidler, 2005a) and modes (Chang Rundgren & Rundgren, 2010; Liu et al., 2010; Patronis et al., 1999; Wu & Tsai, 2007; Yang & Anderson, 2003). According to Topcu (2008), the quality of informal reasoning is just as important as the modes of informal reasoning. From this starting point, the researchers have attempted to assess the individuals' quality of informal reasoning. When the studies focusing on the individuals' informal reasoning regarding the complex socio-scientific issues were examined, it was revealed that individuals' quality of informal reasoning was often assessed through some indirect measures such as structure and complexity of the arguments (Sadler & Zeidler, 2005b; Topcu et al, 2010; Wu & Tsai, 2007). In other words, the quality of informal reasoning was often measured as the quality of argumentation because of their practical resemblance (Atabey & Topcu, 2017). Although informal reasoning and argumentation can be seen as the same, both of these constructs have theoretically unique characteristics. The distinction between these two constructs (i.e. informal reasoning and argumentation) was also emphasized by the literature (Means & Voss, 1996). According to Means and Voss (1996), high-quality arguments can arise from high-quality informal reasoning; however low quality arguments may not be corresponded to low-quality informal reasoning, it may be also the result from poor articulated but high-quality informal reasoning. From this evidence, it can be easily understood that informal reasoning and argumentation are two distinct constructs. While the informal reasoning refers to both cognitive and affective considerations included in the negotiation of complex socio-scientific issues, argumentation refers to a form of discourse (Voss & Means, 1991) including the external "expression of informal reasoning" (Sadler & Zeidler, 2005b, p.73). Therefore, it can be stated that argumentation can be considered as an important part of informal reasoning, since informal reasoning involves the ability to generate and evaluate arguments within itself (Means & Voss, 1996; Zohar & Nemet, 2002).

2.4 Argumentation and Argumentation Quality

Especially for the last few decades, individuals' arguments on different topics both in scientific and socio-scientific contexts have been the subject of many studies. In the extent of these studies, the *argument* term has been defined by several researchers (Kuhn, 1991; Means & Voss, 1996; Sampson & Clark, 2008; Toulmin, 1958).

According to Jiménez-Aleixandre and Erduran (2008), “any justification of a statement or set of statements is, for Toulmin, an argument to support a stated claim” (p. 15). Similarly, Kuhn (1991) described an argument as “an assertion with accompanying justification” (p.12). Alternatively, Means and Voss (1996), used the term argument to describe ‘‘a conclusion supported by at least one reason’’ (p. 141). When the aforementioned definitions were examined, it was easily seen that an argument can be described as a decision supported with a complementary component (Capkinoglu et al., 2020). In addition to these definitions, Sampson and Clark (2008) described the argument as the artifacts created by students in order to express and justify their claims. In this respect, argumentation focuses on the process in which the individuals generate and justify their claims (Driver et al., 2000; Sampson & Clark, 2008).

According to Jiménez-Aleixandre and Erduran (2008), an argument has two dimensions as individual and social. The individual dimension refers to the type of discourse in which the individuals express their viewpoint about an issue by providing reasons, whereas the social dimension refers to the type of discussion where two or more individuals from the opposite sides of an issue express their viewpoints and try to convince each other (Capkinoglu et al., 2020; Dawson & Venville, 2009). Considering this differentiation, it can be concluded that an argument in the social dimension tends to be expressed explicitly, whereas an argument in the individual dimension can be expressed in more implicit way (Capkinoglu et al., 2020). When the studies focusing on how the individuals generate arguments and engage argumentation were examined, it can be seen that the researchers have obtained the students’ arguments in several formats, basically through verbal (oral) or written expressions. By considering the dimensions of an argument, it can be understood that written format of argumentation tends to exhibit individual dimension of an argument, while verbal (oral) format of argumentation tends to exhibit social dimension of an argument. Since the present study obtained the middle school students’ arguments in a written way and did not provide any dialogic environment that enables a discussion about the issues, the present study focuses on the individual dimension of an argument.

From the historical perspective, studies on the models of argumentation are based on the layout of arguments presented by Toulmin (1958), the pioneer of the argumentation studies. In his book titled *The Uses of Arguments*, one of the most influential books in the field of argumentation, Toulmin described the basic components of an argument as claim, data, warrant, backing, qualifier and rebuttal. According to Toulmin Argument Pattern (TAP), claim is an assertion; data is the basis that supports this claim; warrant is the link that presents the relevance between the claim and data; and backing is the statements that strengthen the warrant and determine the general conditions regarding the relevance between the claim and data. In the extent of the framework, qualifier refers to the degree that the claim can be relied on. Finally, rebuttal expresses that under which conditions (e.g. exceptional or extreme situations) the claim may not be applicable (Erduran et al., 2004). Figure 2.2 presents the six components of Toulmin Argumentation Pattern (TAP) and their relations.

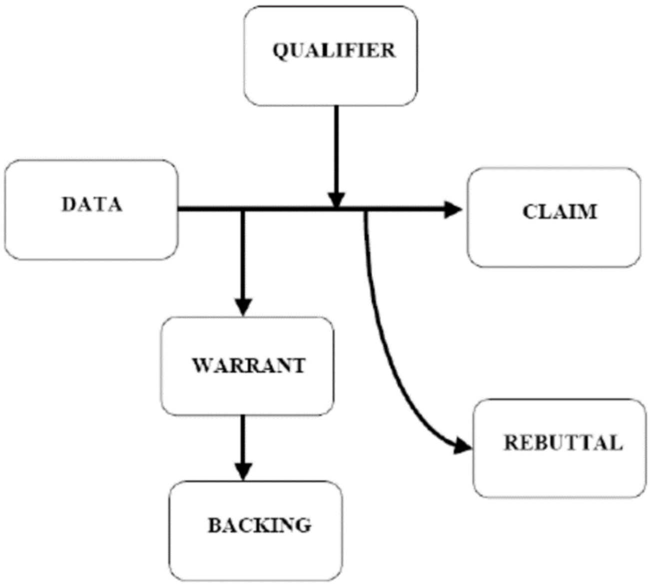

Figure 2.2 Six components of Toulmin's Argument Pattern (TAP). Adopted from "The Uses of Arguments" by S. Toulmin, 1958, Cambridge Press.

Although Toulmin's Argument Pattern (TAP) has been widely accepted as an effective theoretical framework to examine the structure of arguments, it does not provide an evaluative framework to assess the individuals' quality of argumentation. In other words, sorting the students' responses into some structural categories (i.e. claim, data, warrant, backing, qualifier and rebuttal) would not be enough to assess the quality of arguments generated by the students. Therefore, several researchers (Erduran et al., 2004; Osborne et al., 2004) have taken TAP a step further and use some TAP-based levels to assess the individuals' quality of argumentation.

In their study, Osborne and colleagues (2004) conducted a two-year project titled "Enhancing the Quality of Argument in School Science" to assess the effect of argumentation-based intervention on 8th grade students' argumentation quality. In the extent of this project, students' both whole class and small group discussions on socio-scientific contexts were audio and videotaped. In the first phase of the study, the students made discussions on "whether a new zoo should be built or not" at the beginning of the year. In the second phase of the study, the topic "building a new zoo" was discussed by the students at the beginning of the year, while "siting of a leisure centre in a nature reserve" SSI topic was discussed by the students at the end of the year (p. 15). In order to analyze the students' quality of argument, the researchers coded the students' arguments by using TAP first and then developed an analytical framework including five TAP-based levels. While developing the analytical framework, they considered the components that a valid argument should include. Although Zohar and Nemet (2002) indicated that a claim without any justification would not enough to be considered as an important component of an argument, Osborne et al. (2004) emphasized that a claim is the simplest step to generate an argument, that is why it should be accepted as a component for a valid argument. Therefore, Level 1 includes claims without any justifications, while Level 2 includes claims with any grounds (i.e. data, warrants or backings). The reason behind the usage of "grounds" is the challenge to differentiate data, warrants and backings from each other. In order to overcome this problem, Osborne and colleagues (2004) differentiated the first-order components (claims, grounds and rebuttals) from the second-order components (data, warrants and backings) and took only the first-order components into consideration while developing their analytical framework. At that point, rebuttal was another important component to be included for a valid argument. According to Kuhn (1991), generating rebuttal is "the most complex skill" since an individual generating rebuttal must "integrate an original and alternative theory, arguing that the original theory is more correct." (p. 145). Considering this criterion, the rest three TAP-based levels of Osborne and colleagues' (2004) analytical framework include rebuttal: Level 3 (claims, grounds and weak rebuttal), Level 4 (claims, grounds and clearly stated rebuttal) and Level 5 (claims, grounds and more than one rebuttal). When the data obtained from both at the beginning and at the end of the year was examined, it was revealed that most of the students (38% and 30%, respectively) were able to generate arguments from Level 2 (i.e. an argument includes claim and any grounds). While the number of arguments in Level 3 and above increased (from 40% to 55%) over the year, the number of arguments in Level 1 decreased (from 22% to 15%). After the students' discussions regarding both socio-scientific issues (i.e. building a new zoo and siting of a leisure centre in a nature reserve) were analyzed, it was revealed that most of the students (34% and 32% respectively regarding the first and second SSI) fit in the Level 2. In other words, overall findings of the study indicated that students had difficulty to generate rebuttals regarding both SSI topics.

In the extent of the same project, Erduran and colleagues (2004) proposed another evaluative framework in which they collapsed the components presented by teachers into *clusters* as abbreviations (e.g. CD, CDW or CDWR). For example, CDWR represents the cluster includes claim-data-warrant-rebuttal. According to Erduran et al. (2004), the greater number of components in a cluster, the more sophisticated quality of argument. For instance, CD (claim-data) was less complex than CDW (claim-data-warrant). However, there was a limitation: they only concentrated on the quantity of the arguments rather than the quality of the components. In other words, using this analytical framework means that CDWB (claim-data-warrant-backing) and CDWR (claim-data-warrant-rebuttal) have equal quality regardless of the component type generated in the arguments since both clusters had four components.

Sadler and Fowler (2006) also collapsed the second-order components (i.e. data, warrants and backings) into one category and called it as *grounds* in order to minimize the limitations about the unclear distinction between the components of TAP. In order to investigate to what extent individuals use scientific content knowledge to justify their positions regarding three genetic engineering scenarios, namely gene therapy and cloning, the researchers interviewed with 45 participants including 15 high school students who have diverse content knowledge on genetics; 15 science-major undergraduate students who have advanced-level content knowledge on genetics; and 15 non-science major undergraduate students who have low-level content knowledge on genetics. While developing the analytical framework to assess both high school and undergraduate students' quality of argument, they mainly focused on the justifications used by the students and developed a 5-point rubric including numerical scores from zero to four. While zero points represent "no justification", one point represents "justification with no grounds"; two points represent "justification with simple grounds"; three points represent "justification with elaborated grounds; and four points represent "justification with elaborated grounds and a counter position" (p. 9). Analyses revealed that science major undergraduate (SM) students' quality of arguments were significantly higher than high school (HS) and non-science major undergraduate (NM) groups although the mean scores did not significantly differ between HS and NM. Except SM students who have advanced level content knowledge on genetics, HS and NM students mostly got one point for their arguments; followed by two points, zero-points and three points, while four points was the least obtained point by students. Considering this result, it can be understood that the students whose content knowledge is average and low-level, but not advance-level, mostly could generate either justification with no grounds or justification with simple grounds. In other words, they had difficulty to generate elaborated grounds and counter position for their justifications.

In another study that investigated to what extent high school students' (n=56) content knowledge contributes their quality of argumentation, Sadler and Donnelly (2006) asked students to complete genetics-knowledge test and generate their position, counter-position and rebuttals regarding three genetic engineering scenarios. In consistent with Toulmin's layout of argument (1958), high school students' quality of argumentation was assessed through a scoring rubric including scores range from zero to two (0-2) based on three criteria: position and rationale; multiple perspective-taking and rebuttal. For position and rationale, zero points refer to no clear claim; one point refers to claim without grounds; and two points refer to claim with grounds. For multiple perspective-taking, zero points refer to not considering multiple perspective-taking even specifically asked; one point refers to considering multiple perspective-taking when specifically asked; and considering multiple perspective-taking without any prompts. For rebuttal, zero points refer to not addressing counter-position; one point refers to addressing counter-position without challenging its grounds; and two points refer to addressing counter-position by challenging its grounds. Quantitative analyses showed that content knowledge regarding genetics did not significantly contribute high school students' argumentation quality. Moreover, qualitative analyses of the interviews conducted with the students confirmed that students did not frequently apply their genetics-knowledge in resolution of related SSI.

Although TAP has been widely used in numerous argumentation studies as an analytical framework to identify the components of an argument and assess the students' quality of arguments through the TAP-based levels, it has some limitations reported by several researchers (Chang & Chiu, 2008; Erduran et al., 2004; Kelly et al., 1998; Sampson & Clark, 2008). The main limitation in applying TAP is the difficulties in identifying claim, data, warrant, backing and qualifier because of the blurred lines among the components. As mentioned in the previous section, Erduran and colleagues (2004) stated that the main difficulty in applying TAP is the unclear differentiation among the claim, data, warrant and backing. Moreover, Erduran and colleagues (2004) emphasized that TAP is restricted relatively short arguments

(Kelly et al., 1998). In another study, Kelly and colleagues (1998) investigated high school students' argumentation regarding electricity topic through TAP. While applying TAP, they realized the limitation that the argument layout of TAP is not consistent with "actual talk" (p. 856). In this respect, Kelly et al. (1998) reported that they found that "statements that look like a claim could serve as a warrant given the particular context of a particular segment of the conversation" (p.857). Considering this example, when the researchers encounter these ambiguities, either they have to make some inferences regarding the components or the terms should be better defined so that the researchers can understand when a statement is a warrant, backing or another component of TAP (Evagorou et al., 2012). In order to overcome this "blurred lines" problem, Kelly and colleagues (2004) emphasized that one of the strategies is considering the contextualized use of language. That means, they did not assume that all the statements following "because" is warrant.

So far, the literature review has focused on TAP-based levels to assess the students' argumentation quality. However, the literature is not restricted to the studies focusing on TAP-based levels, it also possesses some studies that developed different analytical frameworks to assess the students' quality of argumentation (Lizotte et al., 2003; Zohar & Nemet, 2002) since some researchers have started to seek some alternative analytical frameworks due to the aforementioned limitations of TAP.

According to Lizotte and colleagues (2003), a qualified argument should include *claim* refers to a conclusion; *evidence* refers to an appropriate data justifying the claim; *reasoning* represents the relation between the data and claim; and *rebuttal*. Although Lizotte et al.'s work was based on the analysis arguments in scientific context, Atabey and Topcu (2017) employed Lizotte and colleagues' (2003) analytical framework to apply in socioscientific context but with a nuance. Although Lizotte and colleagues' analytical framework includes rebuttal as a component, Atabey and Topcu (2017) did not include rebuttal in their analysis by asserting that rebuttal is more suitable for the older students and rest of the components (i.e. claim, evidence and reasoning) were sufficient to assess the younger students' quality of arguments. For the analysis, the researchers used a scoring rubric including scores range from zero to two (0-2) to investigate the effect of SSI-based instruction on 7th grade students' quality of argument regarding global warming and reducing the emission of greenhouse gases. Through this rubric, claim, evidence and reasoning were scored over 2 points. After the analysis, it was revealed that SSI-based instruction improves the middle school students' quality of argument with medium effect size for claim and large effect size for evidence and reasoning.

In another study developed an evaluative framework based on scoring to assess the students' argumentation skills, Zohar and Nemet (2002) examined the effects of explicit argumentation instruction on 9th grade students' (n=99 for the experimental group; n=87 for the comparison group) quality of argument about human genetics. In their analytical framework, Zohar and Nemet (2002) took three criteria into consideration in order to assess the high school students' quality of argument. Firstly, in parallel to the work of Means and Voss (1996), they did not accept claims without any justification as a valid argument and accepted only justifications that has an adequate content to support the claims. Secondly, in parallel to the work of Johnson (1992), they considered the arguments with more acceptable reasons as stronger arguments, although Means and Voss (1996) indicated that low-quality of argument does not always reflect low-quality of informal reasoning. Thirdly, although not as advanced as in Kuhn's work (1991), they distinguished simple justifications from more complex ones by using a rubric including scores range from zero to two (0-2). Both the number of justifications (0=no justification; 1=one valid justification; 2=more than one valid justification) and argument structure (0=no valid justification; 1=simple structure; 2=composite structure) were scored to assess the Israeli high school students' argumentation skills. Since all the issues had three components (i.e. argument, counter-argument and rebuttal) and all the components were scored over 4 points in total, students could get 12 points in total for each dilemma. After the intervention, it was revealed that high school students' both knowledge test scores and argumentation skills improved and the difference is significant between experimental group and control group.

When the studies focusing on the students' argumentation quality was examined, it was revealed that some common components were considered as indicators of quality such as claims (Osborne et al., 2004), justifications and grounds (Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Zohar & Nemet, 2002). According to Mason and Scirica (2006), a qualified argumentation involves consideration and evaluation of alternatives as well as individuals' own position. Additionally, incorporating counter arguments and re-evaluating individuals' own arguments were also emphasized (Kuhn, 1991; Voss & Means, 1991). Therefore, counter-arguments were also considered another indicator of high-quality argumentation. In addition to these components, rebuttal, the most complex skill (Kuhn, 1991), was another important component as a reflection of high-quality argumentation. Moreover, Perkins and colleagues (1983) emphasized that the ability to evaluate pros and cons of an argument was another factor that contributes to quality of argumentation.

In light of the literature focusing on the criteria to assess students' quality of argumentation regarding SSI, Chang and Chiu (2008) drew a conclusion about what components a qualified argument should possess, namely the indicators of argumentation in the context of SSI. Accordingly, there are five indicators: (1) "making claims", (2) "providing supporting reasons", (3) "presenting counter-arguments", (4) "showing qualifiers" and (5) "evaluating arguments" (p. 1756).

As an alternative evaluative framework, Lakatos' Scientific Research Programmes includes four connected components: hard-core (HC), positive heuristics (PH), negative heuristics (NH) and protective belt (PB).

According to Chang and Chiu (2008),

> *The HC is the core and foundation of the theory, and it possesses firm and unchangeable features that are very difficult to attack and degenerate in the programmes; the PB is composed of auxiliary hypotheses for preventing the HC from being attacked; the NH and PH are both strategies embedded in the PB with separate functions to forbid rebuttals and to expand theory (p. 1758).*

When the description presented above was carefully examined, it was easily understood that there is a parallelism between the components of Lakatos' Scientific Research Programmes and aforementioned five indicators of argumentation. Making claims and providing supporting reasons, the first and second indicators of argumentation, are located in the core of Lakatos' Scientific Research Programmes. While NH protects the HC (i.e. one's the original theory) by generating the counter-arguments or limitations (the third indicator), PH protects the HC by presenting "qualifier showing the alternative line to inquiry" (the fourth indicator). Finally, PB in which PH and NH embedded represents the fifth indicator of argumentation by evaluating different arguments. The relationship between the components of Lakatos' Scientific Research Programmes and aforementioned five indicators of argumentation was presented in Table 2.2.

Table 2.2 The Relationship between the Components of Lakatos' Scientific Research Programmes and Five Indicators of Argumentation. Adapted from "Lakatos' Scientific Research Programmes as a Framework for Analysing Informal Argumentation about Socio-scientific Issues" by S. N. Chang & M. H. Chiu, 2008, Routledge, Taylor & Francis Group, p. 1758.

Components of LSRP*	Indicators of Argumentation	Definitions
HC*	(1) making claims (2) providing supporting reasons	Individuals could provide their own claim supporting by one or more reasons.
NH*	(3) presenting counter-arguments	Based on the claim, individuals could know the limitation of the claim they made.
PH*	(4) showing qualifiers	Based on the claim, individuals could know the progress or the extension of the claim.
PB*	(5) evaluating arguments	Individuals could evaluate arguments.

*LSRP: Lakatos' Scientific Research Programmes, HC: Hard-Core, NH: Negative Heuristics, PH: Positive Heuristics, PB: Protective Belt

In the literature, several researchers (Chang & Chiu, 2008; Rundgren et al, 2016) adopted Lakatos' Scientific Research Programmes in order to analyze students' argumentation quality. In their study, Chang and Chiu (2008) investigated science-major and nonscience-major undergraduate students' (n=70) argumentation quality regarding four SSI (i.e. DDT and malaria, conflict about dioxins, genetically modified food, and organic food). After students' written arguments were obtained and analyzed, it was revealed that science-major and nonscience-major undergraduate students were able to present claim and supporting reasons (M=8.25, SD=2.36; M=7.30, SD=1.60 respectively), whereas they had difficulty to generate PH (M=0.63, SD=0.90; M=0.17, SD=0.38 respectively) and NH (M=0.68, SD=1.02; M=0.47, SD=0.78 respectively). That means, students from both majors could not adequately expand their arguments and consider opposing alternatives although science-major students performed better than nonscience major ones. In contrast to the previous study, Rundgren and colleagues (2016) investigated seven upper secondary students' argumentation quality regarding a local SSI (i.e. toxin contamination in fish from Baltic Sea). After the qualitative analyses through Lakatos' Scientific Research Programmes, it was revealed that all of the students were able to provide counter-arguments or limitations as negative heuristics (NH) regarding their position, and extend their arguments by presenting additional supports (PH).

When the literature on the analytical frameworks to assess students' informal reasoning modes and argumentation quality was examined, it was revealed that some of the analytical frameworks (Chang & Chiu, 2008; Erduran et al., 2004; Osborne et al., 2004) considered structure-based quality (i.e. the components of arguments), while some others (Christenson et al., 2012; Sadler & Donnelly, 2006; Sadler & Fowler, 2006; Wu & Tsai, 2007; Zohar & Nemet, 2002) considered content-based quality (i.e. integration of scientific knowledge and evaluating issues from multiple perspectives). Unless the researchers adopt some integrated frameworks such as the work of Wu and Tsai (2007), they need to use two different analytical frameworks to develop better understanding in terms of both structure (quantity of components and complexity) and content of arguments. Therefore, in addition to the studies focusing informal reasoning modes and quality of argumentation separately, there are also some studies (Dawson & Venville, 2009; Dawson & Venville, 2013; Georgiou & Mavrikaki, 2013; Sadler & Zeidler, 2005b; Venville & Dawson, 2010) examining these constructs through the same data-set by using different analytical frameworks; one to investigate informal reasoning modes and another to assess the quality of argumentation. The reason behind adopting two different frameworks is the effort to develop the understanding regarding how individuals negotiate SSI in a more holistic way.

In their study, Dawson and Venville (2009) investigated Australian high school students' (n=30 from 8th, 10th and 12th grades) informal reasoning patterns and quality of argument regarding biotechnology SSI topic. In data collection procedure, students' responses were obtained through semi-structured interviews. TAP with modified version of 5-levels analytical framework indicated by Osborne and colleagues (2004) was used to assess the students' quality of argument, while informal reasoning patterns (i.e. rationalistic, emotive and intuitive) indicated by Sadler and Zeidler (2005a) were used to investigate the students' informal reasoning. The reason behind the modification of 5-levels scheme described in Osborne and colleagues' work (2004) is the students' lack of opportunity to generate rebuttals when the interviews were conducted. In other words, Australian students in the study were not expected to refute someone's claim since the nature of their study was based on a monologic discourse rather than a dialogic one. Therefore, in parallel to the work of Sadler and Fowler (2006), Dawson and Venville (2009) presented a modified scheme where Level 1 including claim; Level 2 including claim, data and/or warrants; Level 3 including claim, data/warrants, backing or qualifier; and Level 4 including claim, data/warrants, backing and qualifier. When the students' responses were analyzed, it was revealed that intuitive informal reasoning was the most frequent pattern appeared on the students' arguments; followed by emotive and rationalistic patterns. Moreover, it was revealed that high school students in Australia mostly generated arguments in Level 2 that represents claim and supporting evidence(s); followed by Level 1, Level 3 and Level 4. It means that Australian high school students could relatively easily express their claims and supporting data or warrant, while they found difficult to provide backing and qualifier. In another study, Kucukaydin (2019) adopted the analytical framework including 4 levels developed by Venville and Dawson (2010) and investigated 8th grade students' (n=10) quality of argument regarding waste management SSI topic. In similar to the previous study (Dawson & Venville, 2009), majority of the students could support their claims with data or warrant (i.e. Level 2), however only one of the students reached the last level (i.e. claim, data/warrant, backing and qualifier). Similarly, Georgiou and Mavrikaki (2013) investigated 10th grade Greek students' both argumentation quality and informal reasoning through eight open-ended questions regarding biotechnology SSI topic including genetically modified foods and other applications. Students' responses were analyzed utilizing 1-5 Level analytical framework based on TAP (Osborne et al., 2004) to assess the students' argumentation quality and informal reasoning patterns (i.e. rationalistic, emotive and intuitive) presented by Sadler and Zeidler (2005a). In parallel to the previous study, most of the arguments (60.6%) were coded as Level 2; followed by Level 1 (26.3%), Level 3 (12.0%), Level 4 (0.8%) and Level 5 (0.3%). Regarding informal reasoning, the Greek students mostly used intuitive pattern (54.8%) in their biotechnology-related arguments; followed by emotive (14.6%), rational (11.2%) and combinations of different patterns.

As other researchers in the previous studies presented in this section, Es and Varol (2019) also adopted two different frameworks in order to investigate theology (n=47) and science education (n=27) undergraduate students' arguments regarding nuclear power plants. While a modified version of SEE-SEP Model was utilized to examine the students' informal reasoning modes, Lakatos' Scientific Research Programmes was used as an analytical framework to assess the students' quality of argumentation. In the extent of the SEE-SEP Model described in the previous section, Chang Rundgren and Rundgren (2010) considered the subject area of technology as a sub-category of science, therefore there was no need to add another category called as technology. Different from that study, Es and Varol (2019) added the subject area of technology as another category and proposed SEE-STEP Model as a modification of SEE-SEP Model. The researchers justified their modification by giving some examples such as Science-Technology-Society (STS) movement and STEM approach. According to Es and Varol (2019), it can be easily understood from these examples that science and technology are different domains in both conceptual and practical manner, therefore they should be differentiated. As a result of this modification, SEE-STEP Model has seven subject areas with additional technology, three aspects and a total of 21 codes as combinations of these subject areas and aspects. In their study, data from the undergraduate students were obtained through Nuclear Energy Decision and Evaluation Form including two close-ended and one open-ended questions developed by the researchers. When the students' informal reasoning modes were analyzed, it was revealed that the undergraduate students mostly considered the subject areas of economy and environment while supporting their claims and generating counter-arguments regarding nuclear power plants. In other words, rest of the subject areas (i.e. sociology/culture, science, technology, ethics/morality and policy) was either not or rarely used by the students. When the components of students' argumentation were analyzed, it was revealed that the undergraduate students mostly generated PH to extend their claims (M=0.96, SD=0.90) more than NH to generate counter-arguments or limitations (M=0.55, SD=0.72). According to Evagorou and colleagues (2012), this finding might be resulted from the students' tendency to use the evidences to support their claims and ignore the conflicting evidences. Considering all of these findings, it can be concluded that majority of undergraduate students did not have good quality of argument and could not generate arguments from multiple perspectives. Similarly, Es and Ozturk (2021) developed a nine-steps activity and investigated 7th grade middle school students' (n=24) informal reasoning modes and quality of argumentation regarding fishing ban as a local SSI. When the students' informal reasoning modes were analyzed, it was revealed that students mostly considered the subject areas of economy and environment and they did not generate any argument from the subject areas of technology and ethics/morality regarding the fishing ban issue. This finding is consistent with the finding of the previous study (Es & Varol, 2019) that presents the dominance of economy and environment subject areas. When the students' quality of argumentation was analyzed, in similar to the previous study (Es & Varol, 2019), students' PH scores with an average of 3.58 are more than their NH scores with an average of 2.25. That means, students had difficulty to generate counter-arguments or limitations, while they could relatively easily extend their claims. This finding is consistent with the aforementioned notion of intellectual baggage proposed by Zeidler (1997). According to Zeidler (1997), students tend to use information consistent with their stance, whereas they tend to ignore conflicting evidences. Similarly, Liu and colleagues (2010) indicated that students tend to find the solutions compatible with their existing knowledge and belief more convincing. Therefore, students may have difficulty to generate counter-arguments (i.e. NH in the present study).

2.5 Issue Familiarity, Informal Reasoning Modes, Argumentation Quality

In the literature, some of the studies focusing on the role of SSI context indicated that students' informal reasoning modes and argumentation quality might vary across different SSI (Baytelman et al., 2020; Christenson et al., 2012; Christenson et al., 2014; Irmak, 2021), whereas some of the studies indicated that SSI context had no influence on students' informal reasoning modes and argumentation quality (Topcu et al., 2010). In other words, there is an inconsistency between the findings of the studies regarding the role of SSI context in students' informal reasoning modes and argumentation quality (Garrecht et al., 2021). Although there is no consensus in the literature regarding the role of SSI context, majority of the researchers in the field of science education agree that basic familiarity regarding an issue is needed for students to engage in argumentation (Garrecht et al., 2021; Lewis & Leach, 2006; Topcu et al., 2010).

In the literature, familiarity has been defined by several researchers (Garrecht et al., 2021; Khishfe, 2012b; Zhang et al., 2022). According to Garrecht and colleagues

(2021), issue familiarity was considered as “the knowledge about an issue, with greater familiarity enabling students to engage with the issue under debate to a greater extent” (p. 5). In addition, individual factors (e.g. students’ motivation to learn the related SSI) have also an influence on students’ effort to familiarize themselves regarding the related issue (Garrecht et al., 2021). In other words, students may spend more time on engaging cognitive tasks regarding the SSI context which they have more motivation to learn about. Similar to the aforementioned definition of familiarity, Khishfe (2012b) indicated that issue familiarity refers to prior content knowledge and personal relevance regarding an issue. From a different point of view, Zhang and colleagues (2022) addressed the feeling of familiarity (FOF) as “FOF arises when the current task is closely tied to previous experiences or when participants attribute the fluency on the current task to prior experiences” (p. 4). In addition to these definitions, several researchers also indicated that individuals’ familiarity regarding an issue might come from mass media such as newspaper, the Internet, television (TV), news, and advertisements (Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017).

In a study indicating that SSI context had an influence on students’ argumentation quality, Garrecht and colleagues (2021) investigated the relationship between 9^{th} and 10^{th} grade students’ (n=163) issue familiarity and argumentation quality regarding animal testing as SSI context. In the extent of the study, it was aimed to increase the students’ issue familiarity regarding animal testing through an intervention. The intervention consisted of a teaching unit including several cognitive tasks. According to the researchers, issue familiarity was considered as “the knowledge about an issue, with greater familiarity enabling students to engage with the issue under debate to a greater extent” (p. 5). In other words, an increased number of arguments was considered as increased issue familiarity as a result of familiarization intervention. As a result of the intervention, it was revealed that increased issue familiarity improved students’ diversity of discipline-related arguments although all disciplines were not improved equally. In addition to this finding, Garrecht and colleagues (2021) pointed out that individual factors (e.g. students’ motivation to learn the related SSI) also influence students' effort to familiarize themselves regarding the issue under discussion. Therefore, the researchers indicated that animal testing is a potentially "effective issue to engage students in multidisciplinary argumentation even without additional knowledge" (p. 14), since teachers already had some difficulties regarding limited time and lack of materials while teaching SSI in the classrooms (Garrecht et al., 2021).

Similar to the findings of previous study, Lewis and Leach (2006) investigated the relationship between students' scientific content knowledge and ability to engage in reasoned discussions regarding biotechnological applications. Results showed that when the students were familiar with the issue, they were able to generate more reasoned arguments. Moreover, Lewis and Leach (2006) also emphasized that the students ignored the new issues when they were "outside of their experience and had little relevance to their immediate lives" (p. 1275). Similarly, Khishfe (2012b) indicated that "students might better connect to the issue especially if it is more familiar and related to their everyday lives" (p. 492).

In another study reporting that both interest and familiarity may have an influence on students' argumentation quality, Capkinoglu and colleagues (2020) investigated 7th grade students' (n=36) argumentation quality regarding five local SSI, namely an artificial lake, chicken coops, leather tanneries, base stations, and hydroelectric power plants (HPP). For this aim, students were assigned to three groups, namely, the newspaper group, the presentation group, and the outdoor group. Results showed that HPP topic was the most challenging SSI for all groups. To clarify, all groups, even the most successful group (i.e. the newspaper group) generated low quality arguments regarding HPP. According to Capkinoglu and colleagues (2020), a possible reason behind the students' failure to generate high quality argument was that HPP may be the least attractive context among all SSI regardless of the learning group.

2.6 Theoretical Link Between SSI and Epistemological Beliefs

In contrast to aforementioned STS movement, SSI consists of a conceptual framework that combines individuals' moral and epistemological orientations, affective processes and character development as the bases of the science education (Sadler & Zeidler, 2005a; Zeidler et al., 2005). By definition, SSI are complex, open-ended, often contentious dilemmas with no definitive answers (Sadler, 2004) and they generally tend to be "controversial; multi-faceted; subject to multiple, sometimes, contradictory perspectives; and connected to scientific concepts" (Herman et al, 2018, p. 146). In the light of these characteristics, it can be easily understood that nature of SSI can be associated with ill-structured problems. In contrast to well-structured problems that can be solved by following some logical steps, ill-structured problems may not be easily solved as they do not have clear-cut solutions, in other words, they are open to alternative approaches to be solved. While solving an ill-structured problem, individuals require to take multiple perspectives into consideration, evaluate the alternative solutions regarding the problem by considering several criteria and provide a justification supporting the rationale behind the selected solution (Angeli & Valanides, 2012). In this manner, personal epistemological beliefs play an important role in developing justification regarding ill-structured problems (Kitchener, 1983). According to Voss and Means (1991), in order to justify a claim regarding an ill-structured problem in the context of argumentation, good reasoners need to generate arguments supporting their own claims, consider counter-arguments against to their claims and evaluate both of them to refute the counter-arguments or reconsider their original argument. In other words, individuals utilize their epistemological beliefs while making decisions on complex ill-structured problems (King & Kitchener, 1994**.** According to Kitchener (1983), there are three level of cognitive processing: cognition, metacognition and epistemic cognition. While the levels of cognition and metacognition only are adequate to solve a well-structured problem, they are not sufficient to handle an ill-structured problem. Therefore, individuals need to have an epistemic cognition as well as cognition and metacognition for all the reasoning and argumentation processes mentioned above regarding ill-structured problems (Kitchener, 1983). At this point, negotiating SSI, as an ill-structured problem, requires an epistemic cognition. Additionally, Schraw and colleagues (1995) indicated that well-structured and ill-structured problems requires independent cognitive processes and different epistemological beliefs. In order to generate an argument, consider multiple perspectives, provide a counter-argument, weight the alternatives, develop a position and support that position with appropriate justifications, an individual must first recognize that ill-structured problems (e.g. SSI) do not have single correct answer and other alternatives regarding the solution of these problems might be also considered. This recognition can be undoubtedly associated with one's epistemological beliefs. In this manner, epistemological beliefs refer to personal epistemological beliefs that people hold regarding nature of knowledge and nature of knowing (Hofer & Pintrich, 1997). If individuals believe that knowledge is absolute and not open to alternatives, then they are not able to differentiate ill-structured problems from the well-structured ones. If an only if individuals believe that ill-structured problems do not have clear-cut solutions and open to multiple perspectives, then they are able to negotiate that problem, make informal reasoning and engage in argumentation (Angeli & Valanides, 2012; Kitchener, 1983).

2.7 Epistemological Beliefs

In this section of the chapter, historical development of epistemological belief models and the studies focusing on epistemological beliefs are presented respectively.

2.7.1 Historical Development of Epistemological Belief Models

From the historical perspective, studies regarding the models of epistemological beliefs started with two longitudinal research conducted by Perry (1968), and continued with women's ways of knowing (Belenky et al., 1986), argumentative reasoning (Kuhn, 1991), epistemological reflection model (Baxter Magolda, 1992) and reflective judgment model (King & Kitchener, 1994) in a chronological order. First, Perry (1968) interviewed with first year students from Harvard College (n=31) and proposed a scheme including nine positions as stages in a sequence that represents individuals' intellectual and ethical development. Afterwards, Perry and his colleagues administered it to four-year college students (n=109) in order to satisfy the validation of scheme. As a result of these studies, nine positions were collapsed into four categories: *dualism*, *multiplicity*, *relativism* and *commitment within relativism*. Although these studies made a significant contribution to the literature, they had some limitations. According to Perry (1968), the first limitation was that the students from single college (i.e. Harvard College) studied between the years 1954 and 1963 constituted the participants of the study, while the second limitation was that the researchers themselves were also the interviewers of the study.

In addition to the limitations that Perry (1968) stated, there were also some criticisms particularly about the generalizability and characteristics of sample selected in the extent of his studies as most of the participants in his studies were white men from a high-status college. This occurrence led the second model of epistemological beliefs: women's ways of knowing (Belenky et al., 1986). Belenky and colleagues (1986) studied with women (n=135) from different backgrounds in terms of age, ethnicity, class and educational status. After the interviews, they proposed five epistemological categories which are "*silence*, *received knowledge*, *subjective knowledge*, *procedural knowledge* and *constructed knowledge*". Although the model proposed by Belenky et al. (1986) expand the extent of Perry's work (1968) by focusing on women epistemology, it was also criticized due to the sample only consisting of women.

The third model regarding epistemological beliefs, namely the Model of Argumentative Reasoning, was proposed by Kuhn (1991). In her study, Kuhn (1991) interviewed with individuals from different ages on ill-structured questions: "What causes prisoners to return to crime after they are released?", "What causes unemployment?", and "What causes children to fail in school? The purpose of these questions were to reveal the participants' argumentative reasoning in terms of developing a position, considering opposite point of views and generating rebuttals against to these opposite point of views. According to the model proposed by Kuhn (1991), there are three types of epistemological views as *absolutist*, *multiplist* and *evaluative*. After the analyses regarding the relationship between epistemological beliefs and argumentative reasoning skills, it was revealed that individuals' epistemological beliefs play an important role in their argumentation skills. More specifically, individuals who exhibited evaluative view of epistemology were tended to generate counter-arguments against to their original position.

Fourthly, Epistemological Reflection Model proposed by Baxter Magolda (1992) was another model focusing on personal epistemological beliefs. Different from the works of Perry (1968) and Belenky et al. (1986), Baxter Magolda interviewed 101 undergraduate and graduate students from both genders (n=51 females; 50 males) and administered the instrument called Measure of Epistemological Reflection (MER). After the analyses, Baxter Magolda proposed four types of knowing under the Model of Epistemological Reflection: *absolute knowing*, *transitional knowing*, *independent knowing* and *contextual knowing*. This model made an important contribution to the literature because it attempted to eliminate the limitations of previous works by including both men and women in the sample of study.

The fifth model focusing on individuals' epistemological beliefs was Reflective Judgment Model proposed by King and Kitchener (1994). Their study was a longitudinal study in which the participants from high school students to adults had been interviewed for 15 years. Like the work of Kuhn (1991), the individuals were expected to develop a position and provide justifications to support their positions regarding some ill-structured problems. As a result of the participants' responses, King and Kitchener (1994) proposed a model includes seven stages represent different epistemological perspectives. Then, these stages were collapsed into three categories as *pre-reflective thinking* including the stages 1-3, *quasi-reflective thinking* including the stages 4-5 and *reflective thinking* including the stages 6-7. The model of Reflective Judgment was also criticized due to the subjects of ill-structured problems. According to Buehl (2003), the subjects covered as ill-structured problems were related to general knowledge rather than school knowledge.

Although the studies presented so far regarding the models of epistemological beliefs made unique contributions to the literature, they all have a common point related to the structure of these models: unidimensional developmental perspective. According to the first group researchers in the five developmental models mentioned so far, the model of epistemological beliefs has a stage-like structure. In other words, epistemological beliefs, as one general dimension, evolve through stages on a continuum. Unlike the first group researchers, Schommer (1990) proposed a different perspective regarding to the models of epistemological beliefs: multidimensional perspective. According to Schommer (1990), the model of epistemological beliefs can be described as “a belief system that is composed of several more or less independent dimensions” (p. 498) rather than one general dimension. That means, an individual’s epistemological beliefs may be more-developed regarding one dimension, whereas his/her epistemological beliefs may be less-developed regarding another dimension.

In her study, Schommer (1990) hypothesized five dimensions for individuals’ independent epistemological beliefs. These hypothesized dimensions were the structure of knowledge (simple knowledge), certainty of knowledge (certain knowledge), source of knowledge (omniscient authority); the control (innate ability) and speed (quick learning) of knowledge acquisition. According to Schommer (1990), an individual who has naïve epistemological beliefs regarding these five hypothesized dimensions asserts that "knowledge is simple rather than complex" for simple knowledge; "knowledge is handed down by authority rather than derived from reason" for omniscient authority; "knowledge is certain rather than tentative" for certain knowledge; "the ability to learn is innate rather than acquired" for innate ability, and "learning is quick or not at all" for quick learning (p. 499). To validate these dimensions, Schommer (1990) administered 63-item Epistemological Questionnaire in the Likert format to junior college students (n=117) and university students (n=149) with nearly equal numbers of females (n=143) and males (n=120). Factor analysis revealed four of the five hypothesized dimensions: certain knowledge, simple knowledge, quick learning, and fixed ability (Schommer, 1990). The findings of study confirmed that epistemological belief system includes more or less independent dimensions rather than a single developmental dimension.

Although the dimensions of certainty, simplicity and source of knowledge (Schommer, 1990) have been found parallel to the general acceptance in the literature, the dimensions of quick learning and innate ability were criticized by Hofer and Pintrich (1997). According to Hofer and Pintrich (1997), personal epistemology includes two types of beliefs (i.e. beliefs about nature of knowledge and beliefs about nature of knowing), also known as "core structure of individuals' epistemological theories" (p. 119). In parallel to this assertion, they pointed out that the dimensions of quick learning and innate ability belong to neither the nature of knowledge nor the nature of knowing as they are related to nature of learning. Afterwards, Hofer and Pintrich (1997) extracted these two dimensions from the scheme and added the dimension of justification. In this way, they described the epistemological beliefs as a multidimensional model including two dimensions for nature of knowledge (i.e. simplicity and certainty of knowledge) and two others (source of knowledge and justification of knowing) for nature of knowing. Schommer's Epistemological Questionnaire (SEB) and its Turkish version adapted by Deryakulu and Sener (2002) have been widely used in both national and international studies.

When the related studies discussed so far, it was revealed that most of them were conducted with late adolescents, undergraduate students and adults from different backgrounds. This tendency may be resulted from the assumption that epistemological beliefs of younger students was difficult to define (Kuhn, 1988). By considering the focus groups of these studies, it can be stated that there was a need to study with younger students. For this purpose, Elder (1999) developed an instrument called as *Scientific Epistemological Beliefs Scale* in order to assess 5th grade students' (n=194) epistemological beliefs and the items of questionnaire were categorized as four groups. These groups were “changing nature of science (stability), coherence of knowledge (structure), source of knowledge (source) and role of experiments (refers to knowledge justification in science)” (Hofer & Pintrich, 1997, p. 189). Later, multidimensional scaling was used and three scales were generated for the underlying factor structure: change, source and reason. After the analyses, it was revealed that students’ epistemological beliefs displayed heterogenous understandings regarding the dimensions of scale although they exhibited relatively sophisticated epistemological beliefs regarding changing nature of science. That means, there were both students with sophisticated or naive epistemological beliefs, although they mostly tended to believe that knowledge in science is tentative.

Based on the work of Elder (1999), Conley and colleagues (2004) developed an instrument called as *Epistemological Beliefs Questionnaire* to assess 5th grade students’ (n=187) epistemological beliefs regarding four dimensions (i.e. source, certainty, development and justification) and investigate whether their epistemological beliefs change over time or not. These dimensions were developed based on the aforementioned beliefs (beliefs about nature of knowledge and beliefs about nature of knowing) proposed by Hofer and Pintrich (1997). The dimensions of certainty and development were compatible with the beliefs about nature of knowledge, whereas the dimensions of source and justification were compatible with the beliefs about nature of knowing. After a nine-week unit in the subject of chemistry was conducted, the instrument was administered to students. The instrument consisted of 26 Likert type items, particularly, five items for the source dimension, six items for the certainty dimension, six items for the development dimension and nine items for the justification dimension. After the analyses, it was revealed that students had fairly sophisticated epistemological beliefs regarding all dimensions of EBQ. More specifically, they had the highest scores on the dimension of justification, followed by development, whereas they had the least scores on the dimensions of source and certainty. It was also revealed that students’ epistemological beliefs changed over time, particularly in the dimensions of source and certainty. In other words, students' scores in the dimensions of development and justification did not significantly differ between in pre-test and post-test. Moreover, it was reported that the dimensions of source and certainty showed a high correlation (i.e. above .90). That means, the high correlation between these dimensions indicated that they did not displayed different dimensions.

2.7.2 Studies Focusing on Younger Students' Epistemological Beliefs in Turkish Context

In this section, studies, particularly the recent studies in Turkish context, focusing on younger students' epistemological beliefs are presented. Especially in the last two decades, many researchers have studied on younger students' epistemological beliefs in Turkish context. When the related literature was examined, it was revealed that Epistemological Beliefs Questionnaire developed by Conley et al. (2004) and adapted into Turkish by Ozkan (2008) has been frequently used by several researchers (Aydın & Gecici, 2017; Boz et al., 2011; Kurt, 2009) to investigate younger students' epistemological beliefs.

Ozkan (2008) conducted a pilot study with 156 seventh grade students in to examine the factor structure of the Epistemological Beliefs Questionnaire developed by Conley et al. (2004). Sticking to the original dimensions of questionnaire, four-factor structure was considered first to analyze pilot test data. After the items which have negative item-total correlation (item 2 and item 7) were removed from the analysis, total reliability increased from .78 to .82. After the second factor analysis was performed, it was revealed that the dimensions of source and certainty were highly correlated and merged into one dimension labelled as "source/certainty". Therefore, adapted version of the questionnaire consisted of three factors as source/certainty, development and justification. According to Conley and colleagues (2004), high correlation between the dimensions source and certainty ($r = .91$ for Time 1, and $r = .92$ for Time 2) makes it difficult to differentiate between both concepts logically (p. 195). Considering the aforementioned high-correlation, fusion of source and certainty was not a surprising result. Moreover, similar to the findings of Conley and colleagues' study (2004), it was revealed that seventh grade students' (n=1240) epistemological beliefs were relatively sophisticated regarding all dimensions of EBQ. More specifically, they had the highest score on the dimension of justification (M=3.99, SD=0.64), followed by development (M=3.60, SD=0.61) and source/certainty (M=3.28, SD=0.63).

Similarly, Kurt (2009) investigated 6th, 8th and 10th grade students' (n=1557) epistemological beliefs by adopting Epistemological Beliefs Questionnaire adapted into Turkish by Ozkan (2008). In contrast to three factor structure proposed by Ozkan (2008), 6th, 8th and 10th grade students' epistemological beliefs were explained with four-factor structure proposed by Conley et al. (2004). Descriptive analysis indicated that the students had fairly sophisticated epistemological beliefs with the mean scores above the mid-point of 1-5 Likert scale. Similar to the previous studies, the students had the highest scores on the dimension of justification among four dimensions of EBQ. In other words, the students tended to believe that construction of scientific knowledge requires data, experiments and justifications. Similarly, Boz and her colleagues (2011) investigated 4th, 6th and 8th grade students' (n=427) epistemological beliefs through EBQ adapted into Turkish by Ozkan (2008). Among three dimensions of EBQ (source/certainty, development, and justification), the students in all grade levels had the highest score on the dimension of justification, followed by development, whereas they had the least score on the dimension of source/certainty, especially in the lower grades. More recently, Aydin and Gecici (2017) investigated 6th grade students' (n=196) epistemological beliefs through EBQ adapted into Turkish by Ozkan (2008). Similar to the previous study, descriptive analysis indicated that the students had the most sophisticated epistemological beliefs on the dimensions of justification (M=3.71, 3.53), followed by development (M=3.31, 3.32), whereas they had the least sophisticated beliefs on the dimension of source/certainty (M=2.59, 2.72) for female and male students respectively.

To examine younger students' epistemological beliefs, *Scientific Epistemological Beliefs Scale* developed by Elder (1999) and adapted into Turkish by Acat et al.

(2010) was also frequently adopted by the researchers in Turkish context (Baser Gulsoy et al., 2015; Can & Celik, 2020; Yenice & Ozden, 2013). In their study, Acat and his colleagues (2010) adapted Scientific Epistemological Beliefs Scale by investigating 8th grade students' (n=212) epistemological beliefs. As a result of the study, five dimensions of the scale were replicated in Turkish context (i.e. authority and certainty, process of knowledge production, source of knowledge, reasoning, and changeability of knowledge). In their study, Baser Gulsoy and colleagues (2015) investigated 5th and 6th grade students' (n=320) epistemological beliefs through the adapted version of Scientific Epistemological Beliefs Scale including five dimensions which are *authority and certainty*, *process of knowledge production*, *source of knowledge*, *reasoning*, and *changeability of knowledge*. Descriptive analysis showed that students obtained the highest scores on the dimensions of process of knowledge production (M=3.91), followed by reasoning (M=3.86), and changeability of knowledge (M=3.66) with the mean scores quite higher than the absolute mean of 5-point Likert scale. The students' scores on the dimension of source of knowledge (M=3.06) fell behind the aforementioned dimensions, whereas they obtained the lowest scores on the dimension of authority and certainty (M=2.74). Although the mean scores on the dimension of authority and certainty were slightly above the absolute mean of 5-point Likert scale, the study reported that students displayed sophisticated epistemological beliefs. In parallel to the findings of previous study (Baser Gulsoy et al., 2015), Can and Celik (2020) examined 6th and 7th grade students' (n=285) epistemological beliefs through Scientific Epistemological Beliefs Scale adapted into Turkish by Acat et al. (2010). Similarly, the students had the highest scores on the dimensions of reasoning (M=4.10), process of knowledge production (M=3.89), and changeability of knowledge (M=3.78). The students' scores on the dimension of source of knowledge (M=2.85) were slightly higher than the absolute mean of 5-point Likert scale, whereas they had the lowest scores on the dimension of authority and certainty (M=2.42). In a similar pattern, it was reported that students had fairly sophisticated epistemological beliefs on the dimensions except authority and certainty. In their study, Yenice and Ozden (2013) investigated 8th grade students' (n=355) epistemological beliefs through the Scientific Epistemological Beliefs Scale adapted into Turkish by Acat et al. (2010). As a result of the descriptive analysis, it was revealed that the students' epistemological beliefs were closer to the sophisticated beliefs and mid-level. Also, several studies (Cano, 2005; Cano & Cardelle-Elawar, 2004; Ogan-Bekiroglu & Sengul-Turgut, 2011) emphasized that epistemological beliefs of the students can change and develop from simplistic to more realistic and complex upper levels over time.

2.8 Epistemological Beliefs, Informal Reasoning Modes, Argumentation Quality

When the literature focusing on epistemological beliefs was examined, it was revealed that numerous studies have focused on the relationship between epistemological beliefs and other constructs such as achievement and academic performance (Buell, 2018; Cano & Cardelle-Elawar, 2004; Conley et al., 2004; Pamuk et al., 2017), self-efficacy (Kapucu & Bahcivan, 2015; Kizilgunes et al., 2009; Metallidou, 2013; Sadi & Dagyar, 2015), attitude (Kapucu & Bahcivan, 2015; Onen, 2011), gender (Buell, 2018; Muis & Gierus, 2014; Zaleta, 2014), conceptual learning (Kaymak & Ogan-Bekiroglu, 2013), socioeconomic status (SES) (Conley et al., 2004; Ozkal et al., 2010) and anxiety level (Lin et al., 2013). In accordance with the focus of the present study, relationships between epistemological beliefs, informal reasoning modes and quality of argumentation in the context of SSI are particularly addressed in this section to present the direction of the findings.

When the literature focusing on the relationship between the constructs of the present study were examined, it was revealed that the literature presents some conflicting evidences from the fields of psychology, science education and business, although the existence of relationship was dominantly reported in the findings of the studies. Many of the studies revealed that individuals' epistemological beliefs may contribute informal reasoning modes or argumentation quality (Baytelman et al., 2018;

Baytelman et al., 2020; Bendixen et al., 1994; Bendixen et al., 1998; Liu et al., 2010; Mason & Scirica, 2006; Oztuna Kaplan & Cavus, 2016; Ozturk & Yilmaz-Tuzun, 2017; Schommer & Dunnell, 1997; Wu & Tsai, 2011), whereas some of the studies indicated that there is no systematic link between these constructs (Angeli & Valanides, 2012; Mintchik & Farmer, 2009; Topcu et al., 2011).

As the first group researchers indicating a relationship between the aforementioned constructs, Bendixen and colleagues (1994) investigated the relationship between college undergraduate and graduate students' (n=125) epistemological beliefs and reflective judgment. While the students' epistemological beliefs were obtained through the instrument including 63 items in Likert type developed by Schommer (1990), their reflective judgment was determined based on the levels proposed by Kitchener and King (1981). The related correlational analyses showed that individuals who have strong beliefs regarding the dimensions of fixed ability, simple knowledge and quick learning were more likely to be associated with the lower stages of the reflective judgment model. Similarly, Bendixen and colleagues (1998) asserted that one of the personal influences on moral reasoning is individiuals' epistemic beliefs and examined the relationship between undergraduate students' epistemic beliefs and moral reasoning. Epistemic beliefs of the undergraduate students were obtained through Epistemic Beliefs Inventory including 32 items based on the dimensions of Schommer's instrument (1990), while their moral reasoning was assessed through short version of Defining Issues Test (DIT) including three dilemmas. Correlational analyses revealed that beliefs in the dimensions of simple knowledge and quick learning were negatively correlated with undergraduate students' moral reasoning. After the hierarchical regression analysis was conducted, it was also revealed that undergraduate students' epistemic beliefs could explain considerable proportion of the total variance in moral reasoning scores above other variables of the study (i.e. gender, age, education and syllogistic reasoning). In particular, the dimensions of simple knowledge, certain knowledge, omniscient authority, and quick learning make unique contributions to undergraduate students' moral reasoning.

In another study reporting that there was a connection between the students' epistemological beliefs and solutions to deal with the everyday life dilemmas, Schommer and Dunnell (1997) studied with gifted high school students (n=69). The students' epistemological beliefs were obtained through the instrument including 63 items in Likert type developed by Schommer (1990), whereas their solutions to dilemmas regarding school and everyday life were obtained through the Dear Abby[1] letters and classified as "simplistic solution, fixed solution, blame other people solution, and scant solution" (p. 154). Regression analyses showed that students' epistemological beliefs (particularly the dimensions of fixed ability, quick learning and certain knowledge) predicted their solution types. More specifically, the students whose epistemological beliefs on these dimensions were strong tended to produce simplistic and unchanging responses as solutions to related dilemmas.

In another study from the first group researchers, Mason and Scirica (2006) examined to what extent students' argumentation skills could be predicted through their epistemological beliefs by controlling content knowledge and interest factors. For this purpose, eight grade students from two public middle schools in Italy (n=62) were asked to read the texts including two-sided information regarding two socioscientific issues (global warming and genetically modified organisms) and expected to generate arguments, counter-arguments and rebuttals as indicators of argumentation skills. For the scores, students' argumentation skills were assessed through 0-4 points rubric based on the validity and number of justifications and their domain-specific epistemological beliefs (i.e. judgments of personal taste, aesthetics, values, truth about the social world and truth about the physical world) were obtained through an instrument including 15 items developed by Kuhn et al. (2000). While 74.2% of the students displayed multiplist orientation, 25.8% of them were considered as evaluativists and none of the students in the study displayed absolutist

[1] Dear Abby is a newspaper column with lots of readers in the United States for giving advices to teenagers.

orientation. After the analyses, it was revealed that students' epistemological understandings significantly predicted their argumentation skills for all the indicators. More specifically, students who displayed evaluativist orientation presented higher quality of argumentation skills than the students who displayed multiplist orientation. In other words, evaluativists generated higher quality of arguments, counter-arguments and rebuttals for each SSI topic. From this empirical evidence, it was concluded that higher level of epistemological beliefs tends to reflect higher quality of argumentation skills. Further analyses also showed that *judgments of truth about the social world*, one of the domains of epistemological beliefs, was related to their counter-argument skills regarding both SSI, whereas it was also related to argument and rebuttal skills regarding genetically modified organisms. From this empirical evidence, it can be interpreted that the relationships between epistemological beliefs and students' argumentation skills may vary across different SSI.

Wu and Tsai (2011) investigated the relationships between high school students' scientific epistemological beliefs (SEB) and informal reasoning regarding nuclear power usage as SSI topic. Tenth grade students from two private high schools in Taiwan (n=68) constituted the participants of the study. The participants' SEB scores were obtained through the 26-items Likert type instrument developed by Conley et al. (2004), while their informal reasoning was obtained through a modified version of the open-ended questionnaire developed in their former study (Wu & Tsai, 2007). For the analyses, high school students' epistemological beliefs were basically assessed on four dimensions (i.e. source, certainty, development and justification), whereas their informal reasoning was analyzed through the integrated framework including both qualitative indicators (i.e. decision making mode, reasoning mode, reasoning quality) and quantitative measures (i.e. number of supporting arguments, counter-arguments, rebuttals and total number of arguments). It was revealed that students' scores were the highest on development (M=4.24, SD=0.49); followed by justification (M=3.98, SD=0.41), certainty (M=3.81, SD=0.53) and source (M=3.61, SD=0.64). When the students' informal reasoning was examined, it was revealed that students mostly used more than one supporting argument (M=1.25, SD=0.56) and counter-argument (M=1.18, SD=0.49), whereas they had difficulty to generate rebuttal (M=0.50, SD=0.66). Moreover, students could adopt more than two modes in their arguments and mostly generated science-oriented and technology-oriented arguments (M=1.09, SD=1.05); followed by ecology-oriented (M=0.81, SD=0.70), economic-oriented (M=0.74, SD=0.59) and social oriented (M=0.25, SD=0.47). Finally, correlational analyses revealed that justification and development dimensions of SEB were significantly correlated with the number of rebuttals generated by the students. That means, the students who recognize the importance of experiments to justify scientific knowledge; and the ones believe that scientific knowledge has a tentative and evolving nature tended to generate more rebuttals. According to Hofer and Pintrich (1997), justification of knowledge can be considered as a higher-quality process than general critical thinking and simple inductive-reasoning. Therefore, it may not be surprising that this higher quality of cognitive process may be the possible explanation behind the generation of more rebuttals, one of the most critical indicators for high quality arguments.

In their study, Oztuna Kaplan and Cavus (2016) adopted mixed method design to investigate the relationship between 8th grade students' epistemological beliefs and their perspectives regarding genetics-related SSI, namely biotechnological applications and genetic engineering implementations (e.g. genetically modified organisms and GM food). First, adapted version of Epistemological Beliefs Scale developed by Schommer (1990) was administered to the students (n=464) and the students were differentiated into two groups as the ones who displayed naive and sophisticated epistemological beliefs. Then, a sample of students' (n=25 for sophisticated, n=24 for naive epistemological beliefs) written responses to open-ended questions regarding genetics-related dilemmas were taken in the second phase of the study. After the analyses, it was revealed that the students who displayed sophisticated epistemological beliefs generated more comprehensive and versatile views including both beneficial and harmful aspects than the students who displayed naive epistemological beliefs. While the students whose epistemological beliefs were sophisticated tended to generate more detailed expressions, the ones whose epistemological beliefs were naive tended to generate shorter expressions without any interpretations. Moreover, sophisticated students were more likely to consider moral and ethical aspects while evaluating the issues than naive students.

More recently, Baytelman and colleagues (2018) investigated the potential contributions of preservice primary teachers' (n=240) epistemological beliefs to their informal reasoning regarding three different SSI: "usage versus non-usage of vaccines against a new flu virus", "consumption of bottled water versus tap water", "usage of underground versus overhead high voltage lines in residential areas" (p. 158). For this purpose, preservice primary teachers' (PSPTs) informal reasoning was obtained through modified version of open-ended questions developed by Wu and Tsai (2011), whereas their epistemological beliefs were obtained through an instrument based on five dimensions: certainty, simplicity and development for knowledge; source and justification for knowing. While the quantity of informal reasoning refers to the number of arguments, the quality of informal reasoning represents the scores ranges from 0 to 4 based on the analytical framework developed by Sadler and Fowler (2006). After the correlational analyses, it was revealed that simplicity was positively correlated with the number and quality of all three types of arguments (i.e. supportive arguments, counter-arguments and rebuttals); source were positively correlated only with the number of all three types of arguments; certainty and justification were positively correlated only with the quality of supportive arguments. Finally, there was no correlation between the dimension of development with any of the variables. Additionally, multiple regression analysis showed that only the dimension of simplicity significantly predicted PSPTs' quantitiy of the supportive arguments, counter-arguments and rebuttals. That means, PSPTs who believed that knowledge is not simple and it contains interrelated ideas and concepts rather than isolated pieces of information tended to greater number of supportive arguments, counter-arguments and rebuttals.

As an extension of the previous study, Baytelman and colleagues (2020) investigated whether the university students' (n=243) epistemological beliefs could predict their argumentation skills regarding the same three SSI as in the previous study (Baytelman et al., 2018). In order to collect data, the university students were expected to generate supportive arguments, counter-arguments and rebuttals from the perspectives of social, ethical, economic, scientific and ecological, whereas their epistemological beliefs were asssesed through 30-item DEBS instrument including five dimensions of epistemological beliefs (i.e. certainty, simplicity and development for knowledge; source and justification for knowing). While the quantity refers to the number of arguments, the quality represents the scores ranges from 0 to 4 based on the analytical framework developed by Sadler and Fowler (2006); and diversity refers to the number of arguments in different perspectives. Multiple regression analyses revealed that university students' epistemological beliefs, particularly the beliefs about structure of knowledge, could predict their argumentation skills in terms of quantity, quality and diversity. More specifically, university students who have sophisticated epistemological beliefs in the dimension of simple knowledge tended to generate greater number of, better quality and more diverse arguments. Additionally, further analysis revealed that the SSI-context also significantly predicted the quantity of supporting arguments, counter-arguments and rebuttals, but not for the quality and diversity.

As second group researchers indicating there is no relationship between epistemological beliefs, informal reasoning modes and quality of argumentation, Angeli and Valanides (2012) investigated the relationship between graduate students' (n=20) epistemological beliefs and quality of thinking on an ill-structured problem regarding the reunification of Cyprus as a complex geopolitical issue. While students' epistemological beliefs were obtained through the questions adapted from the work of King and Kitchener (1994), quality of thinking was obtained through their written arguments as working individually and in pairs. For the analyses, the researchers collapsed the six epistemological categories into three categories as absolutist, relativist and reflective thinking. Moreover, students' quality of thinking was differentiated into four types of thinking from simplistic to complex: level 1 presenting disconnected points of view; level 2 presenting monological points of view supported by superficial reasons; level 3 presenting monological points of view supported by deep reasons, level 4 presenting multilogical and critical thinking also including opposite points of view. In similar to other studies in the literature (Dawson & Venville, 2009; Georgiou & Mavrikaki, 2013; Kucukaydin, 2019; Osborne et al., 2004), students mostly fell in the level 2, that means, they generated points of view supported by simple reasons without considering opposite point of views. After the analyses, it was revealed that there were some cases in which students whose epistemological beliefs were found as more-sophisticated display low performance on solving the ill-structured issue, whereas students whose epistemological beliefs were less-sophisticated display high performance regardless of working individually or in pairs. From this empirical evidence, the researchers concluded that students' epistemological beliefs and quality of thinking did not display a systematic connection between them. In another study indicating that there was no systematic connection between these constructs, Topcu and colleagues (2010) studied with elementary pre-service teachers (n=96) in order to examine the relationship between their epistemological beliefs and moral reasoning. Epistemological beliefs of the elementary pre-service teachers were obtained through Schommer Epistemological Questionnaire including 63 items in Likert type, while their moral reasoning was assessed through Defining Issues Test (DIT) including dilemmas based on Kohlberg's theory of moral reasoning. In contrary to the researchers' expectation that simple knowledge, certain knowledge, quick learning and innate ability were found as correlated with moral reasoning, analyses revealed that there was no significant correlation between these constructs (i.e. epistemological beliefs and moral reasoning). With a similar finding, but in a different context, Mintchik and Farmer (2009) investigated the relationship between the senior accounting students' (n=140) epistemological beliefs and their moral reasoning in the context of business-related ethical dilemmas. In similar to the findings of the study conducted by Topcu et al. (2010), it was revealed that there was no correlation between the students' epistemological beliefs and moral reasoning in the context of accounting. The researchers indicated that "reflective thinking and moral reasoning represent separate dimensions of cognitive process which develop at a different pace and might require different pedagogy for its delivery" (Mintchik & Farmer, 2009, p. 267).

So far, the literature review regarding the relationship addressed in the present study has focused on the relationship between particularly individuals' epistemological beliefs, informal reasoning modes and quality of argumentation. With a similar but distinct construct, also beliefs about nature of science (NOS) focus on individuals' beliefs regarding science and scientific knowledge. While individuals' personal epistemological beliefs refer to beliefs about nature of knowledge and beliefs about nature of knowing (Hofer & Pintrich, 1997), NOS focuses on only one component (i.e. beliefs about nature of knowledge) of epistemological beliefs (Khishfe, 2012b). More specifically, NOS refers to the "beliefs concerning whether or not scientific knowledge is amoral, tentative, empirically based, a product of human creativity, or parsimonious reflect that individual's conception of the nature of science" (Lederman, 1992, p. 331). Although these constructs have unique characteristics mentioned above, they have also some common points such as the beliefs about nature of knowledge (Lederman, 1992). Therefore, since individuals' epistemological beliefs and orientations can be associated to NOS aspects by the aforementioned nature (Lederman, 1992), the studies focusing on the relationships between understanding of NOS, informal reasoning and quality of argument (Bell & Lederman, 2003; Irmak, 2021; Khishfe, 2012a; Khishfe, 2012b) were also taken into the extent of the present section.

Bell and Lederman (2003) investigated the relationship between individuals' NOS understandings and decision making on four complex socioscientific issues, namely fetal tissue implantation, global warming, the relationship between diet and cancer, and the relationship between cigarette smoking and cancer. Two groups of university professors and research scientists including the ones working science-related disciplines (n=10) and others did not (n=11) constituted the participants of the study. While the participants' understandings of NOS were assessed through The Views of Nature of Science (VNOS-B) Questionnaire, their decision making and reasoning patterns were obtained through the scenarios including some questions and follow-up interviews. In contrast to general trend, it was revealed that there were no differences between the groups' decision making and reasoning patterns although they displayed different views of NOS understanding. In other words, the researchers indicated that there was not a relationship between the individuals' understanding of NOS and decision making on complex SSI. Regardless of the NOS understanding, individuals mostly tended to base their decision making on personal values, social concerns and moral/ethical considerations.

Khishfe (2012a), examined the relationship between high school students' (i.e. 9th graders from four intact sections) understandings of NOS and decision making regarding genetically modified organisms through an explicit NOS instruction. After students' understandings of NOS were assessed through five open-ended questions based on "five target NOS aspects: the tentative, inferential (distinction between observation and inference), empirical, creative and imaginative, and subjective" (p. 77), their understandings of NOS were differentiated as naïve, intermediary and informed. Although the students' decisions regarding GMO did not differ after the treatment, the reasons to justify their decisions generated by the students in the treatment group differ, in favor of reflecting the aspects of NOS more, particularly empirical, tentative and subjective aspects of NOS. In other words, it was found a relationship between the students' understandings of NOS (i.e. understandings of empirical, tentative and subjective aspects) and their decision making while discussing a complex SSI.

In another study, Khishfe (2012b) also investigated the relationship between high school students' (n=219) understandings of NOS and argumentation skills regarding genetically modified organisms and water fluoridation. Students' understandings of NOS based on subjective, tentative and empirical aspects were classified as naïve, intermediary and informed, whereas their argumentation skills were assessed through two open-ended scenarios to elicit their arguments, counter-arguments and rebuttals. Correlational analyses revealed that many of the students who displayed informed understandings of NOS tended to generate more developed arguments. Although the correlations regarding water fluoridation were stronger than genetically modified organisms, counter-argument was the highest correlated component with the aspects of NOS regarding both topics. Since the ability to generate counter-arguments requires to consider alternative views, challenge the original views, evaluate the correctness of both original and opposing views, and recognize the importance of evidences (Khishfe, 2012b; Kuhn, 1991), it should not be surprising that generating counter-arguments were correlated with all aspects of NOS addressed in this study.

More recently, Irmak (2021) investigated the relationship between 8th grade students' NOS understandings (the tenets of empirical-based, subjectivity, and tentativeness) regarding three different SSI, namely, acid rain, genetically modified organisms and global warming. Multiple regression analyses revealed that all tenets of NOS understandings significantly predicted students' quality of informal reasoning regarding GMO and global warming, whereas only the tenets of empirical-based and tentativeness made significant contribution to the students' quality of informal reasoning regarding acid rain. In other words, the tenet of subjectivity did not have any significant power for predicting the students' quality of informal reasoning regarding acid rain.

When the studies focusing on the relationships between the individuals' epistemological beliefs or understandings of NOS, informal reasoning and argumentation skills were examined, it was easily seen that the literature presents some conflicting evidences although majority of the studies revealed a relationship between these constructs. Moreover, it was realized that most of the studies investigating relationships were conducted with older students (i.e. college and undergraduate students) and pre-service teachers. In other words, not much attention has been given to the relationships between the younger students' epistemological beliefs, informal reasoning and quality of argumentation. Therefore, the present study attempts to fill this gap of the literature by focusing on 7th and 8th grade middle school students.

2.9 Summary of the Literature Review

The general flow of the literature review was shown in Figure 2.3.

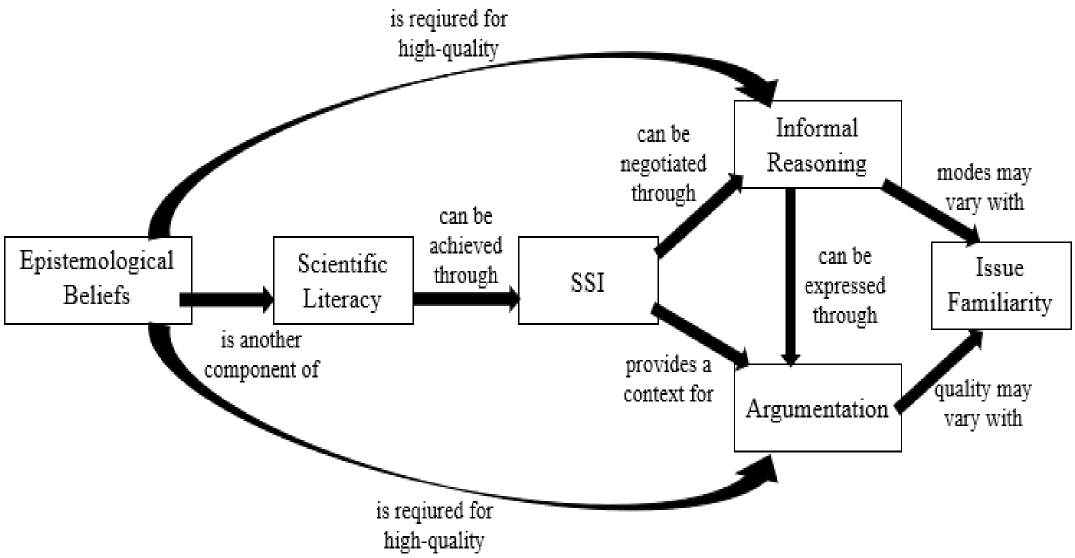

Figure 2.3 The general flow of the literature review

CHAPTER 3

METHODOLOGY

This chapter presents the methodological issues of the study. First, research design and participants are addressed. Then, instrumentation, ethical issues, data collection and analysis procedures, possible threats for internal validity and external validity are presented. Assumptions and limitations are also addressed.

The present study addressed the following research questions:

1. What are the middle school students' informal reasoning modes regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
2. What are the middle school students' argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
3. What are the middle school students' epistemological beliefs on the dimensions of source/certainty, development, and justification?
4. What are the middle school students' issue familiarity regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?
5. What are the relationships between the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes and argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

3.1 Research Design

The present study used a quantitative research design. According to Fraenkel and colleagues (2012, p. 331), the research type that aims to investigate "the relationships among two or more variables" is called as correlational research. Since the relationships between the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality regarding three different SSI were investigated in this study, correlational research design was utilized.

In order to obtain middle school students' informal reasoning modes and argumentation quality regarding different SSI, qualitative data were collected with open-ended questions and analyzed qualitatively first. Then, the qualitative data were scored and transformed into quantitative data through quantitizing process (Onwuegbuzie & Combs, 2011; Sandelowski et al., 2009) so that multiple regression analyses could be conducted. Since the data obtained from middle school students were analyzed both qualitatively and quantitatively, mixed data analysis was used in this study. This type of mixed data analysis has been also frequently used in the studies focusing on SSI (Baytelman et al., 2020; Irmak, 2021; Liu et al., 2010; Ozturk & Yilmaz-Tuzun, 2017; Wu & Tsai, 2011).

3.2 Participants

Target population of the present study was all 7th and 8th grade students from the public schools in Ankara, whereas the accessible population was determined as all 7th and 8th grade students from the public schools in five districts of Çankaya. Due to the COVID-19 pandemic, it was really hard to access the school administrators and teachers. Therefore, convenient sampling was used to obtain the sample. The students from eight middle schools in five different districts of Çankaya constituted the sample of the present study. Data were collected from two of these schools face-to-face, while data from six schools were collected through an online survey platform. In the face-to-face data collection phase, 324 of 391 middle school students completed the instrument, the response rate was found as 82.86%. In the online data collection phase, 141 of 1059 middle school students completed the instrument through the survey platform, the response rate was 13.31%. In total, over the 1450 middle school students, 465 of them (i.e. 324 face-to-face and 141 online) constituted the sample of the study with the 32.07% response rate. According to Fraenkel et al. (2012), at least 10% of the accessible population need to be reached in order to obtain a representative sample. The demographic information of the participants was presented in Table 3.1.

Table 3.1 Demographic Characteristics of the Sample

Characteristics	Type	(f)	(%)	PSSG* (f)	PSSG* M (SD)	PSSG* (Range)
Gender	Female	212	45.6	187	91.9 (9.5)	58-100
	Male	253	54.4	224	92.6 (9.2)	40-100
	Total	465	100.0	411	92.3 (9.4)	40-100
Grade Level	7th grade	252	54.2	225	92.7 (10.0)	40-100
	8th grade	213	45.8	186	91.8 (8.5)	63-100
	Total	465	100.0	411	92.3 (9.4)	40-100

*PSSG: Previous Semester Science Grades

As seen from the Table 3.1, the participants consisted of 212 females (45.6%) and 253 males (54.4%). While 252 of the students (54.2%) were in the 7th grade, 213 of them (45.8%) were in the 8th grade. When the science grades that the middle school students had in previous semester were examined, it could be interpreted that the sample of this study was quite successful in science course.

3.3 Instrumentation

The instrument used (see APPENDIX-A) in the data collection procedure includes four main parts: Demographic Information Form, Epistemological Beliefs Questionnaire, Socioscientific Issues Questionnaire (SSI Questionnaire) and Issue Familiarity Form. Each part of the instrument is explicitly addressed in the following sections.

3.3.1 Demographic Information Form

Demographic Information Form was used to obtain information about the middle school students' demographic characteristics. This part of the instrument included three items that aim to address gender (female or male), grade level (7^{th} or 8^{th} grade) and science grades that the middle school students had in previous semester.

3.3.2 Epistemological Beliefs Questionnaire

Epistemological Beliefs Questionnaire was used to obtain information about the middle school students' epistemological beliefs. The original version of the instrument was developed by Conley and colleagues (2004) and included 26 items in a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instrument included four dimensions of epistemological beliefs (source, certainty, development and justification) and these dimensions represented two general areas that constitute the core structures of personal epistemological theories (PET), namely beliefs about nature of knowledge and beliefs about nature of knowing (Hofer & Pintrich, 1997). More specifically, the dimensions of certainty and development constitute the beliefs about nature of knowledge; whereas the dimensions of source and justification constitute the beliefs about nature of knowing. The dimension of source includes five items (item 1, item 6, item 10, item 15 and item 19) and focuses on the beliefs regarding knowledge originated by an external authority compared to constructed by knower. The dimension of certainty includes six items (item 2, item 7, item 12, item 16, item 20 and item 23) and focuses on the beliefs regarding knowledge based on a single right answer compared to more than one right answer. The dimension of development includes six items (item 4, item 8, item 13, item 17, item 21 and item 25) and focuses on the beliefs regarding fixed and absolute knowledge compared to changing and evolving knowledge. The dimension of justification includes nine items (item 3, item 5, item 9, item 11, item 14, item 18, item 22, item 24 and item 26) and focuses on knowledge without justification compared to the role of using data and evidences to support the arguments, and evaluating claims. Cronbach's alpha values for each dimension of EBQ developed by Conley and colleagues (2004) range from .57 to .81 before the nine-week science unit (Time 1) and from .66 to .82 after the intervention (Time 2).

The instrument was translated and adapted into Turkish by Ozkan (2008). Two items (item 2 and item 7) having negative item-total correlation were excluded from the questionnaire. After removing these items, the total reliability of the instrument with 24 items was found as 0.76. In contrast to Conley and colleagues (2004), Ozkan (2008) reported that three factors were extracted based on exploratory factor analysis (EFA): the dimensions of source/certainty, development and justification. Since the items from the dimensions of source and certainty loaded on a single factor, these dimensions were considered as a single factor called as the dimension of source/certainty. The reliability analysis provided sufficient Cronbach alpha values for each dimension as .70 for source/certainty, .59 for development, and .77 for justification. In the present study, adapted version of EBQ with 26 items was administered.

3.3.2.1 Factor Structure of Epistemological Beliefs Questionnaire (EBQ)

In this study, in order to examine the factor structure of EBQ and ensure the construct validity, an exploratory factor analysis (EFA) was conducted using IBM SPSS Statistics 28. Before conducting EFA, there were some assumptions needed to check in order to determine whether the data were appropriate for factor analysis or not. These assumptions were sample size, factorability of the correlation matrix, linearity and outliers among cases (Pallant, 2011).

1. Sample Size: According to Tabachnick and Fidell (2013), the sample should consist of at least 300 cases to conduct factor analysis. Pallant (2011) also recommended that at least 150 cases are required for a factor analysis. In addition to the recommendations regarding the overall sample size, some

authors reported that the ratio of cases to items should be also considered. Nunnally (1978, as cited in Pallant, 2011) suggested “a 10 to 1 ratio; that is, ten cases for each item to be factor analyzed” (p. 183). Since 465 cases (i.e. middle school students) completed EBQ in this study, this assumption was met.

2. Factorability of the correlation matrix: According to Pallant (2011), correlation matrix should include at least some correlations of r=.3 or greater. Unless (i.e. in case of not finding any correlations above .3), the factor analysis for the related data-set should be reconsidered. When the related correlation matrix was examined, many correlations above .3 were determined. Moreover, “Bartlett’s test of sphericity should be statistically significant at $p < .05$ and the Kaiser-Meyer-Olkin value should be .6 or above” (p. 187). Since the Bartlett’s test of sphericity was found as statistically significant with $p = .00$ and KMO value was .93 which is above the value 0.6, this assumption was also met.

3. Linearity: In order to meet the linearity assumption, the relationship between the variables should be linear since factor analysis is based on correlation (Pallant, 2011). Pallant (2011) indicated that if the overall sample size and the ratio of cases to items are adequate, it is comforting to meet the linearity assumption. Since the present study had an adequate overall sample size and a ratio of cases to items, the linearity assumption was also met.

4. Outliers among cases: Since the factor analysis is sensitive to outliers (Pallant, 2011), it was needed to check the existence of outliers before conducting EFA. When the related data-set was examined, it was determined no outliers because of wrong data entry or unnatural responses, hence this assumption was also met.

After checking the assumptions, EFA was conducted with principal components analysis (PCA) as an extraction method and varimax (orthogonal) rotation. For the analysis, the number of factors was not restricted and the cut-off point for the eigenvalue was determined as 1.00. As a result, three factors above this cut-off point and explaining 47.291% of the total variance were extracted. Since the fourth factor had an eigenvalue of .981, this factor was not included. The three factors extracted from EFA were presented in Table 3.2.

Table 3.2 Factors Extracted from EFA with Related Percentages

Factor	Eigenvalue	% of variance	Cumulative %
1	7.790	29.961	29.961
2	3.251	12.503	42.464
3	1.255	4.827	47.291

According to Pallant (2011), Cronbach's Alpha coefficient is one of the most commonly used indicators of internal consistency and should be above .7 for a scale. The value of Cronbach's Alpha coefficient was obtained as .887 for the total reliability of EBQ with 26 items. However, as can be seen from the Table 3.3, item 7 had negative item-total correlation (-.015), hence it was removed from the analysis. After removing the item 7, the total reliability of EBQ increased from .887 to .896.

Table 3.3 Item-Total Statistics for EBQ

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
re*item1	96,34	162,143	0,288	0,327	0,887
reitem2	96,71	162,058	0,253	0,225	0,889
item3	96,07	159,917	0,443	0,348	0,883
item4	96,37	158,633	0,476	0,347	0,882
item5	95,94	157,152	0,538	0,436	0,881
reitem6	96,31	158,748	0,419	0,311	0,884
reitem7**	97,60	169,935	-0,015	0,208	0,896
item8	96,44	157,751	0,500	0,366	0,882

Table 3.3 (cont'd)

item9	96,04	155,658	0,599	0,506	0,880
reitem10	96,66	160,169	0,353	0,340	0,886
item11	96,25	158,332	0,532	0,429	0,881
reitem12	95,94	153,482	0,608	0,436	0,879
item13	95,96	156,289	0,540	0,400	0,881
item14	95,96	155,623	0,598	0,576	0,880
reitem15	97,04	164,843	0,235	0,319	0,888
reitem16	96,69	159,417	0,408	0,372	0,884
item17	96,05	156,271	0,647	0,532	0,879
item18	95,97	155,288	0,608	0,606	0,879
reitem19	96,16	154,904	0,583	0,444	0,880
reitem20	96,21	158,087	0,471	0,320	0,883
item21	96,51	162,707	0,320	0,289	0,886
item22	96,02	155,366	0,589	0,442	0,880
reitem23	96,45	156,170	0,509	0,382	0,882
item24	96,20	158,633	0,525	0,441	0,882
item25	96,21	161,595	0,447	0,362	0,883
item26	95,99	157,056	0,523	0,513	0,881

*re: revised items

**the items that have negative item-total correlation

As can be seen from Table 3.4, Factor 1 represented the dimension of justification, Factor 2 represented the dimension of source/certainty, also stated by Ozkan (2008), and Factor 3 represented the dimension of development. Although most of the items quite strongly (above .4) loaded on the related factors, some of them loaded on a different factor that they originally do not belong to. More specifically, Factor 1 included the items of justification dimension with three additional items which are item 12, item 13 and item 17, originally belong to the dimension of source/certainty (item 12) and development (item 13 and item 17). Factor 2 included the items of source/certainty dimension with one missing item (item 12). Factor 3 included the items of development dimension with two missing items (item 13 and item 17). The related factor loadings were presented in Table 3.4.

Table 3.4 Factor Loadings for Three Factors (26 items with PCA and Varimax Rotation)

Items	Factor 1	Factor 2	Factor 3
item14	0,798		
item18	0,786		
item26	0,738		
item5	0,677		
item9	0,649		
item22	0,639		
item24	0,632		
item13**	0,620		
item11	0,614		
item3	0,606		
item17**	0,605		0,421
reitem12**	0,521	0,479	
re*item7	-0,407	0,373	
reitem16		0,663	
reitem15		0,660	
reitem1		0,628	
reitem10		0,621	
reitem19		0,613	
reitem23		0,608	
reitem6		0,597	
reitem2		0,539	
reitem20		0,508	
item4			0,644
item21			0,587
item8			0,579
item25			0,529

*re: revised items

**The items that loaded on a different factor that they originally do not belong to.

Final EFA with 24 items (i.e. after removing item 7 and 13) was conducted using PCA as an extraction method and varimax (orthogonal) rotation. As a result, three factors above the cut-off point (1.00) and explaining 48.666% of the total variance were extracted. The scree plot that indicated a sharp break after the third factor also supported this decision. The related scree plot was presented in Figure 3.1.

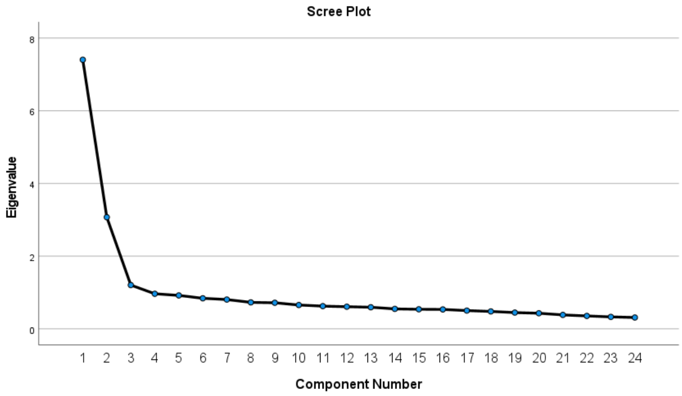

Figure 3.1 Scree plot regarding the factor structure of EBQ

Factor loadings regarding the EFA with 24 items using PCA and varimax rotation were presented in Table 3.5.

Table 3.5 Factor Loadings for Three Factors (24 items with PCA and Varimax Rotation)

Items	Factor 1	Factor 2	Factor 3
item14	0,795		
item18	0,790		
item26	0,749		
item9	0,672		
item5	0,671		
item22	0,642		
item11	0,635		
item3	0,621		
item24	0,620		
item17	0,601		0,425
re*item12	0,514	0,487	
reitem15		0,669	
reitem16		0,664	
reitem1		0,638	

Table 3.5 (cont'd)

reitem10	0,622	
reitem23	0,609	
reitem19	0,609	
reitem6	0,601	
reitem2	0,535	
reitem20	0,516	
item4		0,659
item8		0,620
item21		0,599
item25		0,587

*re: revised items

After removing aforementioned two items (item 7 and 13) from the analysis, total reliability of EBQ was found as .890. The final dimensions of EBQ, items belonging to these dimensions and related Cronbach's alpha values were presented in Table 3.6.

Table 3.6 The Dimensions of EBQ, Items, and Related Cronbach Alpha Values

Core structure of PET*	Dimensions	N	Items	Sample Item	Cronbach's alpha values
Nature of Knowing	Justification	9	3, 5, 9, 11, 14, 18, 22, 24, 26	Good answers are based on evidence from many different experiments.	.888
Nature of Knowing & Nature of Knowledge	Source/Certainty	10	1, 2, 6, 10, 12, 15, 16, 19, 20, 23	Everybody has to believe what scientists say.	.818
Nature of Knowledge	Development	5	4, 8, 17, 21, 25	The ideas in science books sometimes change.	.740

*PET: Personal Epistemological Theories

According to Pallant (2011), the value of Cronbach's alpha can be low (e.g., .5) due to the low number of items in the short scales. Therefore, the Cronbach's alpha values for the dimensions of justification and source/certainty were relatively higher than the value for the dimension of development.

The three-factor structure obtained from the final EFA was examined through confirmatory factor analysis (CFA). IBM AMOS 24 was used to conduct CFA and test the proposed model. Several model fit indices were used to assess goodness of fit of the CFA indicating the validity of the factor structure. Moreover, Chi-square statistics, CFI, GFI, AGFI, RMSEA, RMR, and SRMR were used to determine the validity of the specified models. The model fit indices used as criteria for the goodness of fit and recommended values were presented in Table 3.7. Examination of the model fit indices obtained from CFA indicated that the initial model moderately fit the data for this sample (χ^2/df = 2.59, GFI = .89, AGFI = .87 CFI = .90, RMSEA = .06, RMR = .07, SRMR = .08). The initial model was presented in APPENDIX E.

Table 3.7 Model Fit Indices and Recommended Values for Goodness of Fit

Model Fit Index	Recommended Value for Good Fit	Reference
χ^2	> .05 (non-significant)	Tabachnick & Fidell (2007)
χ^2 /df (CMIN/df)	≤ 5 $2 \leq \chi^2/\text{df} \leq 3$ *	Erkorkmaz et al. (2013) *; Sumer (2000)
CFI	$\geq .90$	Sumer (2000); Tabachnick & Fidell (2007)
GFI	$\geq .90$	Joreskog & Sorbom (1993); Sumer (2000)
AGFI	$\geq .85$	Erkorkmaz et al. (2013)
RMSEA	$\leq .08$	Browne & Cudeck (1993)
RMR	$\leq .08$	Hu & Bentler (1999); Schreiber et al. (2006)
SRMR	$\leq .08$	Hu & Bentler (1999); Schreiber et al. (2006)

Considering the initial results, some modifications were made to propose a revised model presenting a good-fit to the data. For this purpose, Modification Index (MI) and Expected Parameter Change (Par change) that recommend some possible error covariances between the variables were examined. In parallel to these suggestions provided by IBM AMOS, three error covariances between the variables (e1 and e2; e1 and e6; e15 and e16) were added to the model. After adding these error covariances, the model presented a good-fit to the data with the acceptable fit indices (χ^2/df = 2.41, GFI = .90, AGFI = .88, CFI = .91, RMSEA = .55, RMR = .69, SRMR = .73). With the help of this modification, all the fit indices were within the recommended values except that the chi-square was significant (p = .00). Schumacker and Lomax (2010) stated that "The χ^2 model-fit criterion is sensitive to sample size because as sample size increases (generally above 200), the χ^2 statistic has a tendency to indicate a significant probability level" (p. 86). In the present study, since the CFA model was tested with 465 middle school students, significant chi-square was not considered as a problem for interpreting the results of CFA. The revised model was presented in APPENDIX F.

3.3.3 Socioscientific Issues Questionnaire (SSI Questionnaire)

Socioscientific Issues Questionnaire was developed by the researchers. This part of the instrument included three different socioscientific issues: *Space Explorations (SPE)*, *Genetically Modified Organisms (GMO)*, and *Nuclear Power Plants (NPP)*. The selected SSI played a central role in this study since they provided contexts to reveal the middle school students' informal reasoning modes and argumentation quality. The reasons behind the selection of these particular SSI were the controversial nature of SSI and the consistency with Turkish middle school science curriculum. Each SSI was presented through a scenario including two open-ended questions and accompanying with two items in a 3-point Likert scale.

Each SSI scenario and accompanying questions were presented on the separate pages of the instrument. Each scenario and questions were developed by the researchers utilizing the works of Chang and Chiu (2008). While developing the scenarios and the related questions, the sequence in the study of Chang and Chiu (2008) was taken into consideration. Each scenario and the related questions were presented in the following structure: (1) background information regarding the related SSI; (2) presenting the dilemma, and (3) questions asked to obtain students' informal reasoning modes and argumentation quality including their Hard Core (HC), Positive Heuristics (PH) and Negative Heuristics (NH). The structure of SSI scenarios was presented in Figure 3.2.

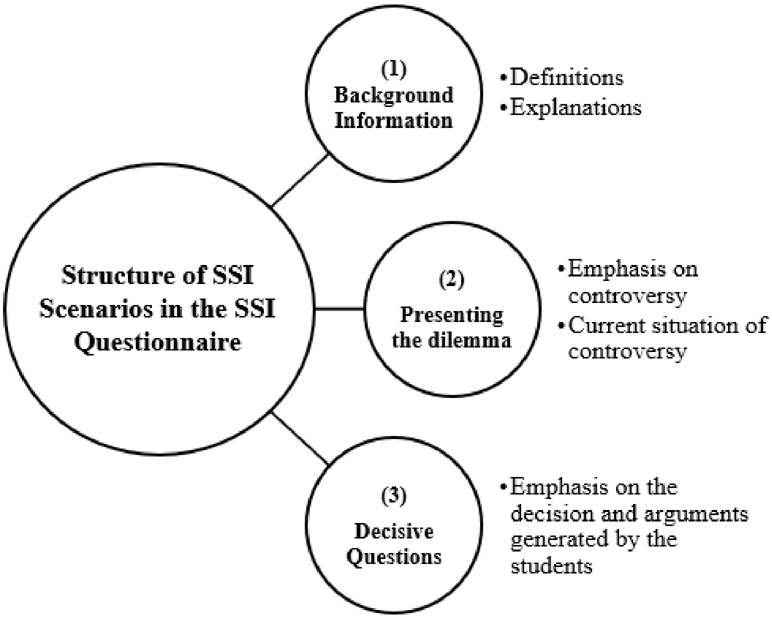

Figure 3.2 Structure of SSI scenarios in the SSI Questionnaire

In the background information part, definitions required to negotiate the related SSI were presented as background information. In the presentation of dilemma part, each SSI was explicitly presented so that the students were easily able to detect the related dilemma. In the decisive questions part, a question that encourages students to generate their own arguments regarding the related SSI was provided. With this question, students were expected to select one of the sides (i.e. for or against) and provide supporting reasons to justify their positions. After the first question, students were asked to rate their degree of certainty out of 3 (1: I am not sure, 2:

Neutral/Undecided, 3: I am totally sure.) by considering their decisions in order to explore to what extent they were sure of their decisions. After this 3-point Likert type item, the second question “What would a person against to your position tell you in order to defend her/his position?” was asked to students and they were expected to generate counter-arguments against to their positions. In contrary to the study of Chang and Chiu (2008) asking students to rate the best argument by considering their priority of acceptance, the present study assessed the students’ evaluation skills with an additional item. After the second open-ended question was asked, students were again expected to rate their degree of certainty out of 3 (1: I am not sure, 2: Neutral/Undecided, 3: I am totally sure) by considering both their own decisions and the counter-arguments in order to explore to what extent they were sure of their decisions after they considered counter-arguments and alternative points of view. In other words, the present study intended to determine students’ argument evaluation skills by providing them to evaluate both their own arguments and counter-arguments. In this way, the researchers aimed to understand whether the students were able to generate protective belt (PB) or not.

For the content validity of SSI-Questionnaire, experts’ opinions were taken. Experts included three faculty members from the department of Mathematics and Science Education, and one experienced science teacher. In addition to the experts in the field of science education, an assistant professor from the department of Turkish Language checked the instrument in terms of grammar and punctuation to ensure the content validity. Information regarding fair presentation of different perspectives on SSI and appropriateness for the students’ level by considering the science curriculum was taken from these experts. Based on these experts’ opinions, necessary revisions were made and the scenarios were finalized.

After the scenarios were finalized, a pilot study was conducted with 14 participants including 7^{th} and 8^{th} grade students. The aim of the pilot study was to test content and construct validity of SSI Questionnaire. Based on the data obtained from the pilot study, several changes were applied to the SSI Questionnaire.

First, the heading of the "Space Debris" scenario was changed. When the middle school students' written arguments regarding Space Debris were examined, it was observed that the term "debris" may lead the students' reasoning towards a negative position. Since space debris and space pollution terms are used interchangeably in Turkish language, pollution term seemed to evoke some negative notions for the students. Therefore, "Space Debris" heading was replaced with "Space Explorations" and content of the related scenario was changed into more neutral position.

Second, the pilot study revealed that students could not find an opportunity to evaluate different arguments and alternatives, that means they were not expected to exhibit their argument evaluation skills (i.e. fifth indicator of argumentation). Therefore, there was a need an additional question in order to assess the students' ability to weight their own arguments and counter-arguments. In parallel to this need, a second question and accompanying sub-question were added to the SSI Questionnaire. The second question were "What would a person against to your position tell you in order to defend her/his position?" in order to assess the students' ability to generate counter-arguments or limitations (i.e. Negative Heuristics in the analytical framework adopted for the present study). After this question, students were again asked to rate their degree of certainty out of 3 (1: I am not sure, 2: Neutral/Undecided, 3: I am totally sure) by considering both their own decisions and the counter-arguments in order to explore to what extent they were sure of their decisions after they considered counter-arguments and alternative points of view. In this way, the researchers aimed to understand whether the students were able to generate protective belt (PB) or not.

Final change was related to the expression of the second open-ended question. The first form of the question was "How would a person against to your position defend her/his own position?". By asking this question, it was intended the students to present counter-arguments or limitations of the original position regarding the related SSI. However, the pilot study analysis revealed that some students stated the ways of defense like "doing experiments", "politely expressing opinions" or “presenting evidences” rather than generating counter-arguments. Therefore, in order to clarify the question, the term “how” was removed from the question and it was changed into “What would a person against to your position tell you in order to defend her/his position?”. In this way, the second question focused on the statements that a person would say as a counter-argument instead of the ways of justification.

To ensure the reliability of SSI-Questionnaire, inter-coder reliability method was used. With this method, a sample of the data (25%) obtained from the middle school students were coded by both the researcher herself and a PhD researcher experienced in the field of argumentation in science education. After the sample of data were coded independently, inter-coder reliability was calculated as .92 with the help of IBM SPSS Statistics 28. Then, disagreements on the inconsistent codes were resolved by consultation of the related data. After the researchers reached a consensus, rest of the data were coded by only the researcher herself.

3.3.4 Issue Familiarity Form

Issue Familiarity Form was developed by the researchers utilizing from several studies (Garrecht et al., 2021; Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017). According to Garrecht and colleagues (2021), issue familiarity was regarded as “the knowledge about an issue” (p. 5), and individual factors (e.g. students’ motivation to learn the related SSI) also play a role in students’ familiarity. Therefore, students’ level of knowledge, level of interest, and willingness (i.e. to learn; to read and research; to do project) were included as items in Issue Familiarity Form. Moreover, several researchers also indicated that individuals’ familiarity regarding an issue might come from mass media such as newspaper, the Internet, television (TV), news, and advertisements (Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017). Therefore, students’ sources of information were also added to Issue Familiarity Form. In this way, this part of the instrument included 14 items (15 items with an additional item for SPE topic) in a 3-point Likert scale (1: Never, 2: Little, 3: Much) for each SSI. These items were prepared to obtain the middle school students' level of knowledge (e.g. I am knowledgeable regarding SPE), level of interest (e.g. I am interested in GMO), willingness to learn; read and research; and do project, and sources of information, namely, family, friends, teacher (e.g. I learn information regarding NPP from my teacher), textbooks , social media (Facebook, Twitter, Instagram, Youtube, etc.), newpapers and journals, television, students' own observations and experiences. The issue familiarity scores obtained from Issue Familiarity Form was used as a predictor of students' informal reasoning modes and argumentation quality across different SSI, namely, space explorations, GMO, and nuclear power plants.

To ensure the reliability, a pilot study was conducted with 14 participants including 7th and 8th grade students. As seen from Table 3.8, all the Cronbach's alpha values were found above the recommended value .7 (Pallant, 2011) and considered as acceptable for the reliability of Issue Familiarity Form.

Table 3.8 Cronbach's Alpha Values for Each Issue Familiarity Form (Pilot Study)

Topic	N	Number of items	Cronbach's alpha values
Space Explorations	14	15	.844
Genetically Modified Organisms	14	14	.819
Nuclear Power Plants	14	14	.872

Table 3.9 Cronbach's Alpha Values for Each Issue Familiarity Form (Main Study)

Topic	N	Number of items	Cronbach's alpha values
Space Explorations	460	15	.783
Genetically Modified Organisms	456	14	.869
Nuclear Power Plants	455	14	.871

For the reliability, Cronbach's Alpha values for each Issue Familiarity Form administered in the main study were also calculated and presented in Table 3.9. As seen from Table 3.9, all the Cronbach's alpha values were found above the recommended value .7 (Pallant, 2011) and considered as acceptable for the reliability of Issue Familiarity Form.

3.4 Ethical Issues in the Study

First, since the instrument used in the data collection procedure included Epistemological Beliefs Questionnaire translated and adapted into Turkish by Ozkan (2008), it was needed to receive an approval to use Turkish version of the instrument. The related permission obtained was given in APPENDIX B. Second, since the present study was conducted with middle school students (7^{th} and 8^{th} grade students), before the data collection procedure, it was needed to receive an approval from the Human Subjects Ethics Committee in the METU. While one of the received approvals was attached in the APPENDIX C, the other one was presented for the approval from the Ministry of National Education (see APPENDIX-D). Consent form was signed by both parents and students. All middle school students participated in the study based on voluntary participation.

3.5 Data Collection Procedure

Before data collection procedure, a pilot study was conducted. The aim of the pilot study was to test (a) content validity, (b) construct validity, and (c) the students' average time to complete the instrument. Before the pilot study was conducted, required approvals were taken. Due to the COVID-19 pandemic, the instrument was administered through an online platform although it was designed in a paper-pencil format. The pilot study was conducted with only 14 participants including 7^{th} and 8^{th} grade students in the 2019-2020 Summer period. The participants for the pilot study consisted of eleven females (78.6%) and three males (21.4%). While four of the students (28.6%) were in the 7th grade, ten of them (71.4%) were in the 8th grade. The students' previous semester science grades were obtained as range from 62.00 to 100.00 with a mean of 84.28 (SD=11.58). Also, the middle school students' time to complete the instrument ranges from 6.00 to 38.41 minutes with a mean of 19.71 minutes (SD=9.78). In the light of this finding, it was revealed that one lesson period (30 minutes) was adequate for the students to complete the instrument. Therefore, there was no need to separate the instrument into more than one part for different sessions.

For the main data collection procedure, the researcher administered the instrument in the Fall Semester of 2020-2021 school year. Although majority of the participants (69.7%) completed the survey in their natural classroom environment, 30.3% of them had to complete it online due to the restrictions of COVID-19. During face-to-face data collection phase, the students' regular classroom teachers were in the classroom and the students completed the instrument individually. Before administering the instrument in the classes, the classroom teachers were informed in order to ensure that all the teachers could administer the instrument under the same standard conditions. Therefore, one of the internal validity threats, data collector characteristics, was controlled. The instrument was administered in one lesson period and a single session. In addition, the administration time was tried not to be coincided immediately before and after the students' meal time and exam dates in order to eliminate the unintended effects of other variables. During online data collection phase, an online survey platform, SurveyMonkey, was used to administer the instrument. The online survey was delivered to students through the school administrations and teachers. Like face-to-face data collection phase, teachers were informed about the administration of instrument.

3.6 Data Analysis Procedure

This section consisted of five main analysis procedures: *Informal Reasoning Modes Analysis*, *Argumentation Quality Analysis*, *Epistemological Beliefs Analysis*, Issue

Familiarity Analysis and *Multiple Regression Analyses*. Each data analysis procedure is respectively presented in detail.

Before data analysis procedure, independent sample t-tests were conducted to examine whether there was a difference between the data collected face-to-face and online. Since the data collected face-to-face and online did not differ significantly, pooled data was used to conduct further descriptive and inferential analyses.

3.6.1 Analysis for Informal Reasoning Modes (RQ1)

In this study, middle school students' informal reasoning modes across three different SSI were obtained through their written arguments as responses to SSI Questionnaire. The middle school students' written arguments were analyzed based on the SEE-SEP Model developed by Chang Rundgren and Rundgren (2010). The detailed information regarding the SEE-SEP Model is addressed in the following sections.

3.6.1.1 SEE-SEP Model as an Analytical Framework

The holistic model of SEE-SEP represents an acronym that includes the first letters of subject areas covered in the model. The subject areas of sociology/culture (S), environment (E), economy (E), science (S), ethics/morality (E) and policy (P) constitute the model. The model includes aforementioned six subject areas and accompanying three aspects (i.e. knowledge, value and personal experience). Moreover, another purpose of using the abbreviation "SEE-SEP" is to provide individuals to examine (or see) SSI from "separate" perspectives in order to emphasize the importance of multidimensional nature of SSI. Figure 3.3 given below presents the visual representation of SEE-SEP Model including six subject areas and accompanying three aspects.

The visual representation of SEE-SEP Model reflects the aforementioned features of socioscientific reasoning (SSR). On the top of SEE-SEP Model, the researchers made an analogy between a benzene structure that contains six-membered ring of carbon atoms and six subject areas of the model. This analogy represents the features of complexity and multiple perspectives of SSR. More specifically, a circle with two arrows moving in opposite directions was used to emphasize that individuals should evaluate SSI from multiple perspectives in a more comprehensive way. The circle with arrows in the middle of the model also represents the uncertainty feature of SSI by combining the features of skepticism and ongoing inquiry. Under the benzene structure, there was a root including three aspects (i.e. knowledge, value and personal experience) that individuals base their decisions. As a whole, the researchers visualize the model as a diamond structure.

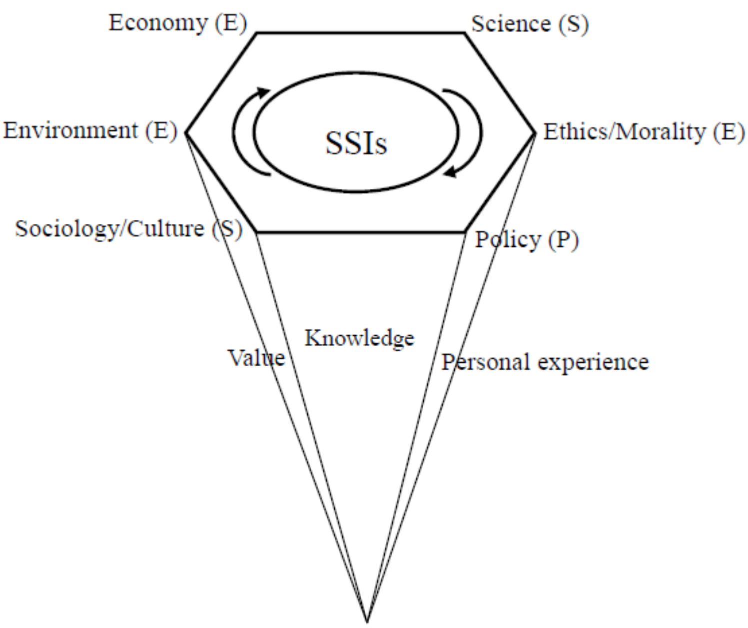

Figure 3.3 The visual representation of SEE-SEP Model. Adopted from “SEE-SEP: From a separate to a holistic view of socioscientific issues” by S. N. Chang-Rundgren and C. J. Rundgren, 2010, Asia-Pacific Forum on Science Learning and Teaching, 11(1), p. 11.

3.6.1.1.1 Subject Areas (SEE-SEP)

In the extent of SEE-SEP Model, there are six different subject areas, namely "*sociology/culture (S), environment (E), economy (E), science (S), ethics/morality (E) and policy (P)"* (Chang Rundgren & Rundgren, 2010, p. 10). In parallel to the previous studies adopting the SEE-SEP Model as analytical framework, the statements including some keywords were considered as a reflection of certain subject areas. The related information including the keywords and some examples taken from the main data collection of the present study were presented in Table 3.9.

In the Table 3.9, the first number that can vary from 001 to 465 indicates the unique number given for the participants. The letter following the first number refers to gender of the participants as "F" for female and "M" for male. The number following the letter represents grade level of the participants as "7" for 7th graders and "8" for the 8th graders. Finally, the last letter refers to SSI topic as "S" for space explorations, "G" for genetically modified organisms, and "N" for nuclear power plants. For instance, 154F7N refers to a 7th grade female student's (154th participant of the study) argument regarding nuclear power plants.

Table 3.9 The Subject Areas, Related Keywords and Some Examples from Middle School Students' Written Arguments.

Subject Areas	Keywords	Examples from the Main Study
Sociology/ Culture	the God (religion), developed/developing countries.	**408F7G:** No, it [GMO] should not be used. If they had to be genetically modified, the God would have created them that way.
Environment	environment, livings (animals, plants, etc.), nature.	**060M8N:** Nuclear power plants are very harmful to the environment, they may harm the nature.

Table 3.9 (cont'd)

Economy	cheap/expensive, financial/economic, cost foreign-source (external) dependency	**079M7N:** I think, it [nuclear power plant] should be built, because electrical energy is a financially challenging issue for Turkey. If the installation takes place, electricity can be cheap.
Science	science, scientists scientific knowledge, uncertainty, unexpected result	**158F8S:** Turkey should continue space explorations because science is always an issue that needs to give priority.
Ethics/Morality	next generations, ethical/unethical, right/wrong to do sth	**419F8G:** It should not be used, … if we want to entrust the future to next generations, I think that GMO products would not be a good choice.
Policy	government, forbidden, convention (contract between states), war/terrorism	**049M8G:** GMO must be produced under government control.

3.6.1.1.2 Aspects (KVP)

In the extent of SEE-SEP Model, there are three different aspects that the students' arguments may be based on. These aspects are *knowledge (K), value (V) and personal experience (P)*. The students whose decisions are based on the aspect of knowledge focus on the concepts, theories, principles, laws and evidences. Students whose decisions are based on the aspect of value focus on affective constructs including attitudes, beliefs, values and affections. Students whose decisions are based on the aspect of personal experience focus on personal experiences such as past practices or familiarity.

3.6.1.1.3 Codes Obtained from the Combinations of Subject Areas and Aspects

In the extent of SEE-SEP Model, codes are obtained from the binary combination of the subject areas and aspects addressed in the previous sections. Since there are six subject areas and three aspects, a total 18 codes are obtained from their binary combinations (see Figure 3.4 Binary combinations of the subject areas and aspects).

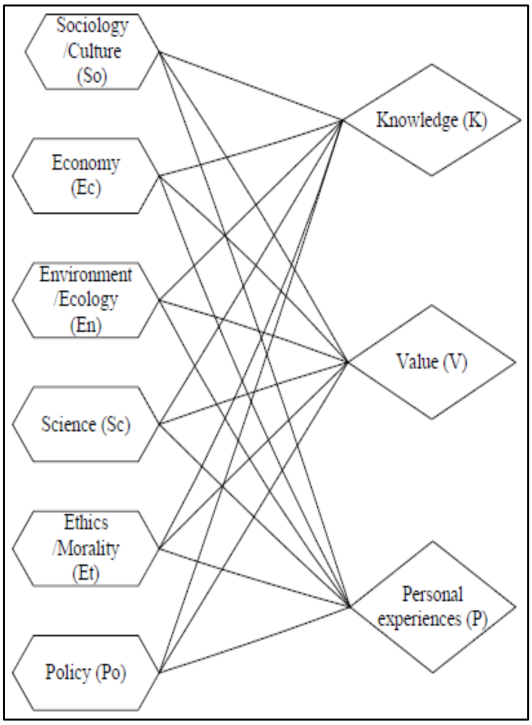

Figure 3.4 Binary combinations of the subject areas and aspects. Adopted from "SEE-SEP: From a separate to a holistic view of socioscientific issues" by S. N. Chang-Rundgren and C. J. Rundgren, 2010, Asia-Pacific Forum on Science Learning and Teaching, 11(1), p. 16.

As a result of the binary combination, *SoK*, *SoV*, *SoP*, *EcK*, *EcV*, *EcP*, *EnK*, *EnV*, *EnP*, *ScK*, *ScV*, *ScP*, *EtK*, *EtV*, *EtP*, *PoK*, *PoV*, and *PoP* codes are obtained. To reveal the students' informal reasoning modes, their written arguments were analyzed based on these codes. To clarify the analysis procedure, description of codes and some example arguments taken from the main data collection of the present study were presented in the Table 3.10.

Table 3.10 Description of the Codes and Some Examples from the Main Study

Code	Description	Examples from the Main Study
SoK	Students focus on concepts, theories, principles, laws and evidences from the sociology/culture subject area to support their arguments.	**251F7S:** It [space explorations] should be continued. Because Turkey is a developing country and it needs to work in order to develop.
SoV	Students focus on affective elements including attitudes, beliefs, values and affections from the sociology/culture subject area to support their arguments.	**269M8S:** Certainly, space explorations in Turkey should continue. As Turkish nation, we should continue to research by doing our best and what we can do.
SoP	Students focus on personal experiences such as past practices or familiarity from the sociology/culture subject area to support their arguments.	**316F8G:** It [GMO] should never be used. … Also, we try not to consume these products in the family.
EcK	Students focus on concepts, theories, principles, laws and evidences from the economy subject area to support their arguments.	**168M8N:** Turkey imports a large part of its electrical demand, it [nuclear power plants] should be built to prevent this.
EcV	Students focus on affective elements including attitudes, beliefs, values and affections from the economy subject area to support their arguments.	**200M7S:** I think it [space explorations] should be continued. Because I think that space explorations will play a big role in reducing Turkey's foreign dependency.
EcP	Students focus on personal experiences such as past practices or familiarity from the economy subject area to support their arguments.	In this study, this code was not generated by the students.

Table 3.10 (cont'd)

EnK	Students focus on concepts, theories, principles, laws and evidences from the environment subject area to support their arguments.	**019F8N:** I think, it [nuclear power plants] should be built. … There are electric cars, we can use them, the use of oil decreases, environment and air pollution decreases.
EnV	Students focus on affective elements including attitudes, beliefs, values and affections from the environment subject area to support their arguments.	**187M7N:** It should not be built because it takes away our nature and trees.
EnP	Students focus on personal experiences such as past practices or familiarity from the environment subject area to support their arguments.	In this study, this code was not generated by the students.
ScK	Students focus on concepts, theories, principles, laws and evidences from the science subject area to support their arguments.	**321F8G:** It [GMO] should be used. Because some of the GMO products are used for useful purposes, for example, if we transfer the gene we get from a cold-resistant plant to the tomato so that the tomato can survive in the cold, its yield will increase.
ScV	Students focus on affective elements including attitudes, beliefs, values and affections from the science subject area to support their arguments.	**327F8G:** It [GMO] should be used because genetic engineers know the best, so I trust them.
ScP	Students focus on personal experiences such as past practices or familiarity from the science subject area to support their arguments.	**014F7N:** It should not be built, because I have watched one of them [nuclear power plant] explode in Japan in a documentary.

Table 3.10 (cont'd)

EtK	Students focus on concepts, theories, principles, laws and evidences from the ethics/morality subject area to support their arguments.	**342F8S:** It [space explorations] should be continued. … The most fundamental right of a person is to live.
EtV	Students focus on affective elements including attitudes, beliefs, values and affections from the ethics/morality subject area to support their arguments.	**437F8G:** Its [GMO's] usage will not only endanger human health, but also greatly affect future generations. Therefore, it's not right to use.
EtP	Students focus on personal experiences such as past practices or familiarity from the ethics/morality subject area to support their arguments.	**084M8G:** It [GMO] should not be used. For example, I know it because my sibling also eats it. Considering corn with sauce, …, my little sibling loves it so much but we do not want to give it because it is GMO.
PoK	Students focus on concepts, theories, principles, laws and evidences from the policy subject area to support their arguments.	**332F8G:** It [GMO] should not be used. As I already know, it is forbidden to produce GMO products in Turkey.
PoV	Students focus on affective elements including attitudes, beliefs, values and affections from the policy subject area to support their arguments.	**166F8S:** Space debris is not only caused by Turkey, in this respect, an agreement should be made with other governments. Turkey should continue space explorations.
PoP	Students focus on personal experiences such as past practices or familiarity from the policy subject area to support their arguments.	In this study, this code was not generated by the students.

Although most of the statements in the students' arguments could be coded by adopting the codes presented in the Table 3.10, some of the statements generated by the students could not be coded under any subject areas of SEE-SEP Model. The following example presents this situation in a clearer way:

> **M268F8N:** *"No, it [nuclear power plants] should not be built. Because I think that the harms of nuclear power plants will outweigh the benefits."*

In this example argument given above, an eighth grade female student against to nuclear power plants presented a reason for her decision without considering any clear subject areas. In other words, it could not be easily understood from this example whether the student took environmental, economic, societal or another concern into consideration. Therefore, these types of arguments were not evaluated in the extent of the SEE-SEP Model.

As seen from the Table 3.10, most of the expressions in the middle school students' arguments could be coded as one code; however, some of the expressions could be coded as a combination of two different codes. The following examples from pilot and main studies present this situation in a clearer way:

> **P010F8S:** *"It [space explorations] should be [continued], the pollution we give up is not more important than the trend information we gain. We cannot sit in our immaculate [very clean] world when everyone is in the space."*

In the first part of the example argument given above, an eighth grade female student compared the importance of environmental pollution and scientific knowledge by considering her own values. Therefore, she considered *EnV code in combination with ScV code*. In the second part of the example argument, she considered her own values regarding both the environment and societal status with respect to other countries have. Therefore, she generated *EnV code in combination with SoV code*.

In another example argument given below, an eighth grade male student supported his stance with a quote of Ataturk indicating the importance of science. Therefore, he considered *SoK code in combination with ScV code*. Similar to this example, in the study of Chang and Chiu (2008), one of the undergraduate students also used a sociological resource (i.e. a Chinese or Taiwanese proverb) to support her/his stance.

M086M8: *"Yes [space explorations should be continued], ..., Ataturk has a saying that I love so much: 'If one day, my words are against science, choose science'."*

In the light of this coding system, 1 point was given for each code used by the students. In this way, the higher score in total represents the more informal reasoning modes because of the multi-perspective nature of SSI reasoning. After the codes were counted carefully, each student's informal reasoning mode score was quantified. To interpret the results, descriptive statistics including mean scores (M) and standard deviations (SD) were also calculated through IBM SPSS Statistics 28.

3.6.2 Analysis for Argumentation Quality (RQ2)

In this study, middle school students' argumentation across three different SSI were obtained through their written arguments as responses to SSI Questionnaire. Students' written arguments were analyzed based on the Lakatos' Scientific Research Programmes proposed by Chang and Chiu (2008). The detailed information regarding the Lakatos' Scientific Research Programmes is addressed in the following sections.

3.6.2.1 Lakatos' Scientific Research Programmes as an Analytical Framework

Lakatos' Scientific Research Programmes included four main components, namely, Hard-Core (HC), Positive Heuristics (PH), Negative Heuristics (NH) and Protective Belt (PB). When the visual representation of Lakatos' Scientific Research Programmes was examined, it was easily seen that HC represents individuals' claim and supporting reasons regarding SSI.

From the perspective of philosophy of science, since "saving a theory with the help of auxiliary hypotheses which satisfy certain well-defined conditions represents scientific progress" (Lakatos, 1980, p. 33), Lakatos' Scientific Research

Programmes also included Positive Heuristics (PH) and Negative Heuristics (NH) as auxiliary hypotheses and pointed out "the concept of a series of theories instead of a theory" (Chang & Chiu, 2008, p. 1757). When the two arrows moving in opposite directions (one represents PH, whereas other represents NH) were examined, it can be stated that both PH and NH are located on the protective belt (PB) to prevent individuals' HC from being attacked. PH protects HC by presenting "qualifier showing the alternative line to inquiry" and extending theory, whereas NH protects HC by generating counter-arguments or limitations. The visual representation of Lakatos' Scientific Research Programmes is given in Figure 3.5.

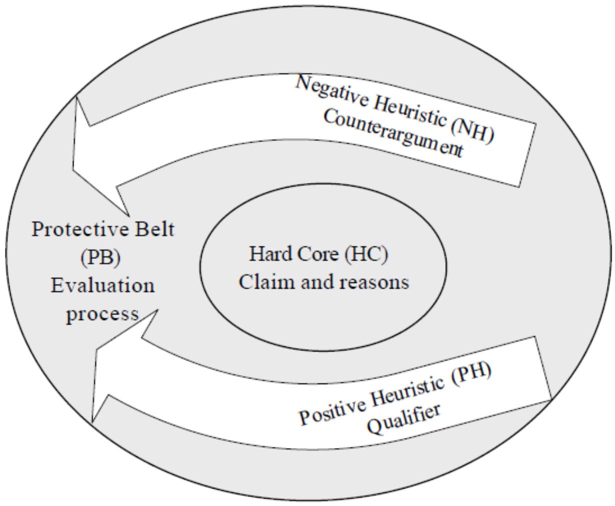

Figure 3.5 The visual representation of Lakatos' Scientific Research Programmes. Adopted from "Lakatos' Scientific Research Programmes as a Framework for Analysing Informal Argumentation about Socio-scientific Issues" by S. N. Chang & M. H. Chiu, 2008, Routledge, Taylor & Francis Group, p. 1759.

In addition to the advantage of examining the students' argumentation quality in a holistic way, another advantage of this analytical framework is the ability to handle "indirect" points generated by the students to support their positions. What means by "indirect" points was presented as an example in the work of Chang and Chiu (2008). In their study, a student who supported the usage of GMO generated the following argument:

I would buy the genetically modified food, because I have not heard about any human dying because of eating it. Besides, genetically modified food perhaps is good research to prevent the crisis of food deficiency in the future. (p. 1757)

In this example, the first sentence refers the student's claim and accompanying supporting reason. However, in the second sentence, the student presented another point of view, different from her/his original reason, to support her/his position. In other words, prevention of food crisis mentioned in the second sentence was not directly related the student's reason about health risks mentioned in the first sentence. This indirect or unrelated points of view, inconsistent with Toulmin's layout of argument, can be easily coded as "qualifier" according to Means and Voss (1996). Since this example may represent the general trend that individuals express some indirect points of view to strengthen their positions, adopting PH as a reflection of "qualifier" can be considered as an advantage to code the students' arguments in a more effective way.

Accordingly, the middle school students' responses to the open-ended questions in the SSI Questionnaire were coded as claim, supporting reason, positive heuristics (PH) and negative heuristics (NH). For each valid component, 1 point was given to the students. In this way, the higher score in total represents the higher argumentation quality. After the components were carefully counted, argumentation quality for each student was quantified. To interpret the results, descriptive statistics including mean scores (M) and standard deviations (SD) were also calculated through IBM SPSS Statistics 28.

The number of claims refers to how many claims were generated by the students. Although it was stated as "number of claims", this number were either zero or one. The number of supporting reasons refers to how many reasons were provided by the students to support their positions regarding each SSI. The number of claims and supporting reasons were intended to obtain through the first open-ended question in the SSI-Questionnaire. The number of positive heuristics refers to how many components were generated by the students to expand their original theory or refute the alternative theories. The number of positive heuristics was intended to obtain through the first open-ended question in the SSI-Questionnaire. The number of negative heuristics refers to how many components were generated by the students to provide counter-arguments or limitations of their original theory. The number of positive heuristics was intended to obtain through the second open-ended question in the SSI-Questionnaire. The information regarding whether the students could generate protective belt (PB) or not was intended to obtain through the question that addressed students' degree of certainty out of 3 (1: I am not sure, 2: Neutral/Undecided, 3: I am totally sure.). In this question, students were expected to consider both their own positions and counter-arguments in order to explore to what extent they were sure of their decisions after they considered counter-arguments and alternative point of views. If the students are sure of their decision even after they considered counter-arguments and alternative point of views, it can be stated that they could generate PB for their positions. Total number of components refer to how many claims, supporting reasons, PHs and NHs were generated by the students. This number was obtained through the addition of the numbers of all the components in the students' arguments.

3.6.3 Analysis for Epistemological Beliefs (RQ3)

In the extent of the present study, the middle school students' epistemological beliefs were obtained through Epistemological Beliefs Questionnaire in a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). After the middle school students' responses to each item were analyzed based on the dimensions of source/certainty, development and justification, the scores on these dimensions were calculated. During the analysis, the items that constituted the dimension of source/certainty were reverse-coded so that a parallelism could be obtained between the scores and epistemological beliefs. That means, higher scores represented more sophisticated epistemological beliefs; whereas lower scores represented less sophisticated epistemological beliefs. Based on this analysis, the scores that the middle school students could obtain ranged from 10 to 50 on the dimension of source/certainty; from 5 to 25 on the dimension of development; and from 9 to 45 on the dimension of justification. To interpret the results, descriptive statistics including mean scores (M) and standard deviations (SD) were also calculated through IBM SPSS Statistics 28.

3.6.4 Analysis for Issue Familiarity (RQ4)

In the extent of the present study, the middle school students' issue familiarity was obtained through Issue Familiarity Form in a 3-point Likert scale ranging from 1 (none) to 3 (much). After the middle school students' responses to each item were analyzed, the scores were calculated. In the analysis, higher scores represented more familiarity. Based on this analysis, the scores that the middle school students could obtain ranged from 10 to 50 on the SPE topic; from 5 to 25 on GMO and NPP topics. To interpret the results, descriptive statistics including mean scores (M) and standard deviations (SD) were also calculated through IBM SPSS Statistics 28.

3.6.5 Multiple Regression Analyses (RQ5)

After descriptive analyses were finalized, some inferential statistics were conducted. More specifically, multiple regression analyses were conducted to find out how well the dimensions of epistemological beliefs (source/certainty, development, and justification) and issue familiarity predicted their informal reasoning modes and argumentation quality regarding three different SSI.

3.7 Internal Validity Threats

This section includes the possible threats to the internal validity. According to Fraenkel et al. (2012), "internal validity means that observed differences on the dependent variable are directly related to the independent variable, and not due to some other unintended variable" (p. 166). Each threat is presented in the following sections.

3.7.1 Subject Characteristics

According to Fraenkel et al. (2012), "the selection of people for a study may result in the individuals (or groups) differing from one another in unintended ways that are related to the variables to be studied" (p. 167). In such circumstances, some characteristics of the sample such as age, gender, ethnicity or various abilities may affect the outcomes of the study. Therefore, subject characteristics may be a threat for this study. The participants of the present study were selected as 7^{th} and 8^{th} grade students from the public middle schools in the districts of Çankaya, therefore, this threat was avoided by providing some common characteristics. However, for instance, middle school students' reading and/or writing abilities that might affect their understanding and responses regarding the items of the instrument could not be controlled.

3.7.2 Loss of Subjects

According to Fraenkel et al. (2012), a loss of subjects threat may occur when "the loss of subjects in a study due to attrition, withdrawal, or low participation rates may introduce bias and affect the outcome of a study" (p. 179). However, since this study was not a longitudinal or intervention study and the instrument was administered in a single session only, loss of subjects was not a threat for the present study. In addition to threat to the internal validity, loss of subjects may be a threat to the external validity. Loss of subjects as an external validity is discussed in the **3.10. External Validity** section.

3.7.3 Location

According to (Fraenkel et al. (2012), a location threat may occur “whenever all instruments are administered to each subject at a specified location, but the location is different for different subjects” (p. 341). Therefore, location may be a threat for the internal validity of the present study. Standardizing conditions is one of the best techniques to eliminate the location threat. For this purpose, the schools were selected in the same district, Çankaya. Also, the instrument was administered in the students’ own classroom which is their natural environment.

3.7.4 Instrumentation

According to Fraenkel et al. (2012), an instrumentation threat includes “changes in the instrument and how it is scored, characteristics of the data collector, and/or bias on the part of the data collector” (p. 179). Therefore, instrumentation may be a threat for the internal validity of the present study. First, since the nature of the instrument did not change throughout the data collection procedure and it was administered in a single session only, instrument decay was not a threat for the internal validity of the study. Second, since the data were collected by the same researcher, data collector characteristics was not also a treat. Finally, data collector bias may be a threat as the data collector may distort the data in order to support the hypothesis for the related study. However, in order to eliminate this threat, the researcher standardized all data collection and analysis procedures and behaved in a neutral way towards the students’ intended or unintended responses that may affect the findings of the study. Also, the researcher analyzed the students’ responses to different instruments at different times. More specifically, students’ responses to Epistemological Beliefs Questionnaire were analyzed first, and students’ responses to open-ended questions in SSI-Questionnaire were analyzed at different times for informal reasoning and quality of argument. Finally, their issue familiarity was analyzed at a different time.

3.7.5 Testing

According to Fraenkel et al. (2012), a testing threat may occur when "the experience of responding to the first instrument that is administered in a correlational study may influence subject responses to the second instrument" (p. 344). Since the participants may notice the possible relationship between the variables studied in the different parts of the instrument, testing may be a threat for the internal validity of the present study. However, since different parts of the instrument (i.e. Epistemological Beliefs Questionnaire, SSI-Questionnaire, and Issue Familiarity Form) do not include similar patterns and outcomes, none of the parts of the instrument cause the middle school students notice any possible relationship between the responses.

3.7.6 History

According to Fraenkel et al. (2012), a history threat may occur when "an unforeseen or unplanned event occurs during the course of the study" (p. 179). Since the correlational studies do not include any intervention or treatment, implementation threat is not applicable for the correlational studies. Therefore, history was not a threat for the internal validity of the present study.

3.7.7 Maturation

According to Fraenkel et al. (2012), a maturation threat may occur when "change during an intervention may be due to factors associated with the passing time rather than to the intervention itself" (p. 173). Since the correlational studies do not include any intervention or treatment, implementation threat is not applicable for the correlational studies. Besides, since the instrument used in the data collection procedure was administered in a single session only, the students' maturity could not change in such a short period. Therefore, maturation was not a threat for the internal validity of the present study.

3.7.8 Attitude of Subjects

According to Fraenkel et al. (2012), an attitude of subjects threat may occur while the participants of the experimental group feel motivated because of the novelty of the treatment or the participants of the control group feel demoralized because of receiving no treatment. Since the correlational studies do not include any intervention or treatment, implementation threat is not applicable for the correlational studies. Therefore, attitude of subjects was not a threat for the internal validity of the present study.

3.7.9 Regression

According to Fraenkel et al. (2012), a regression threat may occur "whenever change is studied in a group that is extremely low or high in its pre-intervention performance" (p. 175). Since the correlational studies do not include any intervention or treatment, implementation threat is not applicable for the correlational studies. Therefore, regression was not a threat for the internal validity of the present study.

3.7.10 Implementation

According to Fraenkel et al. (2012), an implementation threat may occur when "the experimental group may be treated in unintended ways that give them an undue advantage affecting results" (p. 179). Since the correlational studies do not include any intervention or treatment, implementation threat is not applicable for the correlational studies. Therefore, implementation was not a threat for the internal validity of the present study.

3.8 External Validity

This section includes the issues regarding the external validity. According to Fraenkel et al. (2012), “the extent to which the results of a study can be generalized determines the external validity of the study” (p. 103). Two types of the external validity are discussed in the following sections.

3.8.1 Population Generalizability

According to Fraenkel et al. (2012), “the degree to which a sample represents the population of interest” (p. 103) is called as population generalizability. Therefore, sampling technique and sample size should be considered. In the present study, due to the challenges that the COVID-19 pandemic has brought, convenient sampling was used as a sampling technique. That means, this selection may be a threat for the population generalizability. To minimize this threat, the sample size can be increased by selecting more schools so that the findings of the present study can be generalized for the population in a more extensive way. Therefore, the present study was conducted with eight public middle schools from five different districts of Çankaya and the instrument was administered both face-to face and online ways to reach more students and be more representative.

As mentioned in the **3.9.2. Loss of Subjects** section, loss of subjects may be a threat for the external validity in terms of the population generalizability because the findings may be affected due to the loss of certain group of individuals. If the loss occurs among the certain group of people, for example, among the students who have more sophisticated epistemological beliefs but poor informal reasoning patterns or vice versa, then the correlation coefficients would be different from the actual situation. As a result, the findings might be misleading regarding to the external validity in terms of the population generalizability.

3.8.2 Ecological Generalizability

According to Fraenkel et al. (2012), “the degree to which the results of a study can be extended to other settings or conditions” (p. 105). Since the present study was conducted middle school students from the public schools in Çankaya, with three different SSI, namely space explorations, genetically modified organisms and nuclear power plants, the ecological generalizability for the present study was limited in terms of the type of environment (public schools), the district (Çankaya) and content area (SPE, GMO and NPP). These limitations may be a threat for the external validity in terms of ecological generalizability since findings of the present study can be generalized similar settings. To minimize this threat, replication of the present study can be conducted with the middle school students other than conditions of the present study such as in different types of environment (i.e. private schools), in different districts and with different content areas.

3.9 Assumptions

The following assumptions was made for the present study:

1. Since the instrument administered in this study was based on self-reported responses of the students, the first assumption is that the students completed the instrument honestly and sincerely.
2. During the data collection procedure, the students focused on their own responses rather than cheating. There was no interaction between the participants while during the administration of the instrument.
3. During the data collection, the instrument was administered under the standard conditions. All participants received the same implementation.
4. During the data analysis procedures, the SPSS and AMOS statistical software worked properly without any technical error.
5. The sample size of the present study represented the population.

3.10 Limitations

The present study has the following limitations:

1. Sample of the present study was limited to eight public middle schools from five different districts of Çankaya.
2. Since convenience sampling was adopted for the present study due to the COVID-19 pandemic, this can be a limitation in terms of generalizability.
3. In the instrument, data were obtained through the students' self-reported responses. Therefore, it was possible that data obtained from students might be misleading for the findings of the study.
4. The present study has only covered three different SSI, namely space explorations, genetically modified organisms and nuclear power plants.
5. In the extent of the present study, the instrument and analytical frameworks used and sample selected are unique for the present study. Therefore, any other selection of instrument, framework and sample might present different findings.
6. In the extent of the present study, two different analytical frameworks (i.e. SEE-SEP Model and Lakatos' Scientific Research Programmes) were used to investigate the middle school students' informal reasoning modes and argumentation quality respectively. The purpose of using two different analytical frameworks is to provide a more detailed insight to the literature. However, the limitation of the present study is that neither of these analytical frameworks assessed the scientific accuracy of the arguments. Therefore, it did not provide an understanding to what extent the middle school students scientifically support their claims.

CHAPTER 4

RESULTS

In this chapter, descriptive statistics about the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes and argumentation quality regarding three different SSI, namely, space explorations (SPE), genetically modified organisms (GMO), and nuclear power plants (NPP) are presented. Furthermore, multiple regression analyses regarding how well the middle school students' epistemological beliefs and issue familiarity predict their informal reasoning modes and argumentation quality regarding three different SSI (SPE, GMO and NPP) are also given.

4.1 Descriptive Statistics

Descriptive statistics were used to address the first four research questions. More specifically, frequency, mean, standard deviation and range were used to describe informal reasoning modes, argumentation quality, epistemological beliefs and issue familiarity of the sample.

4.1.1 Middle School Students' Informal Reasoning Modes

Research Question 1: What are the middle school students' informal reasoning modes regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

To address the first research question, the middle school students' informal reasoning modes was obtained through their written arguments regarding three different SSI (SPE, GMO and NPP) and analyzed through the SEE-SEP Model. The outcomes about the middle school students' informal reasoning modes consisted of their positions regarding SSI topics, their usage of the aspects of KVP (i.e. knowledge, value and personal experience) and subject areas (SEE-SEP). The related results are given in the next sections.

The middle school students' positions regarding SPE, GMO and NPP topics with the related frequencies and percentages were presented in Table 4.1. According to Table 4.1, most of the middle school students (87.5%) reported that they support space explorations in Turkey, while some of them (10.5%) reported that they are against to space explorations in Turkey; and only 9% of the students indicated no position regarding space explorations. Unlike the SPE topic supported by the substantial number of students, most of the middle school students (62.8%) reported that they are against to genetically modified organisms in Turkey, whereas 30.3% of the students supported GMO in Turkey; and 6.9% of the students did not report any clear position. Unlike the SPE and NPP topics, the middle school students' positions regarding NPP topic did not far outweigh against one side of the issue. While 52.5% of the students reported that they support nuclear power plants in Turkey, 38.7% of them were against to nuclear power plants in Turkey; and 8.8% of the students indicated no position regarding NPP.

Table 4.1 Middle School Students' Positions Regarding Each SSI

SSI Topic	Position	(*f*)	(%)
SPE	For	407	87.5
	Against	49	10.5
	No position	9	1.9
GMO	For	141	30.3
	Against	292	62.8
	No position	32	6.9
NPP	For	244	52.5
	Against	180	38.7
	No position	41	8.8

The middle school students' usage of the aspects of KVP was presented in Figure 4.1. According to Figure 4.1, the aspect of value was the most frequently used by the students regardless of the topic although the percentages varied across different SSI (82.4% for SPE, 77.9% for GMO, and 71.5% for NPP). The aspect of knowledge fell behind the aspect of value with the percentages of 17.3 for SPE, 20.6 for GMO, and 27.6 for NPP), whereas personal experience was the least appeared aspect on the students' arguments (0.3% for SPE, 1.6% for GMO, and 1.0% for NPP).

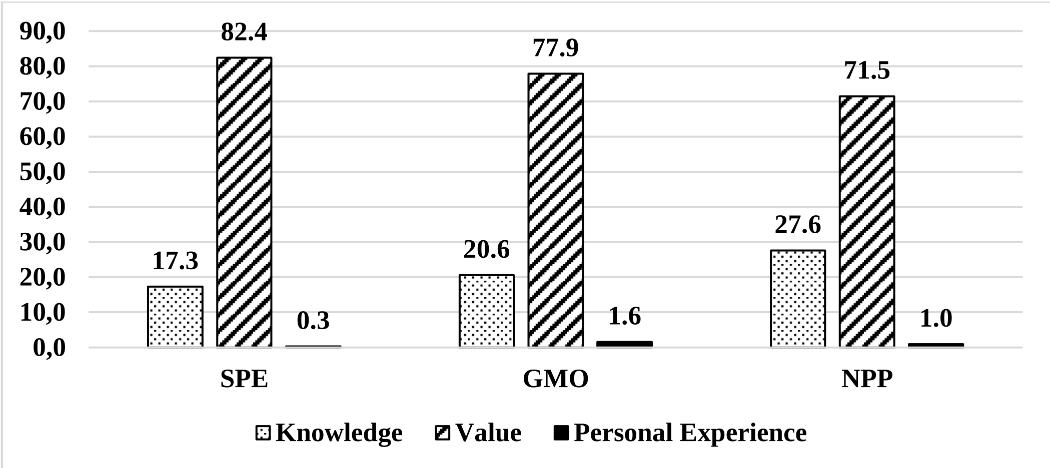

Figure 4.1 Middle school students' usage of KVP regarding different SSI

More specifically, the aspect of value was mostly used in SPE topic (82.4%); followed by GMO (77.9%) and NPP (71.5%) topics. In terms of the knowledge aspect, students mostly used the aspect of knowledge in NPP topic (27.6%); followed by GMO (20.6%) and SPE (17.3%) topics. From the students' written arguments regarding different SSI, it was also revealed that students rarely used the aspect of personal experience in their informal reasoning regardless of the topic. More specifically, students in the present study mostly used the aspect of personal experience in GMO topic with the extent of 1.6%, followed by NPP and SPE topics with only 1.0% and 0.3% respectively.

Descriptive analyses based on the SEE-SEP Model also revealed the middle school students' usage of subject areas, as their informal reasoning modes, in their written arguments regarding three different SSI and the related results were presented in Figure 4.2.

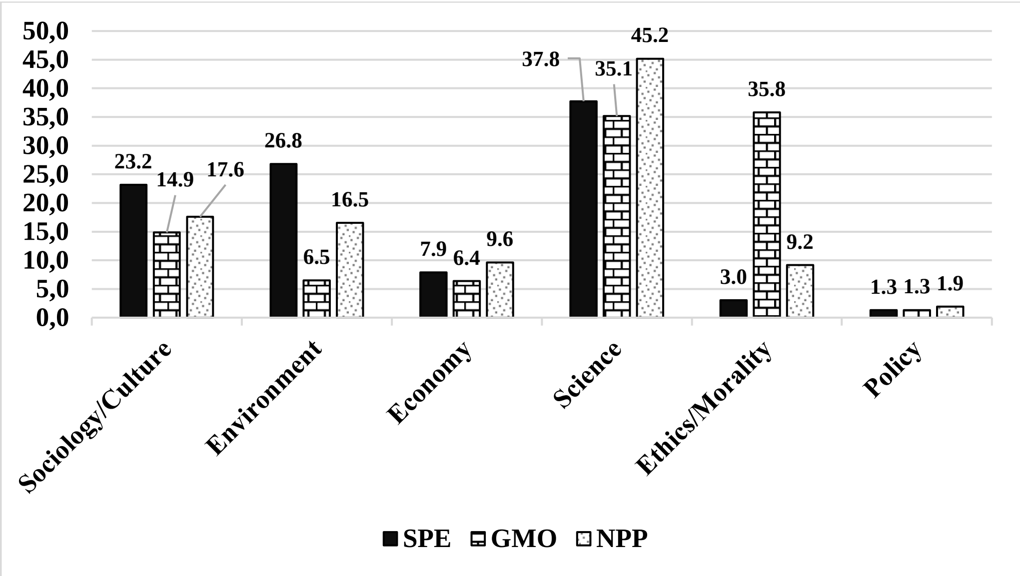

Figure 4.2 Middle school students' usage of subject areas regarding different SSI

According to Figure 4.2, it can be seen that all of the subject areas in the SEE-SEP Model appeared on the students' written arguments with varying percentages across different SSI. In the SPE topic, the subject area of science (37.8%) was mostly used by the students; whereas the subject areas of environment (26.8%) and sociology/culture (23.2%) also frequently appeared on the students' written arguments. The subject areas of economy (7.9%), ethics/morality (3.0%) and policy (1.3%) were not frequently articulated in the students' arguments while arguing SPE. Unlike the SPE topic, ethics/morality (35.8%) was the most frequently used subject area in the GMO topic; followed by the subject area of science (35.1%). The subject areas of environment (6.5%) and economy (6.4%) fell behind sociology/culture (14.9%); whereas the least used subject area was policy with only the percentage of 1.3%. Considering the NPP topic, the subject area of science (45.2%) the most frequently appeared on students' written arguments. Although the subject areas of sociology/culture (17.6%) and environment (16.5%) fell behind the subject area of science, they also appeared on the students' NPP-related arguments. The subject areas of economy (9.6%) and ethics/morality (9.2%) were used by the students with nearly equal percentages, whereas the least used subject area regarding the NPP topic was policy (1.9%). Although the percentages of the subject areas varied across different SSI, science was the most frequently used subject area in the students' written arguments, whereas policy is the least used subject area regardless of the topic.

Although there was no written argument including all 18 codes in the SEE-SEP Model, all of the codes appeared on the students' written arguments except the combinations of EnP (environment and personal experience), EcP (economy and personal experience) and PoP (policy and personal experience). In the SPE topic, the combination of the subject area of science and value (ScV) was the most frequently used code (30.1%) by the middle school students; followed by the combination of SoV (21.9%) and EnV (19.1%). In the GMO topic, the most frequently used code (32.3%) was the combination of the ethics/morality subject area and the aspect of value (EtV); followed by ScV (21.9%), ScK (12.6%) and SoV (11.3%). In the NPP topic, the middle school students mostly used the codes ScV (23.4%), ScK (21.0%), EnV (14.7%) and SoV (14.5%).

Table 4.2 Total Number of Subject Areas Used by the Students

SSI Topic	N	M	SD	Range
SPE	465	2.12	1.29	0 – 8.00
GMO	465	1.62	1.29	0 – 10.00
NPP	465	1.81	1.48	0 – 9.00
ALL SSI	465	1.85	1.12	0 – 7.33

In addition to the outcomes regarding the students' usage of KVP and subject areas, as the components of informal reasoning modes, mean scores and standard deviations were also calculated in order to obtain the total number of subject areas used by the students in arguing different SSI. As seen from Table 4.2, middle school students in the present study were able to consider more than one subject area in average (M=1.85, SD=1.12) while generating arguments regarding SSI. More specifically, students were able to consider more than one subject area while generating arguments regarding NPP (M=1.81, SD=1.48) and GMO (M=1.62, SD=1.29) topics, whereas they were able to consider more than two subject areas (M=2.12, SD=1.29) in their SPE-related arguments.

4.1.2 Middle School Students' Argumentation Quality

Research Question 2: What are the middle school students' argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

To address the second research question, the middle school students' argumentation quality was obtained though their written arguments regarding three different SSI. The outcomes about the middle school students' argumentation quality consisted of mean scores and standard deviations based on the analysis derived from Lakatos' Scientific Research Programmes (Chang & Chiu, 2008). The related results are given in the next sections.

The middle school students' argumentation quality for each SSI topic was presented in Table 4.3. According to Table 4.3, the students' mean scores regarding Hard Core (HC) were the highest in arguing SPE (M=1.80, SD=0.57), followed by GMO (M=1.70, SD=0.65) and NPP (M=1.69, SD=0.75). That means, the middle school students in the present study were able to generate either no or only one supporting reason for their claims, in average (M=1.73, SD=0.46). When the students' Positive Heuristics (PH) and Negative Heuristics (NH) mean scores were examined, it was revealed that they were able to generate less than one PH and NH for each SSI topic. Considering the total scores regarding the argumentation quality, the middle school students had the highest total score on the SPE topic (M=3.06, SD=1.30), followed by the topics NPP (M=2.69, SD=1.55) and GMO (M=2.53, SD=1.37). The results indicated that the students had the lowest score on the GMO topic.

In addition to the components of Lakatos' Scientific Research Programmes (Chang & Chiu, 2008), the middle school students were expected to indicate the degree of certainty (DoC) regarding their decisions for each SSI. For the DoC scores, the answers for the question "To what extent are you sure of your decision?" range from 1 (I'm not sure) to 3 (I'm totally sure) were used. The related results were presented in Table 4.4. As can be seen from Table 4.4, the middle school students mostly reported that they were sure of their decisions regarding the topics SPE (M=2.76, SD=0.49), GMO (M=2.60, SD=0.60) and NPP (M=2.57, SD=0.66) with the scores considerably above the absolute mean of 1-3 point Likert scale.

Table 4.3 Middle School Students' Scores based on their Argument Quality

SSI Topic	Components	(M)	(SD)	Range	Skewness	Kurtosis
SPE	HC	1.80	0.57	0 - 3.00	-0.60	1.02
	PH	0.56	0.74	0 - 6.00	1.86	6.96
	NH	0.71	0.75	0 - 3.00	0.87	0.38
	Total Score	3.06	1.30	0 - 9.00	0.50	1.14
GMO	HC	1.70	0.65	0 - 4.00	-1.12	1.47
	PH	0.28	0.58	0 - 4.00	2.59	8.90
	NH	0.55	0.74	0 - 5.00	1.48	3.20
	Total Score	2.53	1.37	0 - 11.00	1.10	4.72
NPP	HC	1.69	0.75	0 - 4.00	-0.48	0.71
	PH	0.37	0.67	0 - 3.00	1.93	3.37
	NH	0.63	0.78	0 - 4.00	1.45	2.74
	Total Score	2.69	1.55	0 - 9.00	0.54	0.78
ALL SSI	HC	1.73	0.46	0 - 3.00	-1.02	1.91
	PH	0.40	0.49	0 - 4.00	1.99	7.31
	NH	0.63	0.59	0 - 2.67	0.87	0.30
	Total Score	2.76	1.16	0 - 8.33	0.66	1.67

When the DoC scores after asking the question "What would a person against to your position tell you in order to defend her/his position?" were analyzed, it was found that students' degree of certainty for each SSI were quite above the absolute mean of 1-3 Likert scale (M=2.53, SD=0.67 for SPE; M=2.49, SD=0.67 for GMO, and M=2.45, SD=0.70 for NPP). In other words, it can be stated that the students in the present study were able to generate Protective Belt (PB) for their decisions. The results also indicated that the students' DoC-before scores were higher than the DoC-after scores regardless of the SSI topic. That means, students' degree of certainty regarding their decisions decreased after they considered the possible counter-arguments.

Table 4.4 Degree of Certainty (DoC) Scores regarding Each SSI

SSI Topic	Components	(M)	(SD)	Range	Skewness	Kurtosis
SPE	DoC*-before	2.76	0.49	1-3	-1.94	2.99
	DoC*-after	2.53	0.67	1-3	-1.10	-0.02
GMO	DoC*-before	2.60	0.60	1-3	-1.22	0.47
	DoC*-after	2.49	0.67	1-3	-0.98	-0.24
NPP	DoC*-before	2.57	0.66	1-3	-1.25	0.32
	DoC*-after	2.45	0.70	1-3	-0.87	-0.50

*Degree of Certainty

4.1.3 Middle School Students' Epistemological Beliefs

Research Question 3: What are the middle school students' epistemological beliefs on the dimensions of source/certainty, development, and justification?

To address the third research question, the middle school students' epistemological beliefs were obtained though Epistemological Beliefs Questionnaire (EBQ) developed by Conley et al. (2004) and adapted by Ozkan (2008). The mean scores, standard deviations, and range were used to describe the middle school students' epistemological beliefs regarding the dimensions of EBQ. The related results were presented in Table 4.5.

Table 4.5 Middle School Students' Scores Regarding the Dimensions of EBQ

Dimension of EBQ	N	M	SD	Range
justification	465	4.11	0.68	1-5
development	465	3.85	0.62	1-5
source/certainty	465	3.71	0.64	1-5

According to Table 4.5, the middle school students obtained the highest score on the dimension of justification (M=4.11; SD=0.68); followed by development (M=3.85; SD=0.62) and source/certainty (M=3.71; SD=0.64). That means, the middle school students displayed the most sophisticated epistemological beliefs on the dimension of justification, whereas they displayed the least sophisticated epistemological beliefs on the dimension of source/certainty. Although the mean scores varied across the dimensions, descriptive analysis indicated that the middle school students in the present study displayed sophisticated epistemological beliefs on all the dimensions of EBQ with the scores fairly above the absolute mean of 1-5 Likert scale. That means, the middle school students in the present study tended to believe that using data and evidences is required to justify knowledge (for the dimension of justification); knowledge can change and evolve (for the dimension of development); knowledge is constructed by knower, and there may be more than one right answer (for the dimension of source/certainty).

4.1.4 Middle School Students' Issue Familiarity Regarding SSI

Research Question 4: What are the middle school students' issue familiarity regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

To address the fourth research question, the middle school students' issue familiarity regarding each SSI was obtained through Issue Familiarity Form developed by the researchers. Frequencies, percentages, mean scores, standard deviations, and ranges were used to describe the sample's issue familiarity regarding each SSI. The related results were presented in Table 4.6.

Table 4.6 Middle School Students' Scores on Issue Familiarity Form

Items	Scale	SPE		GMO		NPP	
		(*f*)	(%)	(*f*)	(%)	(*f*)	(%)
Knowledge level	Much	189	40.6	86	18.5	109	23.4
	Little	256	55.1	266	57.2	246	52.9
	Never	17	3.7	104	22.4	101	21.7
Interest level	Much	300	64.5	147	31.6	187	40.2
	Little	131	28.2	185	39.8	169	36.3
	Never	30	6.5	125	26.9	100	21.5
Willing to learn	Much	335	72.0	199	42.8	231	49.7
	Little	97	20.9	158	34.0	142	30.5
	Never	28	6.0	100	21.5	84	18.1
Willing to read & research	Much	319	68.6	191	41.1	212	45.6
	Little	116	24.9	162	34.8	150	32.3
	Never	26	5.6	105	22.6	93	20.0
Willing to do project	Much	195	41.9	121	26.0	152	32.7
	Little	184	39.6	151	32.5	154	33.1
	Never	83	17.8	184	39.6	150	32.3
Information Source							
Family	Much	74	15.9	74	15.9	78	16.8
	Little	245	52.7	204	43.9	200	43.0
	Never	142	30.5	179	38.5	178	38.3
Friends	Much	53	11.4	31	6.7	42	9.0
	Little	208	44.7	163	35.1	165	35.5
	Never	200	43.0	264	56.8	248	53.3

Table 4.6. (cont'd)

Teacher	Much	287	61.7	206	44.3	201	43.2
	Little	138	29.7	153	32.9	162	34.8
	Never	37	8.0	97	20.9	92	19.8
Textbooks	Much	214	46.0	144	31.0	148	31.8
	Little	182	39.1	187	40.2	175	37.6
	Never	65	14.0	127	27.3	132	28.4
Social Media	Much	221	47.5	141	30.3	165	35.5
	Little	146	31.4	159	34.2	149	32.0
	Never	94	20.2	159	34.2	142	30.5
Newspaper & Journals	Much	109	23.4	83	17.8	93	20.0
	Little	182	39.1	169	36.3	160	34.4
	Never	171	36.8	206	44.3	202	43.4
Observation & Experience	Much	140	30.1	85	18.3	99	21.3
	Little	216	46.5	172	37.0	162	36.3
	Never	106	22.8	201	43.2	187	40.2
Television	Much	129	27.7	112	24.1	104	22.4
	Little	235	50.5	201	43.2	212	45.6
	Never	98	21.1	144	31.0	140	30.1
Multiple Sources	Much	305	65.6	215	46.2	231	49.7
	Little	118	25.4	142	30.5	136	29.2
	Never	37	8.0	102	21.9	89	19.1
Follow NASA	Much	203	43.7				
	Little	157	33.8	Not Applicable		Not Applicable	
	Never	103	22.2				

According to Table 4.6, considering the knowledge level, the percentage of the students who reported that they have no knowledge was only 3.7% regarding space explorations, 21.7% regarding nuclear power plants, and 22.4% regarding genetically modified organisms. Considering the interest level, the percentage of the students who reported that they have no interest was only 6.5% regarding space explorations, 21.5% regarding nuclear power plants, and 26.9% regarding genetically modified organisms. Considering the willingness to learn, the percentage of the students who reported that they have no willing to learn was only 6.0% regarding space explorations, 18.1% regarding nuclear power plants, and 21.5% regarding genetically modified organisms. Considering the willingness to read and research, the percentage of the students who reported that they have no willing to read and research was only 5.6% regarding space explorations, 20.0% regarding nuclear power plants, and 22.6% regarding genetically modified organisms. Considering the willingness to do project, the percentage of the students who reported that they have no willing to do project was only 17.8% regarding space explorations, 32.3% regarding nuclear power plants, and 39.6% regarding genetically modified organisms. As can be easily seen from the percentages in Table 4.6, the middle school students' self-reported level of knowledge, level of interest, willingness to learn, read and research, and do project were the highest regarding space explorations; followed by nuclear power plants and genetically modified organisms.

In addition, the students' sources of information regarding each SSI were also obtained through *Issue Familiarity Form*. Descriptive statistics indicated that middle school students in the present study mostly obtained information from multiple sources regardless of the SSI topic. More specifically, among the sources of information, the most frequently used source by the students was teacher regardless of the SSI topic (61.7% for SPE, 44.3% for GMO, and 43.2% for NPP). The sources of textbooks and social media (Facebook, Twitter, Instagram, YouTube etc.) fell behind the source of teacher with varying percentages for each SSI. The students reported that they obtained information regarding all SSI from social media (47.5% for SPE; 35.5% for NPP; 30.3% for GMO) and textbooks (46.0% for SPE; 31.8% for NPP; 31.0% for GMO) at almost equal percentages. In addition to the sources of information, one extra item was added to space explorations regarding whether the students follow NASA or not. Majority of the students (43.7%) reported that they use NASA as a source regarding space explorations.

In parallel to the findings in the previous section, the middle school students' mean scores based on Issue Familiarity Form regarding each SSI indicated that the students were more familiar with space explorations (M=2.27, SD=0.34); followed by nuclear power plants (M=2.02, SD=0.46), and genetically modified organisms (M=1.96, SD=0.46). The related results were presented in Table 4.7.

Table 4.7 Middle School Students' Mean Scores on Issue Familiarity Form

Topic	N	M	SD	Range
SPE	460	2.27	0.34	1-3
GMO	456	1.96	0.46	1-3
NPP	455	2.02	0.46	1-3

4.2 Inferential Statistics

4.2.1 Predictors for Middle School Students' Informal Reasoning Modes and Argumentation Quality in the context of SSI

Research Question 5: What are the relationships between the middle school students' epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality regarding different SSI, space explorations, genetically modified organisms, and nuclear power plants?

In the present study, middle school students' epistemological beliefs (i.e. the dimensions of source/certainty, development, and justification), and issue familiarity regarding each SSI were considered as the predictors of the students' informal reasoning modes (in terms of total number of subject areas used by the students) and argumentation quality (in terms of total number of PH and NH) regarding each SSI. In order to investigate how well the aforementioned independent variables predict the dependent variables, three multiple regression analyses were conducted for each SSI topic. Before conducting multiple regression analyses, the assumptions of the multiple regression were checked.

1. Sample Size: According to Pallant (2011), studying with small samples may lead non-generalizable results. In order to meet the requirement of adequate sample size, Tabachnick and Fidell (2007) provided two general formulas: $N \geq 50 + 8m$ for multiple regression and $N \geq 104 + m$ for testing individual predictors (where m is the number of independent variables). In addition to overall sample size, there should be 40 cases for each IV for stepwise regression (Tabachnick & Fidell, 2007). Since the number of independent variables in the present study is four (i.e. the dimensions of source/certainty, development, justification, and issue familiarity regarding each SSI), the minimum sample size required was calculated as 160. Therefore, this assumption was met with 465 participants.

2. Multicollinearity and Singularity: According to Pallant (2011), "multicollinearity exists when the independent variables are highly correlated (r=.9 and above). Singularity occurs when one independent variable is actually a combination of other independent variables" (p. 151). In addition to these conditions, very small tolerance values (lower than .10) or very large VIF values (higher than 10) indicate multicollinearity (Pallant, 2011). In the present study, when the correlations between the IVs were examined, it was revealed that there was no correlation that exceeds the cut-off value (higher than .9). Moreover, all the tolerance values were found as higher than .10 and all the VIF values were found as lower than 10. Therefore, this assumption was met with acceptable correlations, tolerance and VIF values.

3. Outliers: According to Tabachnick and Fidell (2007), multiple regression is very sensitive to extreme cases, therefore outliers should be checked. In addition to checking standardized residual plots and scatterplots, outliers on DV can be detected from extreme standardized residual values (i.e. lower than -3.3 or higher than 3.3). Even if there are some values

outside this range, Pallant (2011) indicated that “with large samples, it is not uncommon to find a number of outlying residuals. If you find only a few, it may not be necessary to take any action” (p. 159). Moreover, Pallant (2011) suggested that Mahalanobis and Cook’s Distances can be checked to detect multivariate outliers. Since the present study had four independent variables (i.e. three dimensions of epistemological beliefs and students’ issue familiarity), the critical value for Mahalanobis Distance obtained from “Critical Values of Chi-Square” Table (Tabachnick & Fidell, 2013, p. 952) was 18.467. When the related data-set was examined, it was revealed that only three cases exceeded this critical value. In order to check whether these cases had an undue effect on the results or not, Cook’s Distance values for each case were examined. Since none of the Cook’s Distance values were higher than 1, there was no need to remove these cases from the analysis.

4. Normality, Linearity and Homoscedasticity of Residuals: According to Pallant (2011), “residuals are the differences between the obtained and the predicted dependent variable (DV) scores” (p. 151). Normality assumption can be met when the residuals are normally distributed about the predicted DV, whereas linearity assumption can be met when the residuals have a straight-line relationship with the predicted DV; and homoscedasticity assumption can be met when the variance of the residuals about the predicted DV scores are the same (represented by rectangularly shaped distribution) for all predicted scores (Pallant, 2011; Tabachnick & Fidell, 2007). These assumptions can be checked from the residuals’ scatterplots generated as an output of multiple regression analysis. To check the normality assumption, normal P-P plots and residuals’ scatterplots were examined. Although the residuals did not lie on the diagonal regression line perfectly due to some minor deviations, they follow the straight line. Therefore, normality assumption was

reasonably met. Also, the straight-line in the scatterplots indicated the linear relationship between the residuals and predicted DV scores. Therefore, linearity assumption was also met. When the residuals' scatterplots were examined, it was also observed that the residuals rectangularly distributed, hence homoscedasticity assumption was also met.

5. Independence of Residuals: For multiple regression analyses, the residuals should be independent from each other. To check this assumption, Durbin-Watson values were examined for each multiple regression analysis. Since all the Durbin-Watson values were between the values 1.5 and 2.5, this assumption was also met.

4.2.1.1 Stepwise Multiple Regression Analyses for SPE topic

In total, three multiple regression analyses were conducted to investigate how well the dimensions of epistemological beliefs and the middle school students' issue familiarity predicted their argumentation quality (in terms of total number of PH and NH) and informal reasoning modes (in terms of total number of subject areas used by the students) regarding the SPE topic. The related results were presented in Table 4.8.

Firstly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their argumentation quality in terms of total number of PH regarding the SPE topic (dependent variable). Multiple regression analysis indicated that the model consisting of the development dimension and students' issue familiarity significantly predicted their PH generation regarding the SPE topic (R^2 = .056, Adjusted R^2 = .052, $F (2, 457) = 13.597$, $p < .05$). In other words, the dimension of development and students' issue familiarity as a whole statistically explained

5.6% of the variance in generating PH regarding the SPE topic with small effect size ($f^2 = 0.059$).

Table 4.8 Multiple Regression Analyses for Predicting the Middle School Students' Argumentation Quality and Informal Reasoning Modes Regarding the SPE Topic

DV	IVs	B	SE B	β	F	Df	Adj. R^2
Generating PH	Overall model				13.597*	(2, 457)	.052
	Development	.215*	.055	.180			
	Issue Familiarity	.294*	.100	.134			
	Constant	-.935*	.293				
Generating NH	Overall model				13.459*	(2, 457)	.051
	Development	.213*	.058	.177			
	Source/Certainty	.127*	.057	.108			
	Constant	-.583*	.253				
Informal Reasoning Modes	Overall model				21.513*	(2, 457)	.082
	Development	.456*	.093	.220			
	Issue Familiarity	.647*	.171	.170			
	Constant	-1.093*	.500				

*p < .05

More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students' argumentation in terms of generating PH regarding the SPE topic. The dimension of development made a unique contribution to the generation of PH regarding the SPE topic by explaining 3.2% of variance ($\beta = .180$, $sr^2 = .032$, $p < .05$) with small effect size ($f^2 = 0.033$). The students' score regarding their issue familiarity was the second best predictor for the middle school students' generation of PH regarding the SPE topic. The students' issue familiarity made a unique contribution to the generation of PH regarding the SPE topic by explaining 1.8% of the variance ($\beta = .134$, $sr^2 = .018$, $p < .05$) with trivial effect size ($f^2 = 0.018$). The regression equation for predicting the middle school students’ argumentation in terms of generating PH regarding the SPE topic was presented below.

$Y = 0.215 X_1 + 0.294 X_2 – 0.935$ where X_1 represents the dimension of development and X_2 represents the middle school students’ issue familiarity regarding the SPE topic.

Secondly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students’ issue familiarity (independent variables) predicted their argumentation quality in terms of total number of NH regarding the SPE topic (dependent variable). Multiple regression analysis indicated that the model including the dimensions of development and source/certainty significantly predicted the students’ NH generation regarding the SPE topic (R^2 = .056, Adjusted R^2 = .051, $F (2, 457) = 13.459$, $p < .05$). In other words, the dimensions of development and source/certainty as a whole statistically explained 5.6% of the variance in generating NH regarding the SPE topic with small effect size ($f^2 = 0.059$). More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students’ argumentation quality in terms of generating NH regarding the SPE topic. The dimension of development made a unique contribution to the generation of NH regarding the SPE topic by explaining 2.8% of variance ($\beta = .177$, $sr^2 = .028$, $p < .05$) with small effect size ($f^2 = 0.029$). The dimension of source/certainty was the second best predictor for the middle school students’ generation of NH regarding the SPE topic. The dimension of source/certainty made a unique contribution to the generation of NH regarding the SPE topic by explaining 1.8% of the variance (β = .108, $sr^2 = .010$, $p < .05$) with trivial effect size ($f^2 = 0.010$). The regression equation for predicting the middle school students’ quality of argument in terms of generating NH regarding the SPE topic was presented below.

$Y = 0.213 X_1 + 0.127 X_2 – 0.583$ where X_1 represents the dimension of development and X_2 represents the dimension of source/certainty.

Thirdly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their informal reasoning modes in terms of the total number of subject areas used by the students regarding the SPE topic (dependent variable). Multiple regression analysis indicated that the model consisting of the development dimension and students' issue familiarity significantly predicted their usage of total subject areas regarding the SPE topic ($R^2 = .086$, Adjusted $R^2 = .082$, $F(2, 457) = 21.513$, $p < .05$). In other words, the dimension of development and students' issue familiarity as a whole statistically explained 8.6% of the variance in the usage of total subject areas regarding the SPE topic with small effect size ($f^2 = 0.094$). More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students' informal reasoning modes in terms of the total number of subject areas used by the students regarding the SPE topic. The dimension of development made a unique contribution to the usage of total subject areas regarding the SPE topic by explaining 4.8% of variance ($\beta = .220$, $sr^2 = .048$, $p < .05$) with small effect size ($f^2 = 0.050$). The students' score regarding their issue familiarity was the second best predictor for the middle school students' usage of total subject areas regarding the SPE topic. The students' issue familiarity made a unique contribution to the usage of total subject areas regarding the SPE topic by explaining 2.9% of the variance ($\beta = .170$, $sr^2 = .029$, $p < .05$) with small effect size ($f^2 = 0.030$). The regression equation for predicting the middle school students' informal reasoning modes in terms of the total number of subject areas used by the students regarding the SPE topic was presented below.

$Y = 0.456\ X_1 + 0.647\ X_2 - 1.093$ where X_1 represents the dimension of development and X_2 represents the middle school students' issue familiarity regarding the SPE topic.

4.2.1.2 Stepwise Multiple Regression Analyses for GMO topic

In total, three multiple regression analyses were conducted to investigate how well the dimensions of epistemological beliefs and the middle school students' issue familiarity predicted their argumentation quality (in terms of total number of PH and NH) and informal reasoning modes (in terms of the total number of subject areas used by the students) regarding the GMO topic. The related results were presented in Table 4.9.

Table 4.9 Multiple Regression Analyses for Predicting the Middle School Students' Argumentation Quality and Informal Reasoning Modes Regarding the GMO Topic

DV	IVs	B	SE B	β	F	df	Adj. R^2
Generating PH	Overall model				8.832*	(1, 454)	.017
	Development	.128*	.043	.138			
	Constant	-.217	.168				
Generating NH	Overall model				12.686*	(1, 454)	.025
	Development	.194*	.055	.165			
	Constant	-.193	.213				
Informal Reasoning Modes	Overall model				22.156*	(1, 454)	.044
	Development	.448*	.095	.216			
	Constant	-.101	.371				

*p < .05

Firstly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their argumentation quality in terms of generating PH regarding the GMO topic (dependent variable). Multiple regression analysis indicated that the dimension of development, one of epistemological beliefs, was the only significant predictor for the students' PH generation regarding the GMO topic ($R^2 = .019$, Adjusted $R^2 = .017$, $F (1, 454) = 8.832$, $p < .05$). The dimension of development explained 1.9% of the variance ($\beta = .138$, $sr^2 = .019$, $p < .05$) in the generation of PH regarding the GMO topic with trivial effect size ($f^2 = 0.019$). The regression equation for predicting the middle school students' argumentation quality in terms of generating PH regarding the GMO topic was presented below.

$Y = 0.128\ X_1 – 0.217$ where X_1 represents the dimension of development.

Secondly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their argumentation quality in terms of generating NH regarding the GMO topic (dependent variable). Multiple regression analysis indicated that the dimension of development, one of epistemological beliefs, was the only significant predictor for the students' NH generation regarding the GMO topic ($R^2 = .027$, Adjusted $R^2 = .025$, $F (1, 454) = 12.686$, $p < .05$). The dimension of development explained 2.7% of the variance ($\beta = .165$, $sr^2 = .027$, $p < .05$) in the generation of NH regarding the GMO topic with small effect size ($f^2 = 0.028$). The regression equation for predicting the middle school students' argumentation quality in terms of generating NH regarding the GMO topic was presented below.

$Y = 0.194\ X_1 – 0.193$ where X_1 represents the dimension of development.

Thirdly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their informal reasoning modes in terms of the total number of subject areas used by the students regarding the GMO topic (dependent variable). Multiple regression analysis indicated that the dimension of development, one of epistemological beliefs, was the only significant predictor for the students' usage of total subject areas regarding the GMO topic ($R^2 = .047$, Adjusted $R^2 = .044$, $F (1, 454) = 22.156$, $p < .05$). The dimension of development explained 4.7% of the variance ($\beta = .216$, $sr^2 = .047$, $p < .05$) in the total number of subject areas used by the students regarding the GMO topic with small effect size ($f^2 = 0.049$). The regression equation for predicting the middle school students' informal reasoning modes in terms of total number of subject areas regarding the GMO topic was presented below.

$Y = 0.448\ X_1 - 0.101$ where X_1 represents the dimension of development.

4.2.1.3 Stepwise Multiple Regression Analyses for NPP topic

In total, three multiple regression analyses were conducted to investigate how well the dimensions of epistemological beliefs and the middle school students' issue familiarity predicted their argumentation quality (in terms of total number of PH and NH) and informal reasoning modes (in terms of the total number of subject areas used by the students) regarding the NPP topic. The related results were presented in Table 4.10.

Table 4.10 Multiple Regression Analyses for Predicting the Middle School Students' Argumentation Quality and Informal Reasoning Modes Regarding the NPP Topic

DV	IVs	B	SE B	β	F	df	Adj.R^2
Generating PH	Overall model				7.799*	(2, 452)	.029
	Development	.145*	.050	.134			
	IF**	.165*	.067	.114			
	Constant	-.524*	.229				
Generating NH	Overall model				11.696*	(2, 452)	.045
	Development	.223*	.058	.178			
	IF**	.202*	.078	.120			
	Constant	-.632*	.264				
Informal Reasoning Modes	Overall model				19.386*	(2, 452)	.075
	Development	.463*	.107	.196			
	IF**	.594*	.144	.187			
	Constant	-1.171*	.490				

*p < .05; **Issue Familiarity.

Firstly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their argumentation quality in terms of generating PH regarding the NPP topic (dependent variable). Multiple regression analysis indicated that the model consisting of the development dimension and students' issue familiarity significantly predicted their PH generation regarding the NPP topic (R^2 = .033, Adjusted R^2 = .029, F (2, 452) = 7.799, $p < .05$). In other words, the dimension of development and students' issue familiarity as a whole statistically explained 3.3% of the variance in generating PH regarding the NPP topic with small effect size (f^2 = 0.034). More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students' argumentation quality in terms of generating PH regarding the NPP topic. The dimension of development made a unique contribution to the generation of PH regarding the NPP topic by explaining 1.8% of variance (β = .134, sr^2 = .018, $p < .05$) with trivial effect size (f^2 = 0.018). The students' score regarding their issue familiarity was the second best predictor for the middle school students' generation of PH regarding the NPP topic. The students' issue familiarity made a unique contribution to the generation of PH regarding the NPP topic by explaining 1.3% of the variance (β = .114, sr^2 = .013, $p < .05$) with trivial effect size (f^2 = 0.013). The regression equation for predicting the middle school students' argumentation quality in terms of generating PH regarding the NPP topic was presented below.

$Y = 0.145\ X_1 + 0.165\ X_2 - 0.524$ where X_1 represents the dimension of development and X_2 represents the middle school students' issue familiarity regarding the NPP topic.

Secondly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their argumentation quality in terms of generating NH regarding the NPP topic (dependent variable). Multiple regression analysis indicated that the model consisting of the development dimension and students' issue familiarity significantly predicted their NH generation regarding the NPP topic (R^2 = .049, Adjusted R^2 = .045, F (2, 452) = 11.696, $p < .05$). In other words, the dimension of development and students' issue familiarity as a whole statistically explained 4.9% of the variance in generating NH regarding the NPP topic with small effect size (f^2 = 0.052). More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students' argumentation quality in terms of generating NH regarding the NPP topic. The dimension of development made a unique contribution to the generation of NH regarding the NPP topic by explaining 3.1% of variance (β = .178, sr^2 = .031, $p < .05$) with small effect size (f^2 = 0.032). The students' score regarding their issue familiarity was the second best predictor for the middle school students' generation of NH regarding the NPP topic. The students' issue familiarity made a unique contribution to the generation of NH regarding the NPP topic by explaining 1.4% of the variance (β = .120, sr^2 = .014, $p < .05$) with trivial effect size (f^2 = 0.014). The regression equation for predicting the middle school students' argumentation quality in terms of generating NH regarding the NPP topic was presented below.

$Y = 0.223 X_1 + 0.202 X_2 - 0.632$ where X_1 represents the dimension of development and X_2 represents the middle school students' issue familiarity regarding the NPP topic.

Thirdly, multiple regression analysis was conducted to investigate how well the dimensions of epistemological beliefs (justification, development, and source/certainty) and the middle school students' issue familiarity (independent variables) predicted their informal reasoning modes in terms of the total number of subject areas used by the students regarding the NPP topic (dependent variable). Multiple regression analysis indicated that the model consisting of the development dimension and students' issue familiarity significantly predicted their usage total subject areas regarding the NPP topic (R^2 = .079, Adjusted R^2 = .075, F (2, 452) = 19.386, $p < .05$). In other words, the dimension of development and students' issue familiarity as a whole statistically explained 7.9% of the variance in the usage of total subject areas regarding the NPP topic with small effect size ($f^2 = 0.086$). More specifically, the dimension of development, one of the epistemological beliefs, was the best predictor of the middle school students' informal reasoning modes in terms of the total number of subject areas used by the students regarding the NPP topic. The dimension of development made a unique contribution to the usage of total subject areas regarding the NPP topic by explaining 3.8% of variance ($\beta = .196$, $sr^2 = .038$, $p < .05$) with small effect size ($f^2 = 0.040$). The students' score regarding their issue familiarity was the second best predictor for the middle school students' usage of total subject areas regarding the NPP topic. The students' issue familiarity made a unique contribution to the usage of total subject areas regarding the NPP topic by explaining 3.5% of the variance ($\beta = .187$, $sr^2 = .035$, $p < .05$) with small effect size ($f^2 = 0.036$). The regression equation for predicting the middle school students' informal reasoning modes in terms of the total number of subject areas used by the students regarding the NPP topic was presented below.

$Y = 0.463 X_1 + 0.594 X_2 - 1.171$ where X_1 represents the dimension of development and X_2 represents the middle school students' issue familiarity regarding the NPP topic.

CHAPTER 5

DISCUSSION, CONCLUSION AND IMPLICATIONS

In this chapter, the present study is summarized and the findings are discussed. Also, educational implications of the study and recommendations for further research are presented.

5.1 Summary of the Study

The purpose of the present study was to examine middle school students' epistemological beliefs, issue familiarity, informal reasoning modes, and argumentation quality regarding three different SSI, namely, space explorations (SPE), genetically modified organisms (GMO), and nuclear power plants (NPP); and to investigate how well middle school students' epistemological beliefs (i.e. the dimensions of source/certainty, development and justification) and issue familiarity predict their informal reasoning modes and argumentation quality regarding the aforementioned SSI. In the present study, correlational research design was used and a total of 465 students (7^{th} and 8^{th} grade) from eight public middle schools in five different districts of Çankaya constituted the sample through convenient sampling. All data were collected in the Fall Semester of 2020-2021 Academic Year. Data regarding middle school students' epistemological beliefs were collected through Epistemological Beliefs Questionnaire developed by Conley and colleagues (2004) and adapted into Turkish by Ozkan (2008), whereas data regarding their informal reasoning modes and argumentation quality across three different SSI were collected through open-ended questions adapted by Chang and Chiu (2008), and Christenson and colleagues (2012). The data obtained from open-ended questions were analyzed qualitatively first, then transformed into quantitative data through quantitizing process (Sandelowski et al., 2009). Multiple regression analyses were also conducted to investigate how well the dimensions of epistemological beliefs and issue familiarity predict the middle school students' informal reasoning modes and argumentation quality regarding three different SSI.

5.2 Discussion of the Findings

In this section, the findings regarding each research question are discussed respectively.

5.2.1 Middle School Students' Informal Reasoning Modes based on SEE-SEP Model

In this study, middle school students' informal reasoning modes was examined by utilizing SEE-SEP Model as an analytical framework (Chang Rundgren & Rundgren, 2010). The SEE-SEP Model includes six subject areas (sociology/culture, environment, economy, science, ethics/morality, and policy) and accompanying three aspects (knowledge, value, and personal experience) that middle school students can utilize while negotiating SSI, namely, space explorations, genetically modified organisms, and nuclear power plants. The findings about the middle school students' informal reasoning modes including their positions regarding each SSI, their usage of KVP (knowledge, value and personal experience) and subject areas (SEE-SEP) are discussed respectively.

The middle school students' positions regarding different SSI varied with different percentages. More specifically, most of the students (87.5%) reported that they support space explorations in Turkey, whereas far fewer students (30.3%) reported that they support genetically modified organisms in Turkey. Regarding the NPP topic, the percentages for the opposite sides of the issue did not far outweigh each other. That is, 52.5% of the students reported that they support nuclear power plants in Turkey, while 38.7% of them were against nuclear power plants to be built in Turkey. This diversification in middle school students' positions can be regarded as an expected outcome considering the complex and controversial nature of SSI, which have no clear-cut solutions (Sadler, 2004). In addition to the compatibility with the nature of SSI, the diversification in the students' positions might be also explained by the students' ways of knowledge evaluation. Studies focusing on students' informal reasoning revealed that students can make different decisions regarding complex SSI by using different evaluation skills, although they are provided to access the same information (Rundgren et al., 2016). In their study, Rundgren and colleagues (2016) investigated upper secondary students' (n=7) informal reasoning regarding the permanent exemption on dioxin contamination of fatty fish from Baltic Sea. The related analyses revealed that some of the students used the data provided to support the issue of exemption, whereas some of them used the same data to support the opposing point of view (i.e. exemption should not be permanent).

Descriptive analysis regarding the usage of KVP revealed that middle school students in the present study mostly used the aspect of value (82.4% for SPE, 77.9% for GMO, and 71.5% for NPP), followed by knowledge (17.3% for SPE, 20.6% for GMO, and 27.6% for NPP) and personal experience (0.3% for SPE, 1.6% for GMO, and 1.0% for NPP) regardless of the SSI topic. In other words, the aspect of value was the most frequently appeared on the students' written arguments, whereas the students' usage of knowledge fell behind the value aspect regardless of the SSI topic. Moreover, the aspect of personal experience was rarely used by the students regarding all SSI topics. Similar to the findings of the present study, previous studies adopting the SEE-SEP Model to investigate students' informal reasoning (Christenson et al., 2012; Christenson et al., 2014; Eriksson & Rundgren, 2012) also reported that students mostly used the aspect of value while negotiating different SSI; followed by knowledge and personal experience. In their study, Christenson and colleagues (2012) examined upper secondary students' (n=80) informal reasoning regarding four different SSI (GMO, nuclear power usage, global warming and consumption) through the SEE-SEP Model. They reported that upper secondary students mostly used the aspect of value (67%), followed by knowledge (27%) and personal experience (6%) regardless of the SSI topic. Moreover, Christenson and colleagues (2014) replicated their previous study (Christenson et al., 2012) to investigate the impacts of discipline background on upper secondary students' (n=208) informal reasoning regarding four different SSI (GMO, nuclear power usage, global warming and consumption). Similar to their previous study, the aspects of knowledge and personal experience less appeared on upper secondary students' informal reasoning than the aspect of value regardless of the SSI topic and discipline background. In parallel to the findings of the present study, Eriksson and Rundgren (2012) also stated that upper secondary students (n=352) mostly used the aspect of value (60%) regarding the wolves in Sweden; followed by knowledge (30%) and personal experience (10%). In another study that adopted the SEE-SEP Model, Karisan and Cebesoy (2021) investigated pre-service teachers' (n=47) informal reasoning regarding two different SSI, namely, gene therapy and preimplantation genetic diagnosis. Like the younger students in the aforementioned studies, pre-service teachers also mostly used the aspect of value (66%) to support their positions regarding the related SSI, followed by knowledge (33%) and personal experience (1%). Similar to these studies adopting the SEE-SEP Model, Zohar and Nemet (2002) also stated that students could not adequately use science content knowledge in SSI discussions. In their study, although 9th grade students' (n=99 for the experimental group; n=87 for the comparison group) usage of content knowledge regarding human genetics increased after explicit argumentation instruction, pre-test results showed that they could not use their content knowledge in the human genetics-related SSI context. More specifically, 32.4% of the students did not use biological content knowledge in their arguments. While 27.0% of them used non-specific biological content knowledge, 24.3% of them used specific but incorrect biological content knowledge, and only 16.2% of the students were able to use specific and correct biological content knowledge in their arguments (Zohar & Nemet, 2002).

In contrast to the aforementioned studies indicating students' failure to use science content knowledge in SSI contexts, some studies asserted that students were able to use content knowledge that they have learnt from the school science in different SSI contexts (Nielsen, 2012b; Sadler & Zeidler, 2005b). In the extent of the study, Nielsen (2012b) investigated students' use of content knowledge in engaging SSI discussions and analyses revealed that the students were able to use science content knowledge in creative and selective ways in order to emphasize the specific aspects of gene therapy. Similarly, Sadler and Zeidler (2005b) examined the relationship between undergraduate students' understandings of genetics concept and their informal reasoning quality**.** Analyses showed that students whose genetics-related understandings were more developed reflected science content knowledge on their informal reasoning more than the students whose genetic-related understandings were less developed did.

The possible explanations for these divergent findings might be related to the notion of intellectual baggage (Zeidler, 1997), students' perception regarding nature of science (Christenson et al., 2012), and "Threshold Model of Content Knowledge Transfer" (Sadler & Donnelly, 2006; Sadler & Fowler, 2006). First, since students bring their cognitive and affective accumulations that constitute their intellectual baggage to the classrooms (Zeidler, 1997), the classrooms cannot be value-free (Zeidler et al., 2005). Therefore, when students negotiate SSI closely related to their intellectual baggage, they tend to use their pre-existing knowledge and beliefs to support their stance (Rundgren et al., 2016). Similarly, Chang Rundgren and Rundgren (2010) stated that individuals tend to use their own values to make decisions, "especially in some SSI, in which there is no obvious evidence to prove its harmlessness or harm" (p. 12). In the present study, the aspect of value was mostly used in SPE topic (82.4%); followed by GMO (77.9%) and NPP (71.5%) topics. From this empirical evidence, it can be concluded that the students' intellectual baggage was very closely related to space explorations topic. When the students' self-reported responses obtained from Issue Familiarity Form were examined, it was revealed that students' level of knowledge, level of interest, willingness to learn, read and research, and do project were the highest on the SPE topic. These empirical evidences supported the assertion that students tend to use the aspect of value when the issue is closely related to their intellectual baggage.

Another explanation might be related to students' perception regarding nature of science (NOS). When students perceive the science "as a body of uncontested knowledge", they tend to use knowledge less than value in the negotiation of SSI (Christenson et al., 2012, p. 351; Lewis & Leach, 2006). From this assertion in the literature, it can be concluded that students in the present study might consider SSI different from "real science" although their epistemological beliefs were fairly sophisticated in all dimensions of EBQ, especially in the dimension of justification.

Another reason behind the students' scarce usage of knowledge compared to value might be related their limited knowledge regarding SSI. At this point, Threshold Theory of Content Knowledge Transfer (Sadler & Donnelly, 2006; Sadler & Fowler, 2006) provided a possible theoretical explanation for this empirical finding. In their study, Sadler and Fowler (2006) explored to what extent students use scientific content knowledge to justify their positions regarding three genetic engineering scenarios. Analyses revealed that science major students who have advanced genetics knowledge displayed high quality of informal reasoning because of the usage of content knowledge, whereas high school students could not reach the threshold and demonstrated low quality of informal reasoning. From this empirical evidence, it was possible that students in the present study might not transfer their content knowledge because of their low-level (i.e. under the knowledge threshold) content knowledge. In other words, the middle school students may not have enough content knowledge to enable them to use the aspect of knowledge in their arguments.

Descriptive analyses also showed that students in the present study mostly used the aspect of personal experience in GMO topic with the extent of 1.6%, followed by NPP and SPE topics with only 1.0% and 0.3% respectively. According to Chang Rundgren and Rundgren (2010), individiuals tend to utilize their personal experiences more, when the related issue is more connected to their daily life. From this empirical evidence, although the students' scores on Issue Familiarity Form were the lowest regarding the GMO topic, it was possible that they may encounter the GMO topic more in their daily life.

In the present study, not only the usage of KVP but also the usage of subject areas, another component of informal reasoning mode, was examined through the SEE-SEP Model (Chang Rundgren & Rundgren, 2010). Descriptive analysis revealed that all of the subject areas appeared on students' written arguments with varying percentages. Regarding space explorations, middle school students mostly considered the subject areas of science (37.8%), followed by environment (26.8%) and sociology/culture (23.2%). The subject areas of economy (7.9%), ethics/morality (3.0%) and policy (1.3%) were not frequently articulated in the students' arguments while negotiating space explorations. Unlike in negotiating space explorations, the subject area of ethics/morality (35.8%) was the most frequently used genetically modified organisms; followed by the subject area of science (35.1%). The subject areas of environment (6.5%) and economy (6.4%) fell behind sociology/culture (14.9%); whereas the least used subject area was policy with only the percentage of 1.3%. Considering the nuclear power plants, the subject area of science (45.2%) the most frequently appeared on students' written arguments. Although the subject areas of sociology/culture (17.6%) and environment (16.5%) fell behind the subject area of science, they also appeared on the students' NPP-related arguments. The subject areas of economy (9.6%) and ethics/morality (9.2%) were used by the students with nearly equal percentages, whereas the least used subject area regarding nuclear power plants was policy (1.9%). Considering the fact that middle school students in the present study used different subject areas while negotiating different SSI, it can be stated that students' informal reasoning modes (i.e. the usage of subject areas) in the negotiation of SSI was context-dependent. That means, the students most frequently considered the subject areas of science and environment in the negotiation of space explorations, whereas they mostly considered the subject areas of ethics/morality and science in the negotiation of genetically modified organisms. Also, the subject areas of science and sociology/culture were most frequently articulated by the students while negotiating nuclear power plants.

The context-dependency of students' informal reasoning modes was also supported by the literature. Similar to the findings of the present study, both the previous studies that adopted the SEE-SEP Model to investigate students' informal reasoning modes (Christenson et al., 2012; Christenson et al., 2014; Eriksson & Rundgren, 2012) and other studies adopting different analytical frameworks (Irmak, 2021) also reported that informal reasoning modes (subject areas in this study) that individuals considered while negotiating different SSI were context-dependent. In their study, Christenson and colleagues (2012) investigated upper secondary students' (n=80) informal reasoning regarding four different SSI through the SEE-SEP Model. In total, the most frequently used subject areas were environment (28%) and science (27%), whereas the least frequently articulated subject area was policy (3%). Similar to the findings of the present study, upper secondary students also tended to use different subject areas while negotiating different SSI. More specifically, they mostly articulated the subject area of science in genetically modified organisms and nuclear power plants; environment in global warming; and sociology/culture in consumption topic. In parallel to these findings, their replicated study (Christenson et al., 2014) reported that students mostly considered the subject areas of environment (M=2.7, SD=2.27) and science (M=2.2, SD=2.96) to provide justifications for their stance, whereas they rarely considered the subject areas of economy (M=0.68, SD=1.72) and policy (M=0.22, SD=0.53). With a very similar pattern, the subject area of science was mostly used by the students in the topics of genetically modified organisms (64%) and nuclear power usage (66%); environment in global warming (43%), and sociology/culture (36%) in consumption topic. In another study adopting the SEE-SEP Model to investigate upper secondary students' informal reasoning modes regarding the wolves in Sweden, Eriksson and Rundgren (2012) revealed that subject areas of science and environment were mostly appeared on the students' arguments, whereas the subject areas of economy and policy were not frequently used by the students. As a different SSI topic, Karisan and Cebesoy (2021) revealed that pre-service teachers (n=47) frequently considered the subject areas of ethics/morality (42%) and science (32%), whereas they rarely considered the subject area of economy while negotiating biotechnology-related SSI, namely, gene therapy and preimplantation genetic diagnosis. Unlike the findings of previous studies, the subject area of environment was not even articulated by the students to support their stance. As another study adopting different analytical framework, Irmak (2021) also reported that students' informal reasoning modes varied across different SSI. More specifically, students mostly generated ecological and social-oriented arguments regarding global warming, whereas they mostly generated ecological and economic-oriented arguments regarding acid rains. Also, social-oriented arguments were mostly generated by the students regarding genetically modified organisms. These similar findings of the studies supported the assertion that students' informal reasoning modes in the negotiation of SSI is context-dependent.

Although students' usage of informal reasoning modes is context-dependent, they may have similar concerns regarding some specific SSI, in particular nuclear power plants and genetically modified organisms. Regarding nuclear power plants, students in the present study mostly used the subject area of science with the highest percentage (45.2%). Similarly, upper secondary students in the studies of Christenson et al. (2012) and Christenson et al. (2014) mostly considered the subject area of science while negotiating nuclear power plants. Regarding the GMO topic, students mostly used the subject area of ethics/morality considering the impacts of GMO on human-health as the participants did in the study of Karisan and Cebesoy (2021) regarding gene therapy and preimplantation genetic diagnosis. Similarly, middle school students in the Irmak's study (2021) mostly generated social-oriented arguments considering human benefit, although the frameworks adopted were different from each other. These similar findings indicated that some informal reasoning modes (e.g. science regarding nuclear power plants; ethics/morality regarding GMO and other genetic engineering applications) may be commonly articulated by the individuals from different cultures. Moreover, it can be regarded as an expected result that students mostly used science while negotiating nuclear power plants and GMO, since these issues are covered in the extent of science curricula of several countries.

Regarding informal reasoning modes, Irmak (2021) also asserted that religious-oriented reasoning mode emerged as a new reasoning mode regarding genetically modified organisms. According to Irmak (2021), religious-oriented arguments were not frequently generated by the students regarding the GMO topic, unlike genetic engineering scenarios. Similar to the findings of her study, the present study also showed that there were some students who support their stance with religious reasons regarding the GMO topic. Therefore, this study supported the findings of Irmak's study indicating that middle school students may support their GMO-related stances with religious-oriented arguments as well.

As another finding regarding middle school students' informal reasoning modes, it was revealed that middle school students in the present study were able to consider more than one subject area in average (M=1.85, SD=1.12) while generating arguments regarding SSI. More specifically, students were able to consider more than one subject area while generating arguments regarding nuclear power plants (M=1.81, SD=1.48) and genetically modified organisms (M=1.62, SD=1.29), whereas they were able to consider more than two subject areas (M=2.12, SD=1.29) in their arguments regarding space explorations. From this empirical evidence, it can be concluded that middle school students in this study were able to consider multiple perspectives while negotiating SSI, although the mean scores were not substantially high. This finding was also consistent with the literature (Dawson & Venville, 2009; Sadler & Zeidler, 2005a; Wu & Tsai, 2007). In their study, Sadler and Zeidler (2005a) indicated that college students frequently used multiple patterns (rationalistic, emotive, and intuitive) while negotiating gene therapy and cloning scenarios. Similarly, Wu and Tsai (2007) indicated that 10th grade high school students were able to consider multiple perspectives (M=2.27, SD=0.77) while negotiating nuclear energy usage. In their study, Dawson and Venville (2009) also adopted informal reasoning patterns as rationalistic, emotive and intuitive (Sadler & Zeidler, 2005a). Although multiple patterns appeared on year 8, 10 and 12 students' arguments, younger students used less multiple patterns than older students did. From this empirical evidence, it can be inferred that middle school students in the present study might not be old enough to consider multiple perspectives with higher mean scores.

5.2.2 Middle School Students' Argumentation Quality

In this study, middle school students' argumentation quality was examined by utilizing Lakatos' Scientific Research Programmes as an analytical framework (Chang & Chiu, 2008). This analytical framework includes four main components as *Hard Core* (HC), *Positive Heuristics* (PH), *Negative Heuristics* (NH), and *Protective Belt* (PB). The middle school students' claims and supporting reasons regarding each SSI were regarded as their Hard Core, since individuals' own claims and accompanying supporting reasons regarding an issue are located in the core of Lakatos' Scientific Research Programmes. Negative Heuristics refer students' generation of counter-arguments and/or limitations, whereas Positive Heuristics refer students' extensions of their own claims and supporting reasons by generating "qualifier showing the alternative line to inquiry" (p. 1758). Also, Protective Belt in which NH and PH embedded represents students' ability to evaluate different arguments (Chang & Chiu, 2008). The findings about the middle school students' argumentation quality including their scores regarding HC, PH, NH and total quality of argumentation, and degree of certainty before and after considering counter-arguments are discussed respectively.

Descriptive analysis regarding HC scores revealed that middle school students in the present study were able to generate claims for their positions. Also, they were able to generate either no or only one supporting reason for their claims, in average for all SSI (M=1.73, SD=0.46). As reported before, only a minority of the students had no clear position regarding space explorations (1.9%), genetically modified organisms (6.9%), and nuclear power plants (8.8%). In other words, majority of the students were easily able to generate claims for their positions. Therefore, this finding was not unexpected since several researchers indicate that claim is the simplest step to generate an argument (Osborne et al. 2004), and the least challenging component generated by the students (Atabey & Topcu, 2017). When the PH and NH scores regarding all SSI were examined, it was revealed that students' both PH and NH scores were substantially low with the mean scores of 0.40 and 0.63 respectively. That means, middle school students in the present study were able to generate less than one PH and NH for each SSI topic. In other words, they were far from being successful in extending their own claims, generating counter-arguments or identifying limitations regarding their own claims.

Although a few exceptions (Rundgren et al., 2016), many studies that investigate students' argumentation quality supported this empirical evidence showing the students' failure to generate high-quality arguments in the context of SSI (Chang & Chiu, 2008; Dawson & Venville, 2009; Georgiou & Mavrikaki, 2013; Kucukaydin, 2019; Liu et al., 2010; Osborne et al., 2004; Sadler & Fowler, 2006). In their study, Osborne and colleagues (2004) investigated the effect of argumentation-based intervention on 8th grade students' quality of argument regarding "building a new zoo" and "siting of a leisure centre in a nature reserve" topics as SSI contexts. For this purpose, students' arguments were assessed through TAP-based levels. Although students' argumentation quality improved after the intervention, most of the students were able to generate arguments from Level 2 both at the beginning and at the end of the year. In other words, students were able to generate claim and any grounds (data, warrant or backing), whereas they had difficulty to generate rebuttals. Similarly, Dawson and Venville (2009) explored Australian high school students' argument quality regarding biotechnology. When the students' responses to semi-structured interviews were examined, it was revealed that they mostly generated arguments in Level 2 indicating claim and supporting evidence. That means, Australian high school students were able to generate their claims and supporting data or warrant, however they could not extend their claims by providing backing and qualifier. More recently, Kucukaydin (2019) investigated 8th grade students' argument quality regarding waste management by adopting TAP-based levels as analytical framework. Similar to the aforementioned studies, majority of the students' arguments could not go beyond the Level 2 and they could only support their claims with data or warrant. In another study adopting TAP-based levels (Osborne et al., 2004) as analytical framework, Georgiou and Mavrikaki (2013) investigated 10th grade Greek students' argumentation quality regarding biotechnology. In parallel to the findings of studies previously mentioned, most of the arguments (60.6%) were coded as Level 2; followed by Level 1 (26.3%), Level 3 (12.0%), Level 4 (0.8%) and Level 5 (0.3%). Moreover, Sadler and Fowler (2006) investigated high school and undergraduate students' argumentation quality regarding three genetic engineering scenarios. For this purpose, students with diverse level of knowledge participated in the study. Analyses revealed that high school students and non-science major undergraduate students, except science major students who had advanced level of content knowledge on genetics, mostly obtained one point for their arguments. That means, the students whose content knowledge is average and low-level, but not advance-level, mostly could generate either justification with no grounds or justification with simple grounds. In other words, they had difficulty to generate elaborated grounds and counter-positions for their justifications. These similar findings showed that students could relatively easily generate claims and supporting reasons, whereas they had difficulty to generate qualifiers and counter-arguments, the indicators of high-quality argumentation.

In addition to aforementioned studies, there are also some studies adopting Lakatos' Scientific Research Programmes to assess students' argumentation quality. In their study, Chang and Chiu (2008) investigated science-major and nonscience-major undergraduate students' (n=70) argumentation quality regarding four SSI (i.e. DDT and malaria, conflict about dioxins, genetically modified food, and organic food). Similar to the findings of the present study, descriptive analysis showed that science-major and nonscience-major undergraduate students were able to present claim and supporting reasons (M=8.25, SD=2.36; M=7.30, SD=1.60), whereas they had difficulty to generate PH (M=0.63, SD=0.90; M=0.17, SD=0.38) and NH (M=0.68, SD=1.02; M=0.47, SD=0.78). That means, students from both majors could not adequately expand their arguments and consider opposing alternatives although science-major students performed better than nonscience major ones. In parallel to these findings, Es and Varol (2019) investigated undergraduate students' argumentation quality regarding nuclear power plants by adopting Lakatos' Scientific Research Programmes. Descriptive analysis showed that undergraduate students were only able to less than one PH (M=0.96, SD=0.90) and NH (M=0.55, SD=0.72) indicating they were not successful in extending their own claims, generating counter-arguments and/or limitations regarding nuclear power plants. In contrast to the previous study, Rundgren and colleagues (2016) investigated seven upper secondary students' argumentation regarding a local SSI (i.e. toxin contamination in fish from Baltic Sea). After the qualitative analyses through Lakatos' Scientific Research Programmes, it was revealed that all of the students were able to provide counter-arguments or limitations as negative heuristics (NH) regarding their position, and extend their arguments by presenting additional supports (PH). In another study adopting Lakatos' Scientific Research Programmes as an analytical framework, Es and Ozturk (2021) reported that 7th grade middle school students' PH scores (M=3.58) were higher than NH scores (M=2.25) regarding fishing ban as a local SSI. Both of the studies showed that students had difficulty to generate counter-arguments and/or limitations, whereas they were relatively easily able to extend their own claims. According to Evagorou and colleagues (2012), these findings might be resulted from the students' tendency to use the evidences to support their claims and ignore the conflicting evidences. Also, this finding is consistent with the aforementioned notion of intellectual baggage proposed by Zeidler (1997). According to Zeidler (1997), students tend to use information consistent with their stance, whereas they tend to ignore conflicting evidences. Similarly, Liu and colleagues (2010) indicated that students tend to find the solutions compatible with their existing knowledge and belief more convincing. Therefore, students may have difficulty to generate counter-arguments (i.e. NH in the present study). However, in contrast to the aforementioned studies, middle school students in the present study obtained higher NH scores than PH scores. The possible reason for this finding might be that students in the present study were explicitly asked the question "What would a person against to your position tell you in order to defend her/his position?”. Since the participants of the present study were expected to express their arguments in a written way without any discussion environment, the individualistic form of the argument was adopted. Therefore, it was possible that they students might feel they needed to answer this question and consider counter-arguments. In parallel to this explanation, Voss and Means (1991) also stated that “individuals generally do not think of counterarguments unless they are explicitly presented” (p. 340).

The possible explanation for middle school students’ low quality of argumentation regarding all SSI might be associated with their lack of argumentation experience. As stated by Irmak (2021), students’ failure to generate high quality arguments may be explained with their lack of argumentation experience. In parallel to this explanation, several studies in the literature (Atabey & Topcu, 2017; Osborne et al., 2004; Zohar & Nemet, 2002) indicated that SSI-based and argumentation interventions can improve students’ quality of arguments in the context of SSI. In their study, Zohar and Nemet (2002) examined the effects of explicit argumentation instruction on 9th grade students’ quality of argument regarding human genetics. After the intervention, it was revealed that high school students’ both knowledge test scores and argumentation skills statistically significantly improved. Similarly, Osborne and colleagues (2004) investigated the effect of argumentation-based intervention on 8th grade students’ quality of argument by adopting TAP-based levels as analytical framework. After the intervention, the number of arguments in Level 3 and above increased (from 40% to 55%) over the year, whereas the number of arguments in Level 1 decreased (from 22% to 15%). More recently, Atabey and Topcu (2017) investigated the effect of SSI-based instruction on 7th grade students’ argument quality regarding global warming. In their study, students’ written arguments were analyzed based on Lizotte et al.’s (2003) analytical framework including claim, evidence, reasoning, and (except) rebuttal. Analyses revealed that SSI-based instruction improves the middle school students’ argument quality with medium effect size for claim and large effect size for evidence and reasoning.

Although the average scores were fairly low regarding all SSI, it was also revealed that middle school students' argumentation quality scores varied across different SSI. More specifically, middle school students obtained the highest total score on space explorations (M=3.06, SD=1.30), followed by nuclear power plants (M=2.69, SD=1.55), and genetically modified organisms (M=2.53, SD=1.37). Considering the HC (i.e. claim and supporting reasons) scores, students had the highest score in arguing space explorations (M=1.80, SD=0.57), followed by genetically modified organisms (M=1.70, SD=0.65), and nuclear power plants (M=1.69, SD=0.75) with nearly same mean scores. Considering the PH scores, students obtained the highest score on space explorations (M=0.56, SD=0.74), followed by nuclear power plants (M=0.37, SD=0.67), and genetically modified organisms (M=0.28, SD=0.58). Similar to the PH scores, students also had the highest NH scores in arguing space explorations (M=0.71, SD=0.75), followed by nuclear power plants (M=0.63, SD=0.78) and genetically modified organisms (M=0.55, SD=0.74).

The fact that middle school students' argumentation quality varied across three different SSI supported the assertion that SSI context may influence students' argumentation quality. Although some of the researchers (Topcu et al., 2010) indicated that students' argumentation quality did not vary across different SSI, several researchers indicated that individuals may display different levels of argumentation skills while arguing different SSI (Irmak, 2021). The possible reasons behind the differentiation in middle school students' argumentation quality across different SSI might be explained with their issue familiarity (Garrecht et al., 2021; Khishfe, 2012b), and personal experiences (Topcu et al., 2010). Therefore, students' issue familiarity was also used as predictors in the present study to investigate whether issue familiarity predict their informal reasoning modes and argumentation quality regarding different SSI. The related findings are discussed in 5.2.4. Predictors for Middle School Students' Informal Reasoning Modes and Argumentation Quality in the context of SSI.

In the present study, middle school students were also expected to indicate the degree of certainty (DoC) regarding their own decisions for each SSI before and after considering counter-arguments. More specifically, students' answers for the question "To what extent are you sure of your decision?" range from 1 (I'm not sure) to 3 (I'm totally sure) were used to obtain DoC scores. Descriptive analysis revealed that middle school students were mostly sure of their decisions regardless of the SSI topics with the scores considerably above the absolute mean of 1-3 point Likert scale although the scores varied across different SSI. To clarify, middle school students in the present study reported that they were sure of their decisions regarding space explorations (M=2.76, SD=0.49), genetically modified organisms (M=2.60, SD=0.60), and nuclear power plants (M=2.57, SD=0.66). When the DoC scores after asking the question "What would a person against to your position tell you in order to defend her/his position?" were analyzed, it was revealed that students' degree of certainty for each SSI were quite above the absolute mean of 1-3 Likert scale (M=2.53, SD=0.67 for SPE; M=2.49, SD=0.67 for GMO, and M=2.45, SD=0.70 for NPP). From this empirical evidence, it can be inferred that middle school students in the present study were able to generate Protective Belt (PB) for their decisions. Considering the findings of the original study (Chang & Chiu, 2008) indicating that undergraduate students tended to keep their argument made initially, this finding was not surprising. According to Chang and Chiu (2008), this tendency might be explained with the assertion that "The HC is the core and foundation of the theory, and it possesses firm and unchangeable features that are very difficult to attack and degenerate" (p. 1758). Although the students were able to generate PB for their initial decisions, their DoC-after scores were lower than the DoC-before scores regardless of the SSI topic. In other words, students' degree of certainty regarding their decisions decreased after they considered counter-arguments. Considering the decrease in DoC scores in a relatively short period of time without any discussion environment, it might be inferred that middle school students in the present study were open to multiple, even opposite perspectives in the negotiation of SSI. In other words, the students may have a potential to change their initial claims and supporting reasons when they are challenged by counter-arguments.

5.2.3 Middle School Students' Epistemological Beliefs

To determine the factor structure of Epistemological Beliefs Questionnaire, exploratory and confirmatory factor analyses were conducted. The results of these factor analyses supported that Schommer's (1990) multidimensional theory is more appropriate than the unidimensional theory to explain the middle school students' epistemological beliefs. According to Schommer (1990), "personal epistemology is a belief system that is composed of several more or less independent dimensions" (p. 498). More specifically, the middle school students' epistemological beliefs in the present study were explained with Ozkan's (2008) three-factor structure including the dimensions of source/certainty, development, and justification. Unlike Conley and colleagues (2004) presenting four-factor structure, in the study conducted by Ozkan (2008), the dimensions of source and certainty merged into a single dimension labelled as source/certainty. Ozkan (2008) explained the difference in the factor structure with different socio-cultural contexts, age, education and maturation issues. According to Ozkan (2008), Turkish culture respects to authority such as parents and teachers, so the students may think that knowledge is transferred from teachers and what their teachers say is always the single correct answer. Therefore, it was possible that the dimensions of source and certainty merged into a single dimension in this context. In parallel to this possible explanation, Yilmaz-Tuzun and Topcu (2008) stated that many teachers in the Turkish educational system may adopt traditional strategies that cause students to think that "science is a body of knowledge discovered by scientists, in which the teachers' role is to deliver this knowledge to students" (p. 77).

The difference in factor structure may be also resulted from different age and grade levels. Researchers indicated that epistemological beliefs can change from simplistic to complex with age (Cano, 2005; Kurt, 2009; Ozkan, 2008). As a result of his study, Cano (2005) stated that Spanish high school students' (n=1600) epistemological beliefs changed to more realistic and complex throughout their secondary school education. The studies of Kurt (2009) and Ozkan (2008) also supported the assertion that younger students may combine the dimensions of source and certainty together due their less developed epitemological beliefs. In her study, Ozkan (2008) investigated only the seventh grade students' epitemological beliefs, whereas Kurt (2009) studied with sixth, eighth and tenth grade students. In parallel, Ozkan (2008) identified three-factor structure, whereas the results of Kurt's study (2009) showed four-factor structure. From this evidence, it can be stated that older students with sophisticated and complex epistemological beliefs were able to differentiate the dimensions of source and certainty. Since the present study was conducted with seventh and eighth grade students, it was possible that the dimensions of source and certainty merged into a single dimension.

Descriptive analysis indicated that middle school students in the present study displayed fairly sophisticated epistemological beliefs with the mean scores quite above the mid-point of 1-5 Likert scale on each dimension. That means, the students tended to believe that scientific knowledge requires using data and evidences (for justification), scientific knowledge can change and evolve (for development), scientific knowledge is constructed by knower, and more than a single correct answer exists (for source/certainty).

These findings were consistent with the literature indicating that students had fairly sophisticated epistemological beliefs (Baser Gulsoy et al., 2015; Conley et al., 2004; Kurt, 2009; Ozkan, 2008). In their study, Conley and colleagues investigated 5th grade students' (n=187) epistemological beliefs through Epistemological Beliefs Questionnaire including four dimensions as source, certainty, development, and justification. Descriptive analysis revealed that students had fairly sophisticated epistemological beliefs regarding all dimensions of EBQ. More specifically, they had the highest score on the dimension of justification, followed by development, whereas they had the least score on the dimensions of source and certainty. Similarly, Ozkan (2008) adapted EBQ into Turkish by examining 7th grade students' (n=1240) epistemological beliefs regarding three dimensions as source/certainty, development, and justification. It was revealed that students had fairly sophisticated epistemological beliefs regarding all dimensions. More specifically, they had the highest score on the dimension of justification (M=3.99, SD=0.64), followed by development (M=3.60, SD=0.61) and source/certainty (M=3.28, SD=0.63). In another study reporting students' sophisticated epistemological beliefs, Kurt (2009) investigated 6^{th}, 8^{th}, and 10^{th} grade students' (n=1557) epistemological beliefs based on four-factor structure proposed by Conley et al. (2004). Results showed that the mean scores regarding all dimensions of EBQ were above the absolute mean of 1-5 Likert scale. More specifically, the students had the highest scores on the dimension of justification among four dimensions of EBQ. In other words, the students tended to believe that construction of scientific knowledge requires data, experiments and justifications. Different from the previous study, Baser Gulsoy and colleagues (2011) investigated 5^{th} and 6^{th} grade students' (n=320) epistemological beliefs through the adapted version of Scientific Epistemological Beliefs Scale including five dimensions as authority and certainty, process of knowledge production, source of knowledge, reasoning, and changeability of knowledge. Although the mean scores on the dimension of authority and certainty were slightly above the absolute mean of 5-point Likert scale, the study reported that students displayed sophisticated epistemological beliefs.

When the previous studies were examined, it was also revealed that the related mean scores varied across the dimensions, especially in favor of justification dimension, although students displayed fairly sophisticated epistemological beliefs regarding all dimensions. Similar to this pattern, middle school students in the present study obtained the highest score on the dimension of justification, followed by development, whereas the least score on the dimension of source/certainty. In other words, students displayed the most sophisticated epistemological beliefs on justification dimension of EBQ, followed by development, whereas the least sophisticated epistemological beliefs on the dimension of source/certainty. Similar to the findings of both previous research (Conley et al., 2004; Kurt, 2009; Ozkan, 2008) and the present study, more recent studies (Aydin & Gecici, 2017; Boz et al., 2011) also supported this finding. In their study, Boz and her colleagues reported that the students in all grade levels (4^{th}, 6^{th}, and 8^{th}) had the highest score on the dimension of justification, followed by development, whereas they had the least score on the dimension of source/certainty, especially in the lower grades. Similarly, Aydin and Gecici (2017) revealed that 6^{th} grade students' (n=196) had the most sophisticated epistemological beliefs on the dimensions of justification (M=3.71, 3.53), followed by development (M=3.31, 3.32), whereas they had the least sophisticated beliefs on the dimension of source/certainty (M=2.59, 2.72) for female and male students respectively.

The possible reason behind the students' sophisticated epistemological beliefs, in particular regarding the dimension of justification might be explained with the competence in science aimed by Turkish middle school science curriculum. According to Turkish middle school science curriculum (MoNE, 2018), "competence in science refers to the ability and desire to use knowledge and methodology to explain the natural world to define questions and produce evidence-based conclusions" (p. 6). Considering the 2018 Turkish middle school science curriculum that advocates the importance of evidence-based conclusions to explain the natural world, it may not be surprising that students, studying with this curriculum, displayed the most sophisticated epistemological beliefs on the dimension of justification.

5.2.4 Predictors for Middle School Students' Informal Reasoning Modes and Argumentation Quality in the context of SSI

To reveal how well the dimensions of epistemological beliefs (source/certainty, development, and justification) and middle school students' issue familiarity predicted their informal reasoning modes and argumentation quality regarding different SSI (SPE, GMO and NPP), multiple regression analyses were conducted. In other words, the dimensions of epistemological beliefs and students' issue familiarity were considered as the predictors of their informal reasoning modes (total number of subject areas used by the students) and argumentation quality (total number of PH and NH generated by the students) regarding each SSI. After ensuring that all the assumptions were met, three separate multiple regression analyses (each for PH, NH, and total subject areas) were conducted for each SSI.

5.2.4.1 Epistemological Beliefs as Predictors

Inferential analyses revealed that the dimension of development, one of the epistemological beliefs, had a significant predictive power for students' both informal reasoning modes and argumentation quality regarding all SSI, whereas source/certainty, another dimension of the epistemological beliefs, made statistically significant contribution only to the generation of NH regarding space explorations. Moreover, the dimension of justification did not make any statistically significant contribution to students' informal reasoning modes and argumentation quality regardless of the SSI topic.

From these empirical evidences, it can be interpreted that predictors of students' informal reasoning modes and argumentation quality varied across different SSI. This interpretation is consistent with the literature focusing on the relationships between these constructs (Baytelman et al., 2020; Irmak, 2021; Khishfe, 2012b; Mason & Scirica, 2006). In their study, Mason and Scirica (2006) investigated how well epistemological beliefs could predict 8^{th} grade students' argumentation skills (i.e. the generation of argument, counter-argument, and rebuttal) regarding two different SSI, namely, global warming and genetically modified organisms. When the students' domain-specific epistemological beliefs were examined, it was revealed that "*judgments of truth about the social world*", one of the domains of epistemological beliefs, was related to their counter-argument skills regarding both global warming and GMO, whereas it was also related to their argument and rebuttal skills regarding only GMO. From this empirical evidence, it can be stated that the relationships between epistemological beliefs and argumentation quality may vary across different SSI. Similarly, Khishfe (2012b) examined the relationship between high school students' understandings of NOS and argumentation skills regarding genetically modified organisms and water fluoridation. Students' understandings of

NOS based on subjective, tentative and empirical aspects were classified as naïve, intermediary and informed, whereas their argumentation quality were considered as their ability to generate arguments, counter-arguments and rebuttals. Correlational analyses revealed that the relationships between the constructs regarding water fluoridation were stronger than genetically modified organisms. Based on this finding, Khishfe (2012b) indicated that students' NOS or epistemological understandings and their argumentation skills may differ "depending on the content/context within which these views are assessed" (p. 506). In parallel to these findings, Baytelman and colleagues (2020) investigated how well the university students' epistemological beliefs could predict their argumentation skills regarding three different SSI, namely, "vaccination or not, against the NUEVO flu virus; consumption of bottled versus tap water; usage of underground versus overhead high voltage lines in residential areas" (p. 1203). Multiple regression analyses revealed that university students' epistemological beliefs, particularly the beliefs about structure of knowledge, predicted their argumentation skills in terms of quantity, quality and diversity. Further analysis showed that SSI-context in which students generate supporting arguments, counter-arguments and rebuttals has also a significant predictive power for quantity of these components, but not for the quality and diversity. More recently, Irmak (2021) examined whether 8th grade students' quality of informal reasoning could be predicted by their NOS understandings (i.e. the tenets of empirical-based, subjectivity, and tentativeness) regarding three different SSI, namely, acid rain, genetically modified organisms and global warming. Multiple regression analyses revealed that all tenets of NOS understandings significantly predicted students' quality of informal reasoning regarding GMO and global warming, whereas only the tenets of empirical-based and tentativeness made significant contribution to the students' quality of informal reasoning regarding acid rain. In other words, the tenet of subjectivity did not have any significant power for predicting the students' quality of informal reasoning regarding acid rain. These similar findings of the aforementioned studies showed that the degree of relationships between students' epistemological beliefs (or NOS understandings), informal reasoning modes and argumentation quality may vary across different SSI.

When the related findings were examined, it was revealed that none of the epistemological beliefs (except the dimension of development) predicted their informal reasoning modes and argumentation quality regarding genetically modified organisms. Unlike space explorations and nuclear power plants, GMO-related informal reasoning modes and argumentation quality could not be predicted by the independent variables in the present study. One possible reason behind the low predictive power of the independent variables on dependent variables might be explained by the students' failure to generate high-quality arguments considering multiple subject areas regarding the GMO topic. According to Irmak (2021), the reason why subjectivity, one of the tenets of NOS, did not significantly predict students' informal reasoning regarding acid rain may be that they had difficulty to generate argument with respect to other SSI topics (genetically modified organisms, and global warming). From this point of view, in the present study, middle school students' epistemological beliefs did not make any significant contribution to their informal reasoning modes and argumentation quality regarding GMO, since they had more difficulty to generate high quality arguments, and consider multiple perspectives.

Although some of the predictors varied across different SSI, the dimension of development was the best predictor of informal reasoning modes and argumentation quality regarding all three SSI. That means, students who believe that scientific knowledge is subject to change and evolve rather than certain tended to generate more PH and NH, as indicators of high quality argumentation, and consider multiple subject areas, as an indicator of informal reasoning modes, while negotiating SSI.

In the literature, there are several studies asserting that students' beliefs regarding the tentative nature of scientific knowledge were correlated with students' informal reasoning and/or argumentation quality (Bendixen et al., 1998; Irmak, 2021; Schommer & Dunnell, 1997; Wu & Tsai, 2011). In their study, Bendixen and colleagues (1998) investigated the relationship between undergraduate students' epistemic beliefs and moral reasoning. Epistemic beliefs of the undergraduate students were obtained through Epistemic Beliefs Inventory based on the dimensions of Schommer's instrument (1990), whereas their moral reasoning was assessed through short version of Defining Issues Test (DIT) including three dilemmas. After the hierarchical regression analysis was conducted, it was revealed that undergraduate students' epistemic beliefs could explain considerable proportion of the total variance in moral reasoning scores above other variables of the study (i.e. gender, age, education and syllogistic reasoning). In particular, the dimensions of simple knowledge, certain knowledge, omniscient authority, and quick learning make unique contributions to undergraduate students' moral reasoning. Since certain knowledge dimension of Schommer's instrument reflects the beliefs regarding tentative nature of scientific knowledge rather than certain, it can be associated with the dimension of development in the present study. Similarly, Schommer and Dunnell (1997) examined the relationship between gifted high school students' epistemological beliefs and their solutions regarding everyday life dilemmas. Regression analyses indicated that students' epistemological beliefs, especially the dimensions of fixed ability, quick learning and certain knowledge, predicted their solution types. More specifically, students whose epistemological beliefs on these dimensions were developed tended to produce simplistic and unchanging responses as solutions to related dilemmas. In another study focusing on students' epistemological beliefs and informal reasoning, Wu and Tsai (2011) investigated the relationships between 10th grade students' scientific epistemological beliefs (SEB) and informal reasoning regarding nuclear power usage as SSI topic. The high school students' SEB scores were obtained through the instrument developed by Conley et al. (2004), while their informal reasoning was obtained through a modified version of the open-ended questionnaire developed in their former study (Wu & Tsai, 2007). The results showed that the dimensions of justification and development were significantly correlated with the number of rebuttals generated by the students. That means, the students who recognize the importance of experiments to justify scientific knowledge; and the ones believe that scientific knowledge has a tentative and evolving nature tended to generate more rebuttals. More recently, Irmak (2021) investigated how well 8th grade students' NOS understandings (i.e. the tenets of empirical-based, tentativeness, and subjectivity) predict their quality of informal reasoning regarding three different SSI, namely, acid rain, genetically modified organisms, and global warming. Multiple regression analyses revealed that the tenet of tentativeness was able to predict students' scores on informal reasoning quality regarding all SSI.

The reason behind the strong predictive power of development might be that students are able to generate counter-arguments that conflict their original claims, and evaluate the issue by considering multiple, sometimes opposing perspectives, when they appreciate the importance of tentative nature of scientific knowledge. In other words, when they believe scientific knowledge is changing and evolving rather than certain, they become less resistant to evaluate the SSI from different point of views.

Inferential analyses also indicated that the dimension of source/certainty was only the predictor of the generation of NH regarding space explorations. That means, students who believe that scientific knowledge is constructed by knower rather than transmitted by authority, and there is more than one correct answer tended to generate more counter-arguments or provide more limitations regarding space explorations. The dimension of justification did not make any significant contribution to the middle school students' informal reasoning modes and argumentation quality regardless of the SSI topic.

This finding was not consistent with the literature (Hofer & Pintrich, 1997; Wu & Tsai, 2011) indicating that students' epistemological beliefs, in particular the dimension of justification, predicted their argumentation quality (i.e. in terms of the number of rebuttals as an indicator of high-quality argumentation). According to Hofer and Pintrich (1997), the individuals' beliefs regarding the dimension of justification require high-quality cognitive processes, therefore it was not surprising that the beliefs on the justification dimension was able to predict students' argumentation quality. In the present study, the possible reason behind why the dimension of justification did not make any significant contribution to the middle school students' total number of informal reasoning modes and argumentation quality regardless of the SSI topic might be explained students' failure to generate high-quality arguments and considering multiple perspectives. Although the middle school students arguments varied across different SSI, their overall scores on both informal reasoning modes and argumentation quality were substantially low regarding all SSI. That means, although the students had fairly sophisticated epistemological beliefs regarding all the dimensions of epistemological beliefs, especially in the dimension of justification, they were not able to generate high-quality arguments and consider multiple perspectives. In other words, the students' beliefs regarding the dimension of justification could not predict the total number of informal reasoning modes and argumentation quality, since both the students with more sophisticated epistemological beliefs and less sophisticated epistemological beliefs were not able to generate high-quality arguments and consider multiple perspectives regarding all SSI.

5.2.4.2 Issue Familiarity as Predictor

Multiple regression analyses also revealed that students' issue familiarity (i.e. the scores regarding students' level of knowledge, interest, willingness and source of information) statistically predicted the total number of informal reasoning modes and argumentation quality regarding nuclear power plants, and space explorations (except the generation of NH). However, students' issue familiarity did not make any contribution to their informal reasoning modes and argumentation quality regarding genetically modified organisms.

When the middle school students' issue familiarity scores were examined, it was revealed that they were the most familiar with space explorations (M=2.27, SD=0.34); followed by nuclear power plants (M=2.02, SD=0.46), and genetically modified organisms (M=1.96, SD=0.46). In parallel to the findings of multiple regression analyses, the middle school students obtained the highest argument quality score on space explorations (M=3.06, SD=1.30), followed by nuclear power plants (M=2.69, SD=1.55), and genetically modified organisms (M=2.53, SD=1.37). Similarly, as an indicator of informal reasoning, they were able to consider more than two subject areas (M=2.12, SD=1.29) in their SPE-related arguments, whereas they were able to generate more than one subject area while generating arguments regarding NPP (M=1.81, SD=1.48) and GMO (M=1.62, SD=1.29) topics. From these empirical evidences, it can be concluded that middle school students in the present study were able to generate more qualified arguments, and consider multiple perspectives more (in terms of subject areas used), regarding the SSI which they were more familiar with.

This finding of the present study was consistent with the literature indicating that SSI context and issue familiarity play an important role in students' informal reasoning modes and argumentation quality (Baytelman et al., 2020; Garrecht et al., 2021; Irmak, 2021), although some of the studies reported that SSI context did not influence students' quality of informal reasoning (Topcu et al., 2010). Despite the lack of consensus in the literature regarding how students' issue familiarity influences their informal reasoning modes and argumentation quality, majority of the researchers in the field of science education agree that basic familiarity regarding an issue is needed for students to engage in argumentation (Garrecht et al., 2021; Lewis & Leach, 2006; Topcu et al., 2010). In their study, Garrecht and colleagues (2021) investigated the relationship between 9th and 10th grade students' (n=163) issue familiarity and argumentation quality regarding animal testing as SSI context. As a result of the study adopting SEE-SEP Model, it was revealed that increased issue familiarity improved students' diversity of discipline-related arguments although all disciplines were not improved equally. In addition to this finding, Garrecht and colleagues (2021) individual factors (e.g. students' motivation to learn animal testing) also influence students' effort to familiarize themselves regarding the issue under discussion. Therefore, the researchers indicated that animal testing is a potentially "effective issue to engage students in multidisciplinary argumentation even without additional knowledge" (p. 14), because teachers have already some difficulties regarding limited time and lack of materials while teaching SSI in the classrooms (Garrecht et al., 2021). From this point of view, in the present study, the middle school students were already familiar with space explorations. More specifically, they were more knowledgeable about; more interested in; and had more willing to learn, read and research, and do project regarding space explorations. Therefore, it can be stated that space explorations might be an effective issue to engage students in more qualified and multidisciplinary argumentation even without explicit teaching, especially in the limited instructional time.

Similar to the findings of the present study, Lewis and Leach (2006) also investigated the relationship between students' scientific content knowledge and ability to engage in reasoned discussions regarding biotechnological applications. Results showed that when the students were familiar with the issue, they were able to generate more reasoned arguments. Moreover, Lewis and Leach (2006) also emphasized that the students ignored the new issues when they were "outside of their experience and had little relevance to their immediate lives" (p. 1275). Similarly, Khishfe (2012b) indicated that "students might better connect to the issue especially if it is more familiar and related to their everyday lives" (p. 492). Consistent with these findings, Capkinoglu and colleagues (2020) indicated that both interest and familiarity might be associated with the indicators of students' high quality argumentation. In their study, Capkinoglu and colleagues (2020) investigated 7th grade students' (n=36) quality of arguments regarding five local SSI, namely an artificial lake, chicken coops, leather tanneries, base stations, and hydroelectric power plants (HPP). For this purpose, students were differentiated into three groups, namely, the newspaper group, the presentation group, and the outdoor group. After the analysis, it was revealed that hydroelectric power plants were the most challenging SSI for all groups. In other words, all groups, even the most successful group (i.e. the newspaper group) generated low quality arguments regarding HPP. According to Capkinoglu et al. (2020), a possible reason behind this finding was that HPP may be the least attractive context among all SSI regardless of the learning group. In the present study, students were the least knowledgeable regarding, and interested in genetically modified organisms (GMO). Similar to the present study, Christenson and colleagues (2012) reported that GMO was the least preferred (14%) among four different SSI contexts (GMO, nuclear power usage, global warming, and consumption) by the upper secondary students. Likewise, in their replicated study (Christenson et al., 2014), the least preferred SSI context by the upper secondary students were GMO (13%).

More specifically, students' level of knowledge, level of interest, willingness (i.e. to learn, read and research, and do project), and sources of information might influence their informal reasoning modes and argument quality regarding different SSI. Descriptive statistics derived from students' self-reported responses to Issue Familiarity Form revealed that only 3.7% of the middle school students' have no knowledge regarding space explorations, whereas 21.7% of them have no knowledge regarding nuclear power plants. With the highest percentage, 22.4% of the students reported that they have no knowledge regarding genetically modified organisms. In other words, students were the most knowledgeable regarding SPE, whereas the least knowledgeable regarding GMO among three different SSI. Considering that students obtained the highest score on space explorations, followed by nuclear power plants, and genetically modified organisms in terms of both argumentation quality (i.e. total argument quality score) and informal reasoning modes (i.e. total number of subject areas used), it can be inferred that content knowledge contributes to students' informal reasoning modes and argumentation quality in the context of SSI. In other words, middle school students in the present study were able to generate more qualified arguments and consider multiple perspectives more (in terms of subject areas used) regarding the SSI which they were more knowledgeable about. Consistent with this empirical evidence, several studies (Baytelman et al., 2020; Sadler & Zeidler, 2005b) indicated that students' content knowledge contributes to their argumentation quality regarding SSI, with a few exceptions (Sadler & Donnelly, 2006). Although these empirical evidences provide insights regarding the possible relationship between content knowledge and argumentation quality, there is still a need for further research to investigate this relationship in a more systematic way, since the data of present study were based on students' self-reported responses regarding level of knowledge.

Descriptive analysis derived from Issue Familiarity Form also revealed that only 6.5% of the students reported that they have no interest regarding space explorations, whereas 21.5% of them have no interest regarding nuclear power plants. With the highest percentage, 26.9% of the students reported that they have no interest regarding genetically modified organisms. In other words, students were the most interested in the SPE topic, whereas the least interested in the GMO topic. Similar to students' level of knowledge, their level of interest may also contribute their informal reasoning and argumentation skills regarding different SSI. When the students' informal reasoning modes (i.e. total number of subject areas used) and argumentation quality (i.e. total argument quality score) across three different SSI were examined, it was revealed that students obtained the highest score on space explorations, followed by nuclear power plants, and genetically modified organisms. From these empirical evidences, it can be inferred that students were able to generate more qualified arguments and consider multiple perspectives more (in terms of subject areas used) regarding the SSI which they were more interested in. Like students' level of knowledge, although these empirical evidences provide insights regarding the possible relationship between interest and argumentation quality, there is still a need for further research to investigate this relationship in a more systematic way, since the data of present study were based on students' self-reported responses regarding level of interest.

Similar to students' level of knowledge and level of interest, their willingness to learn, read and research, and do project were the highest regarding space explorations, followed by nuclear power plants, and genetically modified organisms. More specifically, the percentage of the students who reported that they have no willing to learn was only 6.0% regarding space explorations, 18.1% regarding nuclear power plants, and 21.5% regarding genetically modified organisms. Considering the willingness to read and research, the percentage of the students who reported that they have no willing to read and research was only 5.6% regarding space explorations, 20.0% regarding nuclear power plants, and 22.6% regarding genetically modified organisms. Considering the willingness to do project, the percentage of the students who reported that they have no willing to do project was only 17.8% regarding space explorations, 32.3% regarding nuclear power plants, and 39.6% regarding genetically modified organisms. As can be easily seen from these percentages, students had the most willing to engage SSI-focused scientific practices, namely to learn, read and research, and do project, regarding the SPE topic, whereas the least willing regarding the GMO topic. From these empirical evidences, it can be inferred that students were able to generate more qualified arguments and consider multiple perspectives more (in terms of subject areas used) regarding the SSI which they were more willing to engage SSI-focused scientific practices. Like the level of knowledge and level of interest, considering the students' informal reasoning modes and argumentation quality regarding each SSI, it can be inferred that students' willingness to engage SSI-focused scientific practices (i.e. to learn, read and research, and do project) contributes their informal reasoning modes and argumentation quality. Therefore, further research should be conducted to provide empirical evidences to the literature.

In the literature, several researchers indicated that individuals' familiarity regarding an issue might come from mass media such as newspaper, the Internet, television (TV), news, and advertisements (Khishfe, 2012b; Ladwig et al., 2012; Yang et al., 2017). Therefore, in addition to level of knowledge, interest and willingness to engage SSI-focused scientific practices, students' sources of information regarding each SSI were also examined through Issue Familiarity Form. Descriptive statistics indicated that the middle school students mostly obtained information from multiple sources regardless of the SSI topic. More specifically, teacher was the most frequently used source by the students regardless of the SSI topic (61.7% for SPE, 44.3% for GMO, and 43.2% for NPP). The sources of textbooks and social media (Facebook, Twitter, Instagram, YouTube etc.) fell behind the source of teacher with varying percentages for each SSI. Although the differences in percentages can be neglected, the students reported that they obtained more information regarding space explorations and nuclear power plants from social media (47.5%; 35.5%) than textbooks (46.0%; 31.8%), whereas they reported that they obtained more information regarding genetically modified organisms from textbooks (31.0%) than social media (30.3%).

In the extent of her doctoral dissertation, Irmak (2021) investigated 8th grade students' (n=414) quality of informal reasoning regarding three different SSI, namely, acid rain, genetically modified organisms, and global warming. Similar to the findings of the present study, students displayed different levels of argumentation skills regarding each SSI, although the quality of informal reasoning scores were fairly low regardless of SSI topic. More specifically, the students obtained the highest score regarding global warming, whereas the scores on acid rain and genetically modified organisms fell behind global warming. Considering that students mostly obtained information regarding global warming from textbooks, whereas regarding acid rain and GMO from the Internet, Irmak (2021) explained the possible reason of students' low quality arguments regarding acid rain and GMO with their usage of the Internet as a source of information. In the literature, several researchers (Irmak, 2021; Ozturk & Yilmaz-Tuzun, 2017) indicated that the media and the Internet might be misleading for the students.

Comparing the middle school students' informal reasoning modes and argumentation quality scores regarding each SSI, and their sources of information, it can be stated that students were able to generate more qualified arguments and consider multiple perspectives more (in terms of subject areas used) regarding the SSI which they obtained information about from social media whereas less qualified arguments and consider less subject areas regarding the SSI which they obtained information about from textbooks. In contrast to the findings of Irmak's study, usage of the Internet may not be misleading for middle school students in the present study. Surprisingly, students were able to relatively higher quality arguments and consider multiple perspectives more regarding space explorations and nuclear power plants than they did regarding GMO, although they reported the social media as their primary source of information regarding SPE and NPP. At this point, it was also possible that students might benefit from the social media as a source of information. Indeed, one extra item added to space explorations regarding whether they follow NASA or not supported the assertion that students may use the Internet properly for educational purposes. Majority of the students (43.7%) reported that they follow NASA much. These inconsistent findings of the studies emphasized that there is a need for further studying on students' usage of the Internet as a source of information in the context of SSI.

5.3 Conclusion of the Study

Considering the findings of the present study, the following conclusions can be drawn:

1. As compatible with the nature of SSI, middle school students' positions varied across different SSI. For instance, most of the students (87.5%) supported that space explorations should be maintained in Turkey, whereas far fewer students (30.3%) supported that genetically modified organisms should be used in Turkey. Therefore, it can be stated that students can arrive different conclusions and decisions regarding complex SSI by using different evaluation skills, although they are provided to access the same information (Rundgren et al., 2016).

2. Regardless of the SSI topic, middle school students the most frequently used the aspect of value; followed by knowledge, whereas the least frequently used the aspect of personal experience. Considering one of the primary goals of science education is providing students to use their scientific content knowledge in different contexts, this finding showed that there is a long way to go for achieving this goal.

3. Middle school students' usage of subject areas, as a component of their informal reasoning, varied across different SSI. More specifically, the students mostly considered the subject areas of science and environment regarding space explorations; ethics/morality and science regarding GMO; science and sociology/culture regarding nuclear power plants. Therefore, it can be concluded that students' informal reasoning modes in the negotiation of SSI was context-dependent.

4. Middle school students were able to consider more than one subject area in the negotiation of GMO and nuclear power plants, whereas they were able to consider more than two subject areas in the negotiation of space explorations. Although the related mean scores were not quite high, it can be concluded that students were able to consider SSI from multiple perspectives.

5. Middle school students' argumentation quality scores were substantially low. More specifically, they were able to generate less than one PH and NH for each SSI topic. In other words, they were far from being successful in extending their claims, generating counter-arguments or identifying limitations regarding their own claims. Considering one of the main goals of science education is providing students to develop argumentation skills, this finding showed that there is a long way to go for achieving this goal.

6. Although middle school students' degree of certainty (DoC) regarding their own decisions decreased after they considered counter-arguments, their DoC scores for each SSI were quite above the absolute mean of 1-3 Likert scale. That means, they were still sure of their own decisions even after considering counter-arguments. From this empirical evidence, it can be concluded that middle school students were able to generate Protective Belt (PB) for their decisions.

7. Although the mean scores regarding the argumentation quality were fairly low for all SSI, the related scores varied across different SSI. More specifically, middle school students obtained the highest total score on space explorations, followed by nuclear power plants, whereas they had the least score on genetically modified organisms. From this empirical evidence, it can be concluded that students' argumentation quality was also context-dependent.

8. Middle school students' epistemological beliefs were explained with three-factor structure, namely, source/certainty, development, and justification (Ozkan, 2008).

9. Middle school students displayed fairly sophisticated epistemological beliefs on all the dimensions of EBQ, in particular on the dimension of justification. To clarify, students obtained the highest score on the dimension of justification, followed by development, whereas they had the lowest score on the dimension of source/certainty.

10. Middle school students mostly utilized multiple sources to obtain information regarding the SSI, namely, space explorations, GMO, and nuclear power plants. More specifically, among the sources of information, the most frequently used source by the students was teacher regardless of the SSI topic. The sources of textbooks and social media (Facebook, Twitter, Instagram, YouTube etc.) fell behind the source of teacher with varying percentages for each SSI.

11. The present study showed that students' issue familiarity predicted their informal reasoning modes (in terms of total subject areas used) and argumentation quality (in terms of total number of PH and NH). In other words, students were able to generate more qualified arguments and consider

multiple perspectives more regarding the SSI which they were more familiar with. More specifically, the middle school students were able to generate more qualified arguments and consider multiple perspectives more regarding the SSI which they were more knowledgeable about; more interested in; and more willing to engage SSI-focused scientific practices (i.e. to learn, read and research, and do project). Therefore, it can be concluded that students' content knowledge, interest, willingness, and sources of information, that constitute their issue familiarity, might be correlated with their informal reasoning modes and argumentation quality.

12. Middle school students' epistemological beliefs predicted their informal reasoning modes and argumentation quality. More specifically, the dimension of development made a unique contribution to students' informal reasoning modes (total number of subject areas considered by the students), PH and NH scores regarding all SSI. That means, as students believe that scientific knowledge is changing, they are able to consider multiple perspectives (subject areas in this study); extend their own claims more; and generate more counter-arguments or provide more limitations. The dimension of source/certainty significantly predicted only the generation of NH regarding space explorations. That means, as the students believe that scientific knowledge is constructed by knower rather than transmitted by authority, and there is more than one correct answer, they are able to generate more counter-arguments or provide more limitations regarding space explorations. Also, the dimension of justification did not make any significant contribution to the middle school students' informal reasoning modes and argumentation quality regardless of the SSI topic.

13. Middle school students' scores on Issue Familiarity Form predicted their informal reasoning modes and argumentation quality regarding space explorations and nuclear power plants except the generation of NH regarding

space explorations. However, the scores did not make any contribution to students' informal reasoning modes and argumentation quality regarding genetically modified organisms.

14. In the present study, the predictors of students' informal reasoning modes and argumentation quality varied across different SSI (SPE, GMO, and NPP). From this empirical evidence it can be concluded that the degree of relationships between students' epistemological beliefs, informal reasoning modes and argumentation quality may vary across different SSI contexts.

5.4 Educational Implications of the Study

Considering the findings presented in the previous chapter, the present study has several educational implications that can be practiced by science teachers, science curriculum developers, and researchers focusing on epistemological beliefs, informal reasoning and argumentation quality in the context of SSI.

From the perspective of science education researchers, one of the main goals of science education is providing students to use content knowledge that they have learnt from the school science in the contexts beyond the classroom. In other words, students are expected to transfer their learning to new situations and different contexts (Haskell, 2001; Sadler & Donnelly, 2006). Although there are some divergent findings in the literature, middle school students in the present study were not able to use their content knowledge in the negotiation of SSI. Regardless of the SSI topic, they tended to use the aspect of value more than knowledge and personal experience. According to Christenson (2011), students' usage of knowledge in lower extent emphasized the importance of practicing the usage of content knowledge in argumentation. In other words, students need scientific knowledge-oriented SSI practices more. Therefore, the first educational implication might be related to integrating content knowledge into the negotiation of SSI in the classrooms. At this point, teachers and other educational practitioners that intend to teach SSI in their classrooms should provide students to integrate the related content knowledge as well as values into the negotiation of SSI. Also, science curriculum might be revised so that revised curriculum focuses SSI-related practices more. Moreover, Karisan and Cebesoy (2021) revealed that pre-service teachers also the most frequently used the aspect of value (66%) regarding gene therapy and preimplantation genetic diagnosis; followed by knowledge (33%), and personal experience (1%). Therefore, teacher education programs should prepare pre-service teachers to integrate scientific content knowledge more into the SSI practices in their classrooms.

Regarding middle school students' informal reasoning modes, it was also revealed that students tended to consider different subject areas while negotiating different SSI. That means, in parallel to the literature focusing on individuals' informal reasoning modes, the usage of subject areas was context-dependent. Therefore, the second educational implication might be related to the ability for providing relevant and rich SSI contexts, since this finding of the present study pointed out the importance of selecting appropriate issues to negotiate in the classrooms. According to Christenson and colleagues (2012), teachers should select appropriate SSI topics, especially when they want to encourage students to engage SSI-based practices in which students use domain-specific knowledge in the negotiation, since students retrieve different scientific knowledge from different subject areas to negotiate different issues. Thus, teachers should be aware of their potential ability for connecting SSI to scientific knowledge from different subject areas. For instance, if teachers intend to engage in scientific knowledge from the subject area of science, space explorations and nuclear power plants were appropriate choices to negotiate in the classrooms. Moreover, the GMO topic could be a good choice to consider the subject areas of ethics/morality and science, whereas the consumption topic could be appropriate to retrieve scientific knowledge from the subject area of sociology/culture.

Another educational implication of the present study might be also related to the selection of SSI in science classrooms, but from a different point of view. Garrecht and colleagues (2021) emphasized that selecting SSI that students more familiar with might be potentially effective to engage students in multidisciplinary argumentation, especially, in limited time and without teaching materials. Considering this finding, it can be stated space explorations might be an effective issue to engage students in more qualified and multidisciplinary argumentation even within these instructional conditions, since the middle school students were already familiar with space explorations. More specifically, they were more knowledgeable about; more interested in; and had more willing to learn, read and research, and do project regarding space explorations.

Regarding the quality of argumentation, it was revealed that middle school students in the present study were not able to generate high quality arguments regarding SSI. The similar findings obtained from both in the present study and the literature (Dawson & Venville, 2009; Georgiou & Mavrikaki, 2013; Kucukaydin, 2019; Liu et al., 2010; Osborne et al., 2004; Sadler & Fowler, 2006) might be explained students' lack of argumentation experience, since several researchers indicated that SSI-based argumentation interventions improved students' quality of arguments regarding different SSI (Atabey & Topcu, 2017; Osborne et al., 2004; Zohar & Nemet, 2002). Considering these empirical evidences, it can be recommended that teachers should provide students to experience argumentation practices more, especially in the context of SSI. If students engage argumentation practices more, they can find an opportunity to improve their argumentation skills. Therefore, teachers should integrate explicit argumentation practices into their lessons more frequently.

When the students' DoC scores both before and after asking the question "What would a person against to your position tell you in order to defend her/his position?" were examined, it was revealed that DoC-after scores were lower than the DoC-before scores regardless of the SSI topic. That means, students' degree of certainty regarding their decisions decreased after they considered counter-arguments. This empirical evidence showed that students may have a potential to change their initial claims and supporting reasons when they are challenged by counter-arguments. Therefore, another educational implication can be related to creating opportunities for students’ core beliefs to be challenged. For this purpose, teachers should create discussion environments in which students’ initial claims and supporting reasons can be challenged by other students and the teacher herself/himself. According to Zeidler and colleagues (2002), “dialogic reasoning and argumentation has been found to challenge the core beliefs of students” (p. 344). Creating dissonance by providing counter-arguments and anomalous data contradicting students’ initial beliefs allows students to re-examine their own “beliefs and thought-processes” (Zeidler et al., 2005, p. 115). In this way, students may engage in high-quality argumentation processes. In this manner, Lakatos’ Scientific Research Programmes can be considered as an effective analytical framework as it can allow students to evaluate PH and NH embedded in Protective Belt to revise their core beliefs.

To investigate how well the dimensions of epistemological beliefs predicted middle school students’ informal reasoning modes and argumentation quality regarding three different SSI, namely, space explorations, GMO, and nuclear power plants, multiple regression analyses were conducted. One of the findings derived from these multiple regression analyses was that the relationships and power of predictions may vary across different SSI. In the present study, source/certainty, one of the dimensions of epistemological beliefs, made statistically significant contribution to the generation of NH regarding space explorations, whereas it did not have any predictive power for other components of informal reasoning modes and argumentation quality. Also, students’ issue familiarity (pre-existing knowledge, interest, willingness, and sources of information) significantly predicted their informal reasoning modes and argumentation quality regarding space explorations and nuclear power plants, whereas they did not make any contribution regarding the GMO topic. From this empirical evidence and similar findings in the literature (Baytelman et al., 2020; Irmak, 2021; Khishfe, 2012b; Mason & Scirica, 2006), it can be interpreted that SSI context has also a predictive power for informal reasoning modes and argumentation quality. Therefore, SSI context should be also considered while developing students’ epistemological beliefs, informal reasoning, and argumentation quality.

5.5 Recommendations for Further Research

Considering both limitations and findings of the present study, the following recommendations can be suggested for further research. First, sample of the present study was limited to 7^{th} and 8^{th} grade students from eight public middle schools in five different districts of Çankaya. Additionally, convenience sampling was adopted due to the COVID-19 pandemic. Therefore, the present study can be replicated with different grade levels and larger samples selected through random sampling techniques in order to ensure the generalizability of the findings. Second, contexts used in the extent of the present study were limited to three socioscientific issues (SSI), namely, space explorations (SPE), genetically modified organisms (GMO) and nuclear power plants (NPP). Therefore, different topics from diverse disciplines can be selected as SSI contexts. Third, the present study adopted two different analytical frameworks (i.e. SEE-SEP Model, and Lakatos' Scientific Research Programmes) to investigate middle school students' informal reasoning modes and argumentation quality regarding different SSI in a more holistic way. In other words, the purpose of using two different analytical frameworks is to provide a better understanding to the literature. Since the findings of the present study were based on these particular analytical frameworks, different frameworks adopted by the researchers might result different findings for further research. Moreover, although two different analytical frameworks provided the findings in a more holistic way, neither of these analytical frameworks mainly assess the scientific accuracy of the arguments. Therefore, since the present study did not provide an understanding to what extent middle school students were able to generate scientifically valid arguments, further research may also focus on the scientific accuracy of the arguments.

The present study revealed that middle school students were not able to use their content knowledge in the negotiation of SSI context. In the literature, some studies (Albe, 2008; Zohar & Nemet, 2002; Christenson et al., 2012; Christenson et al., 2014) provided similar findings regarding students' failure to use their knowledge in

SSI contexts, whereas some of them (Nielsen, 2012b; Sadler & Zeidler, 2005b) indicated students were able to use content knowledge in their arguments. These inconsistent findings of the studies showed that there is a need for further studying regarding how and to what extent students are able to use their knowledge in their informal reasoning and arguments regarding different SSI.

Another recommendation for further research can be conducting follow-up interviews to elicit students' epistemological beliefs sincerely. Since students' epistemological beliefs were obtained based on students' self-reported responses to 5-point Likert scale (i.e. Epistemological Beliefs Questionnaire), it was possible that data obtained from students might be misleading for the findings of the study. For instance, although middle school students' epistemological beliefs were fairly sophisticated on all the dimensions of EBQ, they were not able to generate qualified arguments. Considering the fact that students' epistemological beliefs, especially the dimension of development, significantly predicted their argumentation quality regardless of SSI topics, follow-up interviews can be conducted to reveal students' epistemological beliefs more sincerely.

Considering the fact that middle school students' epistemological beliefs predicted their informal reasoning modes and argumentation quality in the context of SSI, conducting intervention studies can be another recommendation for further research. Researchers should investigate how middle school students' informal reasoning and argumentation quality regarding different SSI can be improved through explicit instruction of epistemological beliefs or NOS. Such an intervention study may provide insights to both science teachers and science curriculum developers to design an effective SSI-based curriculum so that students can generate qualified arguments regarding complex SSI.

In addition to intervention studies, researchers focusing on SSI-based curriculum should also design effective course materials so that science teachers can use these materials to improve middle school students' informal reasoning and argumentation quality regarding complex SSI. In other words, there is a need for curricular materials and instructional strategies to practice SSI-based curriculum in authentic classroom environments. For instance, one of the educational implications of the present study was integrating content knowledge into the negotiation of SSI in the classrooms. As a recommendation, design research can be conducted to provide insights regarding how science teachers integrate scientific content knowledge into SSI-based practices effectively to improve their students' informal reasoning and argumentation quality.

In the present study, middle school students were able to generate the highest quality of arguments regarding space explorations, followed by nuclear power plants, whereas they obtained the lowest quality score on the GMO topic. Also, they were able to consider multiple perspectives more regarding SPE; followed by NPP, and GMO. Descriptive statistics also revealed that students' issue familiarity (level of knowledge, interest, and willingness, and sources of information) were the highest regarding the SPE topic, followed by the topics NPP, and GMO. Considering the predictive power of issue familiarity on students' informal reasoning modes (in terms of total subject areas used) and argumentation quality (in terms of total number of PH and NH) across different SSI, it can be inferred that students' content knowledge, interest, willingness, and sources of information, that constitute their issue familiarity, might be correlated with their informal reasoning modes and argumentation quality. Therefore, there is a need for studying on the possible relationship between these constructs by adopting specific instruments in further research, since the data regarding issue familiarity were based on students' self-reported responses to Issue Familiarity Form in the present study.

Lastly, the present study indicated that students' epistemological beliefs predicted their informal reasoning modes and argumentation quality regarding space explorations, and nuclear power plants. Similarly, in the literature, many of the studies revealed that individuals' epistemological beliefs may contribute informal reasoning modes or argumentation quality (Baytelman et al., 2018; Baytelman et al., 2020; Bendixen et al., 1994; Bendixen et al., 1998; Liu et al., 2010; Mason & Scirica, 2006; Oztuna Kaplan & Cavus, 2016; Ozturk & Yilmaz-Tuzun, 2017; Schommer & Dunnell, 1997; Wu & Tsai, 2011), whereas some of the studies indicated that there is no systematic link between these constructs (Angeli & Valanides, 2012; Mintchik & Farmer, 2009; Topcu et al., 2011). Considering these inconsistent findings of the studies, there is a need for further studying regarding the relationship between epistemological beliefs, informal reasoning modes, argumentation quality, and the role of SSI context.

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APPENDICES

A. Data Collection Instrument for the Present Study

DEMOGRAFİK BİLGİ FORMU

Yönerge: Aşağıda verilen soruları kendinizi en iyi yansıtacak şekilde yanıtlayınız. Sorulara vereceğiniz yanıtlar araştırma amacıyla kullanılacak ve gizli tutulacaktır.

Kişisel Bilgiler:

1. Cinsiyetiniz: □ Kız □ Erkek
2. Sınıfınız: □ 7. Sınıf □ 8. Sınıf
3. Bir önceki dönem Fen Bilimleri dersi karne notunuz:

……………..

EPİSTEMOLOJİK İNANÇLAR ANKETİ

Yönerge: Aşağıda verilen ölçekte her bir ifadeye hangi ölçüde katılıp katılmadığınızı size en uygun kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.	**Kesinlikle Katılmıyorum**	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum**
Tüm insanlar, bilim insanlarının söylediklerine inanmak zorundadır.					
Bilimde, bütün soruların tek bir doğru yanıtı vardır.					
Bilimsel deneylerdeki fikirler, olayların nasıl meydana geldiğini merak edip düşünerek ortaya çıkar.					
Günümüzde bazı bilimsel düşünceler, bilim insanlarının daha önce düşündüklerinden farklıdır.					
Bir deneye başlamadan önce, deneyle ilgili bir fikrinizin olmasında yarar vardır.					
Bilimsel kitaplarda yazanlara inanmak zorundasınız.					
Bilimsel çalışma yapmanın en önemli kısmı, doğru yanıta ulaşmaktır.					
Bilimsel kitaplardaki bilgiler bazen değişir.					
Bilimsel çalışmalarda düşüncelerin test edilebilmesi için birden fazla yol olabilir.					

A. Data Collection Instrument for the Present Study (Cont'd)

Fen Bilgisi dersinde, öğretmenin söylediği her şey doğrudur.					
Bilimdeki düşünceler, konu ile ilgili kendi kendinize sorduğunuz sorulardan ve deneysel çalışmalarınızdan ortaya çıkabilir.					
Bilim insanları bilim hakkında hemen hemen her şeyi bilir, yani bilinecek daha fazla bir şey kalmamıştır.					
Bilim insanlarının bile yanıtlayamayacağı bazı sorular vardır.					
Olayların nasıl meydana geldiği hakkında yeni fikirler bulmak için deneyler yapmak, bilimsel çalışmanın önemli bir parçasıdır.					
Bilimsel kitaplardan okuduklarınızın doğru olduğundan emin olabilirsiniz.					
Bilimsel bilgi her zaman doğrudur.					
Bilimsel düşünceler bazen değişir.					
Sonuçlardan emin olmak için, deneylerin birden fazla tekrarlanmasında fayda vardır.					
Sadece bilim insanları, bilimde neyin doğru olduğunu kesin olarak bilirler.					
Bilim insanının bir deneyden aldığı sonuç, o deneyin tek yanıtıdır.					
Yeni buluşlar, bilim insanlarının doğru olarak düşündüklerini değiştirir.					
Bilimdeki, parlak fikirler sadece bilim insanlarından değil, herhangi birinden de gelebilir.					
Bilim insanları bilimde neyin doğru olduğu konusunda her zaman hemfikirdirler.					
İyi çıkarımlar, birçok farklı deneyin sonucundan elde edilen kanıtlara dayanır.					
Bilim insanları, bilimde neyin doğru olduğu ile ilgili düşüncelerini bazen değiştirirler.					
Bir şeyin doğru olup olmadığını anlamak için deney yapmak iyi bir yoldur.					

A. Data Collection Instrument for the Present Study (Cont'd)

SOSYOBİLİMSEL KONULAR ANKETİ

Yönerge: Konular ile ilgili verdiğiniz yanıtlar bilimsel araştırma amaçlı kullanılacak olup herhangi bir not karşılığı yoktur. Size verilen metinde yer alan soruların doğru ya da yanlış cevapları bulunmamaktadır. Dolayısıyla vereceğiniz yanıtların içten ve açık olması araştırmanın yürütülebilmesi açısından çok önemlidir.

KONU 1: UZAY ARAŞTIRMALARI

Uzay araştırmaları; roket, füze, uydu ve uzay istasyonları gibi teknolojik araçlar vasıtasıyla uzayın araştırılması ve buradan elde edilen bilgilerin haberleşme, hava durumu tahmini, navigasyon (GPS), televizyon yayını gibi çeşitli alanlarda kullanılmasıdır. Ancak görevi biten, işlevsiz veya parçalanan insan yapımı bazı uzay araçları yeryüzüne dönememekte ve Dünya'nın etrafında başıboş dolanmaktadır; bu da uzay kirliliğine sebep olmaktadır. Son yıllarda artan uzay kirliliği sebebiyle uzay araştırmalarının aynı hızda devam edip etmemesi dünya genelinde olduğu kadar Türkiye'de de tartışmalı bir hal almıştır. Bilim insanlarının konu ile ilgili olumlu ve olumsuz veriler ortaya koymasıyla konuya yönelik farklı çözüm önerileri sunulmaktadır.

(a) Bu bilgiler ışığında, sizce Türkiye'de uzay araştırmalarına devam edilmeli midir edilmemeli midir; nedenleriyle yazınız?

……………………………………………………………………………………

(b) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı düşünerek**, kararınızdan hangi ölçüde emin olduğunuzu kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

Uzay araştırmaları konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

(c) Bu konu ile ilgili, sizin görüşünüze karşı olan bir kişi kendi görüşünü savunmak için size neler söyleyebilir?

……………………………………………………………………………………

(d) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı ve belirttiğiniz karşıt görüşü düşünerek**, kendi kararınızdan hangi ölçüde emin olduğunuzu kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

Uzay araştırmaları konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

A. Data Collection Instrument for the Present Study (cont'd)

KONU 2: GENETİĞİ DEĞİŞTİRİLMİŞ ORGANİZMALAR (GDO)

Genetiği değiştirilmiş organizmalar (GDO); genetik mühendisliği yöntemleri ile bir canlıdaki seçilmiş genetik özelliklerin kopyalanarak bu özellikleri taşımayan başka bir canlıya aktarılması sonucu üretilen canlılara verilen isimdir. Böylece, genetiği değiştirilmiş organizmalar kendinde doğal şekilde bulunmayan çeşitli özellikler kazanabilir. Son yıllarda GDO'lu gıdaların insanlar ve hayvanlar tarafından tüketiminin artması ile birlikte gündeme gelen bu konu; dünya genelinde olduğu kadar Türkiye'de de tartışmalı bir hal almıştır. Bilim insanlarının konu ile ilgili olumlu ve olumsuz veriler ortaya koymasıyla konuya yönelik farklı çözüm önerileri sunulmaktadır.

(a) Bu bilgiler ışığında, sizce Türkiye'de genetiği değiştirilmiş organizmalar (GDO) kullanılmalı mıdır kullanılmamalı mıdır; nedenleriyle yazınız?

………………………………………………………………………………………

(b) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı düşünerek**, kararınızdan <u>hangi ölçüde emin olduğunuzu</u> kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

GDO konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

(c) Bu konu ile ilgili, <u>sizin görüşünüze karşı olan bir kişi</u> kendi görüşünü savunmak için size neler söyleyebilir?

………………………………………………………………………………………

(d) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı ve belirttiğiniz karşıt görüşü düşünerek**, kendi kararınızdan <u>hangi ölçüde emin olduğunuzu</u> kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

GDO konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

KONU 3: NÜKLEER GÜÇ SANTRALLERİ

Uranyum gibi radyoaktif elementlerin atom çekirdeğinin parçalanması sonucu, çok büyük miktarda enerji açığa çıkar. Açığa çıkan bu enerji ile su kazanları kaynatılır ve oluşan su buharının basıncından yararlanılarak türbinler döndürülür. Türbinlerin döndürülmesi sonucu elektrik enerjisinin üretildiği santrallere nükleer güç santralleri denir. Son yıllarda hem ülkemizde hem de dünyada artan enerji talepleri ile gündeme gelen bu konu dünya genelinde olduğu kadar Türkiye'de de tartışmalı bir hal almıştır. Bilim insanlarının konu ile ilgili olumlu ve olumsuz veriler ortaya koymasıyla konuya yönelik farklı çözüm önerileri sunulmaktadır.

(a) Bu bilgiler ışığında, sizce Türkiye'de nükleer güç santralleri kurulmalı mıdır kurulmamalı mıdır; nedenleriyle yazınız?

…………………………………………………………………………………………

(b) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı düşünerek**, kararınızdan hangi ölçüde emin olduğunuzu kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

Nükleer santraller konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

(c) Bu konu ile ilgili, sizin görüşünüze karşı olan bir kişi kendi görüşünü savunmak için size neler söyleyebilir?

…………………………………………………………………………………………

(d) Yukarıdaki konu ile ilgili **vermiş olduğunuz kararı ve belirttiğiniz karşıt görüşü düşünerek**, kendi kararınızdan hangi ölçüde emin olduğunuzu kutucuğun içine **çarpı (X) işareti** koyarak belirtiniz.

Nükleer santraller konusundaki kararımla ilgili	**Emin Değilim**	**Kararsızım**	**Eminim**

A. Data Collection Instrument for the Present Study (cont'd)

SOSYOBİLİMSEL KONULARLA İLGİLİ AŞİNALIK FORMU

Yönerge: Aşağıda verilen her bir ifade ile ilgili kendinizi en iyi yansıttığını düşündüğünüz kutucuğun içine **çarpı (X) işareti** koyunuz.

Konuyla ilgili;	**Uzay Araştırmaları**			**GDO**			**Nükleer Güç Santralleri**		
	Hiç	**Az**	**Çok**	**Hiç**	**Az**	**Çok**	**Hiç**	**Az**	**Çok**
Bilgi sahibiyim.									
İçeriklere ilgi duyuyorum.									
Öğrenmeye istekliyim.									
Okumaya/araştırma yapmaya istekliyim.									
Proje yapmaya istekliyim.									
Bilgileri ailemden öğrenirim.									
Bilgileri arkadaşlarımdan öğrenirim.									
Bilgileri öğretmenimden öğrenirim.									
Bilgileri ders kitaplarından öğrenirim.									
Bilgileri sosyal medyadan (Facebook, Twitter, Instagram, Youtube vb.) öğrenirim.									
Bilgileri gazete ve dergilerden öğrenirim.									
Bilgileri kendi gözlem ve deneyimlerimden edinirim.									
Bilgileri televizyondan öğrenirim.									
Bilgileri birden fazla kaynaktan öğrenirim.									
NASA'yı takip ederim.									

B. Permission Obtained for Turkish Version of EBQ

Konu: Ölçek Kullanım İzni
Gönderen: "Cansu Başak UYGUN"
Tarih: 2 Temmuz 2020, Perşembe, 11:34 am
Alıcı:

Şule Hocam merhaba,

Ben Cansu Başak UYGUN. Orta Doğu Teknik Üniversitesi, Matematik ve Fen Bilimleri Eğitimi Bölümünde yüksek lisans yapmakta ve araştırma görevlisi olarak çalışmaktayım. Yüksek lisans tezimin bir bölümü için ortaokul öğrencilerinin epistemolojik inançlarını ortaya çıkarmayı amaçlıyorum. Bu sebeple, adapte etmiş olduğunuz 26 maddelik "Epistemolojik İnançlar Ölçeğini" kullanmak adına sizden izin istiyorum. Katkılarınızın araştırmacılar için çok değerli olduğunu belirterek, şimdiden çok teşekkür ederim.

İyi çalışmalar dilerim.
Arş. Gör. Cansu Başak UYGUN

Konu: RE: Ölçek Kullanım İzni
Gönderen: Şule Özkan Kaşker
Tarih: 2 Temmuz 2020, Perşembe, 12:00 pm
Alıcı: "Cansu Başak UYGUN"

Sayın Cansu Başak UYGUN,

Yüksek lisans teziniz kapsamındaki akademik çalışmanız için "Epistemolojik İnançlar Ölçeğini" kullanabilirsiniz.

Başarılar ve iyi çalışmalar diliyorum.

Dr. Şule ÖZKAN KAŞKER
Uzman
Yetişkin Eğitimi Koordinatörlüğü

C. Approval Obtained from Human Subjects Ethics Committee

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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Sayı: 28620816 / 200

16 HAZİRAN 2020

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Özgül Yılmaz TÜZÜN

Danışmanlığını yaptığınız **Cansu Başak UYGUN'un "Orta Okul Öğrencilerinin Epistemolojik İnançlarının, Argüman Kalitelerinin ve İnformal Muhakemelerinin Sosyobilimsel Konular Bağlamında İncelenmesi"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **200 ODTU 2020** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof.Dr. Mine MISIRLISOY
Başkan

Prof. Dr. Tolga CAN
Üye

Doç.Dr. Pınar KAYGAN
Üye

Dr. Öğr. Üyesi Ali Emre TURGUT
Üye

Dr. Öğr. Üyesi Şerife SEVİNÇ
Üye

Dr. Öğr. Üyesi Müge GÜNDÜZ
Üye

Dr. Öğr. Üyesi Süreyya Özcan KABASAKAL
Üye

D. Approval Obtained from Ministry of National Education

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.12231152 07.09.2020
Konu : Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE

İlgi: a) 28.08.2020 tarihli ve 202 sayılı yazınız.
b) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2020/2 nolu Genelgesi.

Üniversiteniz Fen Bilimleri Enstitüsü Yüksek Lisans Öğrencisi Cansu Başak UYGUN'un **"Ortaokul Öğrencilerinin epistemolojik İnançlarının, Argüman Kalitelerinin ve İnformal Muhakemelerinin Sosyobilimsel Konular Bağlamında İncelenmesi"** konulu tezi kapsamında ekteki Çankaya ilçesine bağlı 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, Millî 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 (3 sayfa)
2-Okul listesi (1 sayfa)
Dağıtım:
Gereği:
ODTÜ
Bilgi:
Çankaya İlçe MEM

Adres: Emniyet Mah. Alparslan Türkeş Cad. 4/A Yenimahalle Bilgi için: Emine Konuk

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e-posta: istatistik06@meb.gov.tr Faks: 0 (___) ___ __ __

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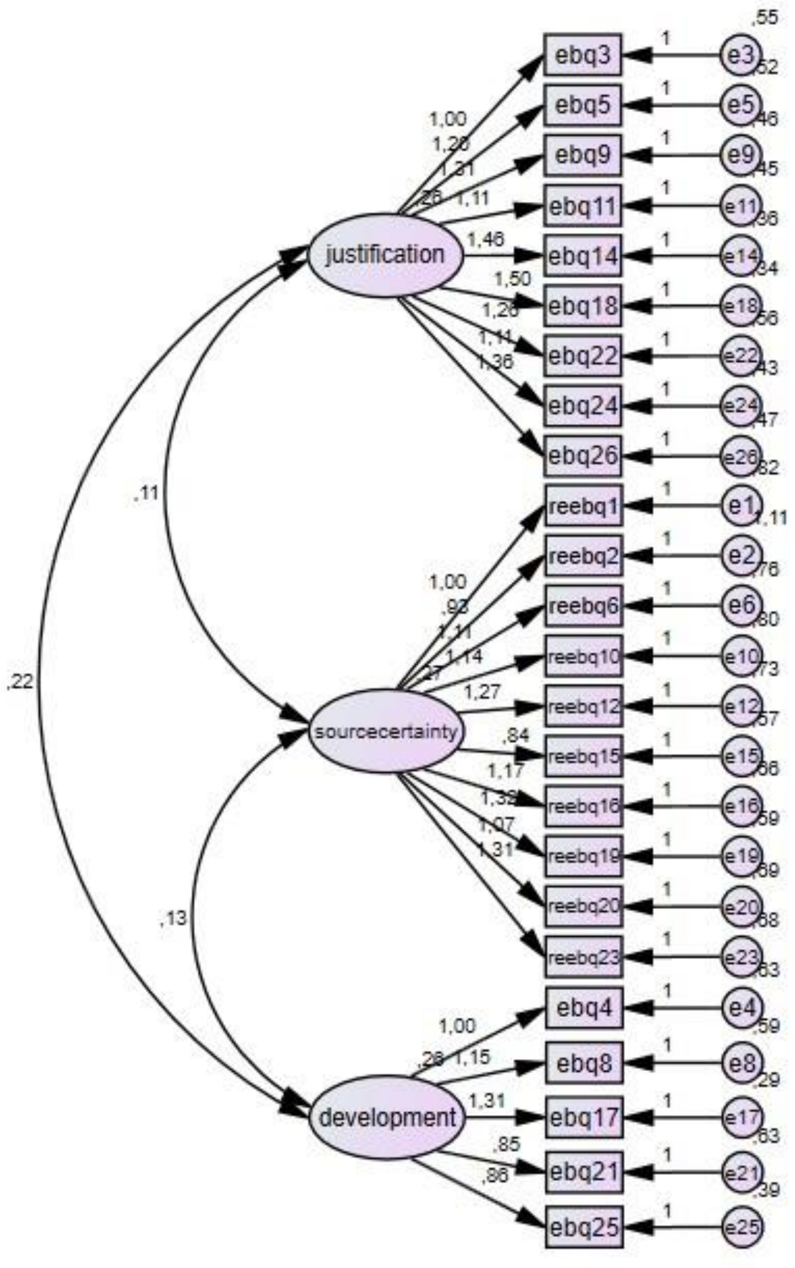
E. Initial CFA Model for EBQ



F. Revised CFA Model for EBQ