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Elementary School Students' Informal Reasoning and Its' Quality Regarding Socio-Scientific Issues*

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ABSTRACT

Purpose: Since developing science literacy is a primary objective of science education and socio-scientific (SSI) decision-making is an important aspect of science literacy, it is valuable to explore how students structure their decisions related to SSIs, and how they discuss and solve SSIs. The aim of present study was to examine elementary school students' informal reasoning patterns related to SSIs, and the quality of these patterns.

Research Methods: In the study, I employed basic qualitative design. To recruit the participants, I used typical case sampling to determine the schools and then I employed critical case sampling to select these participants. I gathered the data through semi-structured interviews and employed thematic analysis in the data analysis process. Findings: The findings revealed that the participants used logical, emotional and intuitive informal reasoning patterns to solve socio-scientific issues. However, a notable result of the study is that the least used reasoning pattern was logical reasoning while the most frequently used pattern was intuitive reasoning. Furthermore, it was found that the participants were engaged mostly in low-quality reasoning.

Implications for Research and Practice: The results of the study revealed that individuals use not only logic, but also emotions and intuition while looking for an answer for SSIs. Therefore, ıt is important for science educators to consider value-laden science teaching.

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Introduction

A primary goal of science education is to cultivate scientific literacy for all students (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996; National Science Teachers Association [NSTA], 2000). This skill requires discussing complex social issues and decision-making related to science (Fowler, Zeidler & Sadler, 2009), and it is accepted that it can be taught through socio-scientific issues (SSIs) (Kolstø, 2001a; Sadler, 2004a; Zeidler & Keefer, 2003). This is because SSIs create active contexts for the development of knowledge and processes that contribute to science literacy, such as forming evidence-based arguments, reaching a consensus, moral reasoning, and comprehending and applying scientific content (Sadler, 2009; Zeidler & Sadler, 2011), and they focus on developing individuals' ability to make conscious decisions (Sadler, 2004b; Zeidler & Keefer, 2003). Therefore, SSIs are an interesting and significant topic for science educators (Driver, Newton & Osborne, 2000; Kolstø, 2001a; Sadler & Zeidler, 2005b).

SSIs are science-based social issues that are complex, open-ended, and controversial; they lack absolute solutions and include contradictions (Sadler, 2004b). They can be encountered in daily life (Kolstø, 2001a), and are centered upon social dimensions of scientific content (Topcu, 2010). SSIs are current events on which there is no consensus while moral and ethical choices should be made, and they influence individuals, involve understanding risks and possibilities, are structured in the form of open-ended contradictions, and can be solved in multiple ways but have no exact solution (Ozden, 2015). Accordingly, in the literature, SSIs are usually associated with developments in biotechnology and environmental problems (Sadler & Zeidler, 2005a). For example, deforestation, genetically modified products (Foong & Daniel, 2013), climate change (Morris, 2014), cloning, the use of nuclear energy, the depletion of the ozone layer, and epidemics are accepted as SSIs (Pedretti, 2003). Certain controversial issues such as embryo selection, stem cell applications, and transplantation of tissues or organs between two different species are also SSIs (Levinson, 2006).

Discussing SSIs requires individuals to produce socio-scientific arguments (Grooms, Sampson & Golden, 2014). This type of argumentation is referred to as informal reasoning (Sadler & Zeidler, 2005b), which is a goal-oriented process that involves demonstrating and evaluating the pieces of proof related to a claim or result (Means & Voss, 1996). Informal reasoning is an evaluation regarding the reasons, consequences, advantages and disadvantages of certain suggestions or decision alternatives (Zohar & Nemet, 2002). It can also be used to describe scientific processes used in discussions and solutions of socio-scientific issues (Sadler & Zeidler, 2004). In accordance with these definitions, informal reasoning pertains to the thought processes that include evaluating the proof and considering different perspectives, which lead to individuals justifying their result with political, economic, moral, and ecological arguments in decision-making related to SSIs.

Traditionally, reasoning is used in the sense of formal reasoning, which is characterized with the rules of logic and mathematics (Sadler, 2003). Formal reasoning

emphasizes producing, evaluating, criticizing and developing claims and proof to explain natural phenomena (Duschl & Osborne, 2002; Osborne, Erduran & Simon, 2004). In other words, formal reasoning is the act of evaluating information (Cavagnetto, Hand & Norton-Meier, 2010). On the other hand, informal reasoning has a slightly ambiguous structure, and is based on the skill of producing and evaluating arguments. However, unlike formal arguments, such informal arguments are evaluated in terms of the soundness criterion, not as processes of information evaluation. This criterion has three primary indicators: 1) the acceptability of the supporting reason, 2) whether the reason supports the conclusion, or in other words, whether it is related to the reason, and 3) the extent to which counterarguments are considered (Means & Voss, 1996). Another criterion is to give priority to non-scientific proof and perspectives such as economic, political, and moral issues (Grooms et al., 2014). Informal reasoning makes use of cognitive as well as emotional characteristics while examining SSIs (Topcu, Yilmaz-Tuzun & Sadler, 2011). Consequently, in informal reasoning, individuals obtain a result based on the pieces of information they gain from multiple sources including personal experience, knowledge, beliefs, and values (Rundgren, 2011).

Regarding SSIs, there are different approaches that examine informal reasoning constructs. To explain the factors that affect individuals' reasoning processes related to SSIs (e.g., cognitive, affective, moral, ethical, economic, social, and political factors), constructs referred to as modes (Patronis, Potari & Spiliotopoulou, 1999; Yang & Anderson, 2003; Wu & Tsai, 2011) and patterns (Sadler & Zeidler, 2005a, b) are used. For instance, Patronis et al. (1999) describe informal reasoning processes with reference to social, ecological, economic, and practical modes. Yang and Anderson (2003) explain informal reasoning processes as scientifically oriented, social oriented, and equally disposed modes. Wu and Tsai (2011) refer to the reasoning processes related to SSIs as social, economic, ecological, and scientific, or as technology-oriented argument modes. While social oriented reasoning involves thoughts about social welfare and sympathy for others, the economic oriented mode reflects the perspective that is based on economic development. Moreover, the ecological oriented mode focuses on thoughts that observe the ecological balance, whereas scientific or technology-oriented modes relate to the advantages or limitations of science or technology (Wu & Tsai, 2011). On the other hand, Sadler and Zeidler (2005a, 2005b) address the informal reasoning process with reference to logical, emotional, and intuitive reasoning patterns. Logical informal reasoning includes thinking rationally, a thought process that refers to pragmatic principles, the issue of cost and benefit, and rational evaluation of technology. Emotional reasoning requires emotions such as empathy and sympathy in the decision-making process, and thus it is a kind of reasoning that focuses on human characteristics (i.e. emotions) in decision making. Lastly, intuitive informal reasoning represents individuals' unexplained sudden impulses in cognitive processes toward solving socio-scientific issues (Dawson & Venville, 2013; Sadler & Zeidler, 2005a, b; Topcu et al., 2011).

The quality of informal reasoning is as important as that of informal reasoning patterns (Topcu, 2008). In this respect, many studies examined the skills individuals

possess in producing arguments in the context of different SSIs (e.g., Albe, 2008; Ekborg, 2008; Jimenez-Aleixandre, Rodriguez & Duschl, 2000; Kortland, 1996; Lee, 2007; Patronis et al., 1999; Sadler, 2003; Ozturk & Yilmaz-Tuzun, 2017; Zohar & Nemet, 2002). These studies mostly based the analysis processes on the principals of informal reasoning (Means & Voss, 1996), the argumentation model (Toulmin, 2003), and the critical thinking developmental model (Kuhn, 1999). Although each of these models has different theoretical bases, all three of them emphasize the importance of producing supporting or opposing arguments related to the solution of socio-scientific issues (Sakschewski, Eggert, Schneider & Bögeholz, 2014). Accordingly, the criteria to be followed in evaluating the arguments that individuals produce in the process of informal reasoning can be specified as follows: (a) Does the individual state an argument related to the case presented? (b) Does the argument have an acceptable justification? (c) What is the quality of the justification proposed? (d) Have both sides of the problem been taken into consideration? In other words, have opposing arguments been stated as well? (e) Have qualifiers, or meta-statements, been used properly? and (f) How many acceptable justifications have been indicated to support the claims asserted? (Means & Voss, 1996). These criteria are used to evaluate the quality of informal reasoning employed in the literature with various modifications (e.g. Dawson & Carson, 2017; Evagorou, Jimenez-Aleixandre & Osborne, 2012; Sadler, 2003; Topcu, 2008; Wu & Tsai, 2011). However, the relevant literature does not provide any consistent models to explain the relationship between the quality of informal reasoning and individuals' argumentation skills (Topcu, 2008).

With regard to the literature on SSIs, studies mostly examined producing arguments in SSIs (Cetin, Dogan & Kutluca, 2014; Molinatti, Girault & Hammond, 2010), developing argumentation skills related to SSIs (Dawson & Venville, 2013; Grooms et al., 2014; Kortland, 1996; Zohar & Nemet, 2002), decision-making processes for SSIs (Evagorou et al., 2012; Grace, Lee, Asshoff & Wallin, 2015; Sakschewski et al., 2014), and informal reasoning and the factors affecting it (Sadler, 2003; Sadler & Zeidler, 2005a, b; Topcu et al., 2011). The data in related studies were gathered from middle school (Emery, Harlow, Whitmer & Gaines, 2017; Khishfe, 2014; Patronis et al., 1999), high school (Dawson & Carson, 2017; Kolarova, Hadjiali & Denev, 2013), pre-service (Grooms et al., 2014; Topcu et al., 2011; Ozturk & Yilmaz-Tuzun, 2017), and in-service teachers (Day & Bryce, 2011; Liu & Roehrig, 2019). It can thus be argued that elementary school students' processes of informal reasoning were ignored by researchers. Therefore, examining these overlooked school students' processes of informal reasoning has a special significance. If SSIs are or will be used as learning contexts in science classes, then elementary school students' informal reasoning patterns and qualities should be understood. This is because SSIs are reorganized as a pedagogical tool for science instruction to develop science literacy (Sadler & Zeidler, 2005a; Topcu, 2008). Since developing science literacy is a primary objective of science education and socio-scientific decision-making is an important aspect of science literacy, it is valuable to explore how students structure their decisions related to SSIs, and how they discuss and solve SSIs. Based on this framework, the aim of this study was to examine elementary school students' informal reasoning patterns related to

SSIs, and the quality of these patterns. Specifically, the study was based on the following research questions:

1. What are elementary school students' informal reasoning patterns regarding multiple SSIs?
2. What are elementary school students' reasoning quality regarding SSIs?

Method

Research Design

In the study, I employed basic qualitative design (Merriam, 2009) to discover and evaluate participants' informal reasoning patterns related to SSIs, and the quality of these patterns with an interpretive approach. Hereby, I didn't consider generalizing the results to a wider population. Instead I preferred a more detailed approach to catch their perspectives regarding selected SSIs. Therefore, basic qualitative design provided me flexible research process to describe and interpret participants' understanding and approaches. In this way, I was able to describe participants' reasoning processes and the quality of these processes at a basic level.

Schools and Participants

In the study, I firstly determined the elementary schools, and afterwards selected the students. In the first step, I used typical case sampling (Patton, 2001) to determine the schools where data would be gathered. By means of this sampling strategy, a researcher tries to understand a certain phenomenon by examining average cases. It is also a useful method because it can be used to show shareholders what is typical rather than making generalizations. In other words, the sample is selected in accordance with descriptive goals (Patton, 2001). In this regard, I decided to gather data in three elementary schools close to the provincial average in terms of socio-economic status in a city located in the west-central Anatolia region of Turkey.

In the second step, I selected the participants among students studying at the schools that had been previously determined. I employed critical case sampling to select these participants. The most important indicator for the existence of critical case sampling is the argument "if this group has a problem, we can be sure that all other groups have a problem" (Patton, 2001, p.236). In this respect, I determined the critical case as students with high overall and science academic achievement who would provide more data and have the most impact on knowledge generation. Accordingly, the participants' overall academic achievement ranged between 77 and 99 points, whereas their science class achievement was between 81 and 98 points. As for gender, eight of the participants were female and eleven were male. Thus, although I did not aim to make generalizations to all cases technically, I hoped to help both myself and the reader to make analytical generalizations for similar cases.

Data Collection

I gathered the data through semi-structured interviews (Berg, 2001, Merriam, 2009), in which I asked a set of pre-determined questions to each participant in a

systematic and consistent order. The participants responded to the questions with as much detail as they wanted, and I allowed them to go beyond the partially-structured questions in order for them to provide more thorough answers (Flick, 2009). I developed a Student Interview Form consisting of five sections for the semi-structured interviews. In the first section, I provided information about myself, the research topic and aims, and the participants' rights. In the second section, I included a student consent form for students to sign prior to participation declaring that they did so voluntarily. The third section comprised of a parental consent form for parents to sign a declaration allowing their children to participate. First, I phoned all parents and explained about research clearly. After that, I wrote a consent form for the children to the parents and sent it with children; then they signed and returned it back. In the fourth section, there was a personal information form for students. Finally, four open-ended questions related to the scenarios and designed to reveal students' informal reasoning patterns and their quality was provided in the fifth section.

To gather data, I developed three scenarios including the socio-scientific issues of Organ Transplantation, Recycling, and Use of Forest Areas, and prepared interview questions related to these scenarios. I reviewed the literature in the process of developing these scenarios and questions. I realized that the existing scenarios of SSIs were mostly related to genetic engineering and global warming (see Liu & Roehrig, 2019; Molinatti et al., 2010; Sadler, 2004b; Sadler & Zeidler, 2005a). For this reason, I did not use the scenarios available in the literature because I determined that they were not suitable to the cognitive development of elementary school students. In fact, I mentioned in the introduction that studies that aimed to determine informal reasoning patterns and their quality gathered data from middle school, high school, and university students, as well as teachers. Therefore, I reviewed the Science Course Curricula for Grades 3-4 (Turkish Ministry of National Education [MoNE], 2013), and then prepared the scenarios that focus on the socio-scientific issues of Organ Transplantation, Recycling, and Use of Forest Areas, and prepared interview questions related to these scenarios. I then presented the scenarios and interview questions to two elementary school teachers and one science education expert studied in SSIs in order to elicit their opinions. Based on the feedback received from the experts, I made the necessary modifications to the form. For instance, instead of the expression "brain death" in the scenario script prepared for organ transplantation, I used the word "dying." Similarly, I used the word "view" instead of "argument" in the interview questions, and rephrased the question as follows: "What kind of explanations can someone who thinks differently than you provide to support his/her own views?" I included opposing ideas in the scenarios because of the nature of these issues. The interview questions I used in the scenario on organ transplantation are as follows: (1) Do you think a woman should donate the organs of her dying husband? Why? (2) How would you persuade a friend about your views? (3) What opposing views would there be for the view you just mentioned? What kind of explanations can someone who thinks differently than you provide to support his/her own views? (4) If you meet someone who thinks differently than you, how would you respond to him/her? How would you defend your views against his/her views?

I used the question structure presented above in all three sessions on the scenarios to enable the participants to describe their views, justify them, determine possible opposing views, and produce arguments to refute the opposing views. In each session, the participants read the scenario related to that SSI. I then asked them whether there was something they could not comprehend, and if they needed further explanation. After this introduction, I asked the participants the interview questions in the same order. I conducted the interviews for each scenario in different sessions and recorded these interviews after obtaining permission from both the participants and their parents. The shortest interview lasted for 13 minutes while the longest one was 21 minutes.

Data Analysis

I employed thematic analysis (Braun & Clarke, 2006) in the data analysis process. Thematic analysis refers to conducting the analysis process based on the similarities, differences, and relationships within the data set. The word 'thematic' is about the goal to look for themes clustered in the data (Gibson & Brown, 2009; Willig, 2013). The steps I followed in thematic analysis are as follows: (i) getting to know the data, (ii) forming the initial codes, (iii) reviewing and associating the codes, (iv) forming and reviewing themes, (v) explaining the themes, and (vi) reporting the findings (Braun & Clarke, 2006; Saldaña, 2009). I elaborated on the data analysis process I performed based on the above-mentioned steps in the following:

In the first step, getting to know the data, I firstly transcribed the interviews. After I transcribed the interviews that I conducted with 19 participants three times, I read these transcriptions separately, and noted my initial thoughts about the data. In the second step, I systematically coded the relevant features within the data for research purposes. In this process, I revealed phrase-based codes such as "global warming," "other species," "making profit," and "good deed," as well as sentence-based codes such as "The rate of carbon dioxide in the air increases," "Animals become extinct," and "Places where animals can live disappear, and they are starting to die." At the end of this process, I created a data index. In the third step, I aimed to discuss the codes I revealed, the characteristics of these codes, their meaning, and adequacy for defining the data. In other words, I tried to make the codes explicit. Since thematic analysis, unlike content analysis, does not require peer review (Vaismoradi, Turunen & Bondas, 2013), the data were not coded by a second researcher. In the fourth step, I grouped the codes by clustering those that formed a meaningful pattern to create themes. I also assigned theme titles to these grouped codes and reviewed other studies in the literature in this process (e.g. Sadler & Zeidler, 2005a, b; Topcu, 2008; Topcu et al., 2011). At the end of the process, I revealed three themes to explain informal reasoning patterns: logical informal reasoning pattern, emotional informal reasoning pattern, and intuitive informal reasoning pattern. As for explaining the quality of informal reasoning patterns, I structured two themes: low-quality informal reasoning pattern and quality informal reasoning pattern. The theme map I came up with at the end of the analysis can be seen in Figure 1.

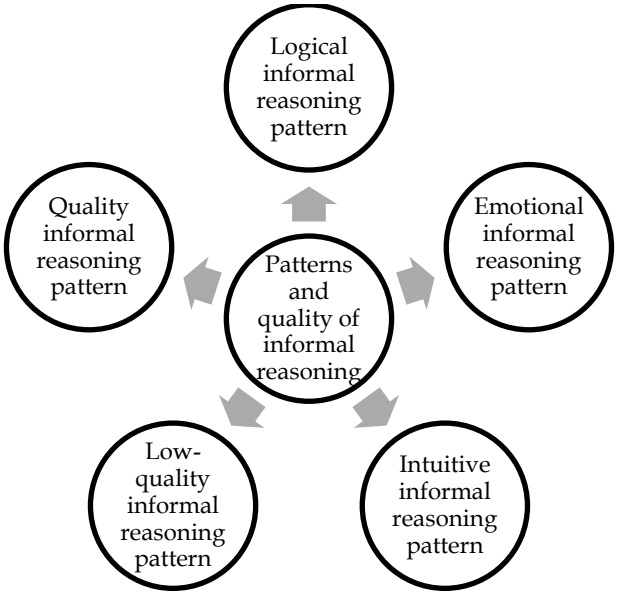

Figure 1. *Informal reasoning patterns related to SSIs and the quality of thinking processes*

In the fifth step, I defined the themes with reference to their similarities and differences with each other. The theme 'logical informal reasoning pattern' included stated views that were based on realistic, rational, and scientific knowledge. The theme 'emotional informal reasoning pattern' referred to being respectful and empathetic to other species' right to live. As for the theme 'intuitive informal reasoning pattern,' I used it as a construct to explain the arguments that the participants stated spontaneously and seemingly without much thought. The low-quality informal reasoning pattern involved the participants presenting and justifying their claims related to SSIs, whereas the quality informal reasoning pattern included the competencies of presenting a claim, justifying it, determining opposing claims and refuting the opposing claims. In the last step, reporting the findings, I established the relationship between the themes and codes, quoted interesting and important parts from the participants' views, and presented the findings with a descriptive approach.

Results

In this section, I presented an overall view of the findings (see Table 1), and then the properties of the data under each theme.

Table 1.

Matrix for the Patterns and Quality of Informal Reasoning

	Informal Reasoning Pattern on Organ Transplantation, and Its Quality					Informal Reasoning Pattern on the Use of Forest Areas, and Its Quality					Informal Reasoning Pattern on Recycling, and Its Quality				
Participants	L. I. R. P.	E. I. R. P.	I. I. R. P.	Lo. I. R. P.	Q. I. R. P.	L. I. R. P.	E. I. R. P.	I. I. R. P.	Lo. I. R. P.	Q. I. R. P.	L. I. R. P.	E. I. R. P.	I. I. R. P.	Lo. I. R. P.	Q. I. R. P.
Nazmi			+	+				+	+				+	+	
Yasemin			+	+				+	+				+	+	
Eylül			+		+		+		+				+	+	
Rabia			+	+			+		+				+	+	
Sıla			+	+				+	+				+	+	
İkra			+	+				+	+				+	+	
Ensar		+		+			+			+		+		+	
Naime		+		+			+		+				+	+	
Umut		+		+			+		+				+	+	
Emir			+	+			+			+			+	+	
Elif			+	+			+			+		+		+	
Naz			+	+				+	+			+		+	
Damla			+	+			+		+			+		+	
Efe			+		+		+			+			+	+	
Nur		+			+		+			+			+	+	
Halil		+			+		+			+	+			+	
Ceren		+		+		+				+	+			+	
Burak		+			+	+				+	+			+	
İlker		+			+	+				+	+				+

L. I. R. P. : Logical informal reasoning pattern, E. I. R. P. : Emotional informal reasoning pattern, I. I. R. P. : Intuitive informal reasoning pattern, Lo. I. R. P. : Low-quality informal reasoning pattern, Q. I. R. P: Quality informal reasoning pattern.

The informal reasoning patterns regarding organ transplantation, use of forest areas, and recycling, along with the quality of these patterns, are shown in Table 1. Regarding the SSI of organ transplantation, none of the students formed a logical informal reasoning pattern. On the other hand, the participants constructed mostly intuitive informal reasoning patterns for all the SSIs. This reasoning pattern was followed by emotional reasoning. The least used reasoning pattern by the participants was logical reasoning. When evaluated in terms of the quality of reasoning patterns, the participants were engaged mostly in low-quality thinking processes. In other words, most of the participants only developed claims related to the SSI scenarios, but did not justify these claims. Besides, only a small number of participants were able to state claims, justify them, determine possible opposing views, and refute these views. Only one participant had the ability to think through these four steps related to all

three scenarios. Apart from this overall view of the data, detailed explanations and properties of the themes can be found in the following sections.

Logical Informal Reasoning Pattern

Logical reasoning represented the participants' use of views and arguments based on reason. This type of informal reasoning was employed in two of the scenarios, which were the use of forest areas and recycling, but did not appear in relation to organ transplantation. Additionally, this reasoning pattern was used by only few participants in both SSIs. Sample quotations regarding the logical reasoning pattern are as follows:

> *Burak: If other countries import domestic waste and turn it into electricity, there will be no need to cut off the power. Since they produce their own electricity and do not buy it from other countries, they make profit from domestic waste by using and exporting the electricity. Then the problem would be solved. When it is solved, more accurate decisions will be made. (Recycling).*

> *Ceren: It is because we can both prevent environmental pollution and produce electricity by importing domestic waste from other countries. That's why power plants wouldn't have to work longer. Especially materials such as iron, paper, plastic, and glass can be found in domestic wastes. If the paper is torn apart, we can recycle it into paper again. In this way, fewer trees will be cut down. (Recycling).*

> *İlker: If our natural areas disappear, there will be too much carbon dioxide in the air. People won't find a place to get fresh air. Global warming will increase and the glaciers will be destroyed. Animals will become extinct. (Use of Forest Areas).*

As is seen in the quotations, the participants provided reasonable justifications to support their claims. For example, Burak explained the recycling of domestic waste with an economic justification, while Ceren referred to an understanding of sustainability. On the other hand, İlker figured out that opening forest areas to settlements by cutting down trees would increase the rate of carbon dioxide, speed up global warming, and cause the melting of glaciers.

None of the participants built up a logical reasoning pattern related to the socio-scientific issue of organ transplantation. Unlike other examples of SSIs, organ donation is not included in elementary school curricula. Therefore, the participants may not have used this type of reasoning pattern because they did not have sufficient content knowledge.

Emotional Informal Reasoning Pattern

The emotional informal reasoning pattern was used in the thinking processes related to all three SSIs. This type of reasoning included considering the consequences of decisions for other people and species, being responsible for them, and wishing for their well-being; in short, showing empathy and being sympathetic. The participants who were engaged in this type of thinking considered how other species and people would be affected by the decisions made. Sample quotations regarding the emotional reasoning pattern are as follows:

Nur: Yes. Because the woman's husband was already dying, she could at least help other people get better by donating his organs. (Organ Transplantation).

Umut: She should donate his organs. Because there are people who are about to die or have to live with a single kidney. (Organ Transplantation).

Damla: No. Because other countries need domestic waste. They need to produce their electricity with that waste. If Sweden imports domestic waste from other countries, they lose money, because Sweden already has their own waste. (Recycling).

Naz: No, they shouldn't import it. Because the country loses money by importing waste from other countries. It also diminishes other countries' plans about domestic waste. Sweden may be developed in this respect, but they prevent other countries from developing. (Recycling).

Naime: No. Because the world is not only ours. It is also the animals'. Mountains and plains are their home. If we build houses in every part of nature, animals will become extinct. (Use of Forest Areas).

Elif: No. Because natural areas are damaged. The places where animals can live disappear, and they are starting to die. (Use of Forest Areas).

Damla: No. Because we already have few natural areas. Plants and animals are also living beings. If we destroy natural areas, we destroy the living areas for plants and animals. (Use of Forest Areas).

As is seen, the participants questioned how living beings other than them (i.e. people, animals, or plants) would be affected by the decisions made in all three scenarios. They emphasized that if the organs of a dying person were donated, other people's lives could be saved; if forest areas were to be opened for settlements, the habitats of other stakeholders would be limited; and thus, they would become extinct. In this respect, the participants stated their concerns for other species by considering the risks and possibilities in the SSI reasoning processes. Similarly, the participants evaluated what should be done for other species to continue their lives with an empathic approach. However, their emotional reasoning was not far from being rationale. On the contrary, wishing for the well-being of others was supported with a logical justification in the sample quotations presented above. The quotations "Natural areas are damaged," "Mountains and plains are animals' home," and "She could at least help other people get better by donating his organs" support this interpretation.

Intuitive Informal Reasoning Pattern

Intuitive thinking was the type of reasoning most commonly employed by the participants and accounted for instant and emotional decision-making. The students who employed intuitive reasoning provided superficial and instant positive or negative answers to the SSI scenarios without thinking enough. This thinking pattern was intuitive, and covered characteristics that were not rational as well. Sample quotations regarding the intuitive reasoning pattern are given below:

Elif: Yes. Because the woman would help others and do a good deed. (Organ Transplantation).

Naz: Yes. Because it would be a good deed. (Organ Transplantation).

İkra: Yes, because we need electricity. (Recycling).

Emir: Yes, it should. Because it produces electric energy. (Recycling).

Eylül: Yes. Because only they can do this. (Recycling).

Naz: No. Because it would be good to have our natural areas. (Use of Forest Areas).

Sıla: No. Because nature gives us the air to breathe. (Use of Forest Areas).

As can be seen in these quotations, the participants provided instant and superficial answers related to the SSI scenarios. While their answers regarding organ transplantation and recycling were positive, they responded to the use of forest areas with negative statements. However, these answers were not rational, as emphasized by responses such as "she would do a good deed," "nature gives us the air to breathe," and "only they can do this." Moreover, they included superficial explanations.

Low-Quality Informal Reasoning Pattern

The low-quality informal reasoning pattern refers to the informal reasoning construct at the basic level. The participants who had low quality thinking structure stated their own claims related to SSIs but could not justify them. In this regard, stating a claim and justifying it are of different levels. Therefore, the participants who developed a low-quality reasoning pattern could not reach the second level. Sample quotations for the low-quality reasoning pattern are given below:

Yasemin: I think she should donate his organs. (Organ Transplantation).

Emir: Yes, she should. Because his organs can keep several people alive. (Organ Transplantation).

Ceren: Yes. We should think of other people. They are living beings as well. They have a right to live. It is a good deed to donate organs to others. It is good for one person to die instead of five persons. If five persons stayed alive, they would be happy. If they got better, their family, relatives, and neighbors would be very happy. (Organ Transplantation).

Eylül: I think they shouldn't use these areas. If houses are built on green lands due to population increase, children will not have a place to play, or have a natural environment. (Use of Forest Areas).

Rabia: We, the children, want playgrounds to have fun. That's why I am against urbanization and want more areas to stay untouched. (Use of Forest Areas).

İkra: No. Streets and parks should be built in natural settlements, which are beautiful places. (Use of Forest Areas).

Nur: Energy can be produced from domestic waste. For this reason, Sweden is right to import garbage. (Recycling).

Efe: Yes, they should. Because they turn the garbage they get from other countries to electricity, so they should buy domestic garbage. I would persuade my friend by saying that

he/she should also say yes because Sweden does not do anything wrong but turns the domestic waste they get from other countries into electricity. (Recycling).

Sıla: No. Because everybody should produce electricity in their own country. Without electricity, we can't see anything. (Recycling).

As is seen, the participants stated their claims related to SSIs with words like "yes" or "no." Despite this, they tried to justify their claims. Nevertheless, they expressed some naive justifications, such as "Because his organs can keep several people alive," "We want playgrounds to have fun," and "Because everybody should produce electricity in their own country." Similarly, the participants' claims and justifications were mostly related to the intuitive thinking pattern. Therefore, I can say that there is a relationship between intuitive thinking and low-quality thinking pattern.

Quality Informal Reasoning Pattern

The quality informal reasoning pattern indicated the most complex and developed informal reasoning construct. The participants who could reach this level were able to state their own claims, justify them, think about possible opposing views, and put forward arguments that could be used to refute such views. In terms of quality, the highest level at which the participants formed arguments was refuting evidence. Sample quotations regarding the quality reasoning pattern are as follows:

Halil: Her husband was about to die. So, he doesn't need his organs which can save other people with a transplant. Since her husband is dying, she can save others with his organs. Therefore, yes, it is more sensible. Someone can say that his organs shouldn't be donated. Or maybe her husband would not die, we would kill him by taking out his organs, he/she would say. Then, if the organs weren't to be donated, other lives could be lost, as well as her husband's. (Organ Transplantation).

Burak: No. If green areas are used, and if forests and rivers are destroyed, then animals, plants, and people can't stay alive. For instance, if trees are cut down, people will die from a lack of oxygen, because trees produce the oxygen we need. And without trees, there would be no life. (…) My friend, if you say yes, then that beautiful nature disappears. Trees, plants, mushrooms, and even microscopic creatures live in that environment. Even microscopic creatures have a place in our lives. If microscopic creatures become extinct, we won't be able to eat most of the nice food. We would just be clean. If we are clean and healthy, and don't have any diseases, we can catch diseases more serious than being clean, and die. My friend can say that if buildings aren't there, people can't find a place to shelter. And if they can't, they die. My opinion is that we should have gardens instead of parks and playgrounds. If old houses in villages are taken down and everybody lives in a single house, and if we plant trees in the environment and replace the old houses with new ones, everything will be all right. But in your perspective people would die, and thus the population would decrease. My friend, if you say yes, the course of the natural environment will deteriorate. Then we will swim in petroleum rather than the sea, catch cans rather than fish, and eat bricks rather than food. I mean, if the course of the environment is deteriorated, bad things will happen. People can die from diseases. So, the population will decrease. And this environment would have been destroyed in vain. (Use of Forest Areas).

İlker: Yes. Because if Sweden buys garbage from other countries, it turns it into energy and becomes rich. Sweden is pretty quick at producing electricity and has put much effort in turning domestic waste into electricity. The use of fossil fuels should end by 2030 because cars cause global warming. One can say that if it buys waste and can't turn it into electricity, there will be a big problem. I think Sweden wants to prevent global warming. That's why they buy domestic waste to increase the use of electricity. They want all cars to run on electricity by 2030. Sweden doesn't want the glaciers to melt down. Also [it wants] to be a rich country. (Recycling).

As can be seen in the quotations, the participants justified their claims related to the SSIs, demonstrated opposing views, and developed justifications to refute these views. As for the types of informal reasoning, the quotations mostly overlapped with logical and emotional reasoning patterns. In this respect, there seems to be a relationship between quality reasoning patterns and logical and emotional reasoning patterns. In fact, the participants who developed logical and emotional reasoning patterns generally constructed quality thinking patterns. On the other hand, the most important ability expected from the participants was to produce arguments to refute opposing views. However, only one participant was able to achieve this ability in all three reasoning processes. Despite this, there were four different participants who could reach this level in different SSI scenarios. As a result, I can say that the participants had difficulty in terms of forming quality informal reasoning patterns and could usually reach the level of determining opposing views. Consequently, it can be argued that there is a need to conduct SSI practices that would take students above this level, or in other words develop their ability to refute opposing views.

Discussion, Conclusion and Recommendations

This study aimed to examine elementary school students' informal reasoning patterns related to SSIs and the quality of these patterns, and revealed significant results for science education. In the study, the three scenarios (organ transplantation, use of forest areas, and recycling) were used to understand the students' reasoning patterns related to SSIs. In other studies conducted in context of SSIs, issues such as environmental problems (Kortland, 1996; Patronis et al., 1999), genetic engineering (Cetin et al., 2014; Christenson, Rundgren & Höglund, 2012; Kolarova et al., 2013; Zohar & Nemet, 2002), climate change (Dawson, 2015; Dawson & Carson, 2017), nuclear energy (Christenson et al., 2012), astrobiology (Hansson, Redfors & Rosberg, 2011), and energy transmission lines (Kolstø, 2001b) were used to examine and discover students' reasoning processes.

The participants used logical, emotional and intuitive informal reasoning patterns while discussing and trying to solve socio-scientific issues. In other words, they employed not only cognitive but also emotional processes while figuring out a solution for the socio-scientific issues. However, the studies referred to the thinking constructs related to SSIs with different names. For example, Ozturk and Yilmaz-Tuzun (2017) described informal thinking patterns as modes in their study with teacher candidates. They observed that the teacher candidates were engaged in economic-oriented, ecology-oriented, types of risk, science and technology-oriented, and political-oriented

reasoning. In a study with high school students, Yang and Anderson (2003) found that the participants used science-oriented, social-oriented, and equally-balanced reasoning modes. In the study, it was reported that the high school students with science-oriented reasoning used scientific knowledge in their decision-making processes, whereas social-oriented students considered social factors while making their decisions. On the other hand, the students with equally balanced modes used both scientific knowledge and social factors (Yang & Anderson, 2003). In another study, Patronis et al. (1999) revealed that students formed social, ecological, economic, and practical informal reasoning patterns. In his study conducted in the context of energy transmission lines and child leukemia, Kolstø (2006) reported that the participants developed the relative risk argument, the precautionary argument, the uncertainty argument, the small risk argument, and the pros and cons argument. As is seen, thinking structures revealed in solving socio-scientific issues are named differently in the current study and different studies in the literature. There is no doubt that naming reasoning processes is closely related to the scope of the scenarios used to gather data. However, it should be emphasized that regardless of the thematic name of these patterns, individuals use cognitive as well as political, social, economic, ethical, and ecological reasoning processes in solving socio-scientific issues.

A notable result of the study is that the least used reasoning pattern was logical reasoning while the most frequently used pattern was intuitive reasoning. Although science and science education are consistently characterized by rationalist thinking patterns (Sadler, 2003), the logical reasoning pattern has been the least used in solving SSIs among three reasoning patterns in other studies as well (Sadler & Zeidler, 2005a; Topcu, 2008; Topcu et al., 2011). On the other hand, there are different research findings reported in the literature. For instance, Kolarova et al. (2013) found that high school students used logical reasoning the most in issues related to genetic engineering. Unlike the current study, they also reported that the least used pattern was intuitive reasoning. Similarly, Ozturk and Yilmaz-Tuzun (2017) demonstrated that almost all the teacher candidates they worked with made evidence-based decisions. Although there are different results in the literature, it is clear that individuals use not only logic, but also emotions and intuition while looking for an answer for SSIs. The point to note here is not to change the representation of the nature of science in science classes, but to accept the importance of emotional and intuitive reasoning that individuals use when discussing complex SSIs (Topcu et al., 2011).

When evaluated in terms of the quality of reasoning patterns, it was found that the participants were engaged mostly in low-quality reasoning. In brief, they usually developed claims related to SSIs, and were able to justify these claims. As a result, they had difficulty in terms of forming quality informal reasoning patterns but could usually reach the level of determining opposing views. There are studies in the literature that overlap or contradict with this result I reported. For example, Jimenez-Aleixandre et al. (2000) stated that ninth graders could not produce quality arguments to support their views on genetics. Likewise, Kortland (1996) observed that middle school students had limited ability to determine opposing views and produce arguments to refute them. According to Kortland, although the students were able to

produce basic arguments, the variety and clarity of the arguments proposed were restricted. In another study, Molinatti et al. (2010) underlined the students' weakness in discussion skills as the most remarkable finding of their study. They indicated that the high school students had difficulty in producing arguments, and were not competent in drawing attention to ethical, legal, economic, or social aspects of problems when producing an argument. In their study of science teachers, Liu and Roehrig (2019) found that the participants were able to support their argument with proof and valid justification, but the pieces of proof put forward were not sufficient. They examined teachers' arguments related to global warming, and although the teachers stated that the rate of carbon dioxide and weather temperature increased simultaneously, they did not discuss the cause-effect relationship between these two events. In the same study, the teachers were reported to form arguments involving personal observations based on their experiences rather than those based on scientific knowledge. They were also reported to have problems in discussing what different perspectives contradict with personal beliefs.

In the literature, results can be encountered which are different from what I reported in the current study and studies summarized above. For example, Patronis et al. (1999) reported that middle school students were able to produce quality arguments. In the study, the students worked in small groups to develop and plan a strategy to cope with a local environmental problem for a couple of months. According to the researchers, the students' work on a local problem enabled them to have a discussion process that was better than expected. Traditionally, science education focuses on directly conveying certain pieces of scientific knowledge. However, contexts that would enable students to think about science-based social issues are not employed by teachers although they are included in current science education curricula. For this reason, in the present study, the students may not have formed quality arguments due to lack of experience in discussing SSIs and content knowledge. In fact, the difference between Patronis et al.'s study (1999) and other studies in the field, including the present study, is that the students gained experience related to SSIs over a period of several months. It is possible that continuous instructional activities toward discussing SSIs and selecting the SSIs from the students' immediate environment may have helped them demonstrate quality thinking patterns. There are studies in the literature that overlap with this argument. For instance, Dawson and Venville's experimental study (2013) showed that the quality of students' argumentation skills can be improved. Before the experimental procedure, the participants were not competent in stating claims and supporting them with data. However, as a result of the practices regarding how argumentation is done, there was an improvement in their argumentation skills. Moreover, the experimental procedure helped the students make more use of logical reasoning patterns. A similar study was also conducted by Zohar and Nemet (2002) who aimed to develop ninth graders' skills of using argumentation related to genetic dilemmas. In the study, while the traditional course book was used in the control groups, advanced genetic concepts on genetic engineering, human genetics, and related social issues were taught to the students in the experimental group. Moreover, in addition to genetic engineering, the students in the experimental group also received instruction related to argumentation skills, and

produced arguments in the context of genetic dilemmas. Ultimately, although the control group did not show a significant development in discussing genetic dilemmas, the experimental group could form arguments in contexts similar to the dilemmas they were exposed to during the experimental procedure.

The qualitative nature and relatively small sample of this study certainly limit the generalizability of the results obtained. However, the results are thought to be significant in terms of demonstrating elementary school students' informal reasoning processes related to SSIs. In the literature, it is reported that certain participants – though small in number– highlighted that SSIs were not suitable to elementary school students' cognitive structures (Ozden, 2011). Yet, the results of the current study contradict such views, and show that SSIs can be used at elementary school level. As for further research, there seems to be a need for studies including practices towards improving the quality of reasoning in elementary school students.

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İlkokul Öğrencilerinin Sosyobilimsel Konulara İlişkin İnformal Akıl Yürütme Örüntülerinin İncelenmesi

Atıf:

Ozden, M. (2020). Elementary school students' informal reasoning and its' quality regarding socio-scientific issues. *Eurasian Journal of Educational Research,* 86, 61-84, DOI: 10.14689/ejer.2020.86.4

Özet

Problem Durumu: Fen eğitiminin temel amacı bilim okuryazarı bireyler yetiştirmektir. Bilimle ilgili karmaşık sosyal meseleleri tartışma ve karar verme yeteneği gerektiren bilimsel okuryazarlık becerisinin sosyobilimsel konular (SBK) yoluyla kazandırılabileceği kabul edilmektedir. SBK bireyleri etkileyen, üzerinde görüş birliği sağlanamamış, risk ve olasılıkları anlamayı içeren, açık uçlu ikilemler biçiminde yapılandırılmış, ahlaki ve etik seçimler yapılması gereken, çözümü birden çok alternatifi kapsayan ama kesin bir çözümü olmayan güncel olaylardır. SBK'ların tartışılması genellikle bireylerin sosyobilimsel argümantasyon yapmasını gerektirmektedir. Bu argümantasyon biçimi informal akıl yürütme olarak adlandırılmaktadır. İnformal akıl yürütme, SBK'da karar alma sürecinde konuyla ilgili kanıtların değerlendirilmesi, farklı bakış açılarının düşünülmesi ve bu zihinsel eylemler sonucunda bireyin kendi vardığı sonucu siyasal, ekonomik, ahlaki, ekolojik vb. argümanlarla gerekçelendirebilmesini içeren düşünme süreçlerini açıklamaktadır. Son yıllarda SBK'da informal akıl yürütme süreçlerini inceleyen ve giderek artan bir alan yazın oluşmaktadır. Ancak bu araştırmalarda ilkokul öğrencilerine odaklanılmamaktadır. Fen sınıflarında SBK'lar öğrenme bağlamı olarak kullanılıyorsa ya da kullanılacaksa, ilkokul öğrencilerinin informal akıl yürütme örüntülerini ve akıl yürütmelerinin niteliklerini anlamak önemlidir. Böylece öğrencilerin SBK'lara ilişkin kararlarını nasıl yapılandırdıklarını, SBK'ları nasıl tartıştıklarını ve çözdüklerini keşfedilebilerek bu basamakta yapılan fen etkinliklerine ilişkin anlayış kazanılabilir.

Araştırmanın amacı: Bu araştırmada ilkokul öğrencilerin SBK'lara ilişkin informal akıl yürütme örüntüleri ile bu örüntülerin niteliğini keşfetmek amaçlanmıştır. Bu

kapsamda şu araştırma soruları oluşturulmuştur: (1) İlkokul öğrencilerinin farklı SBK'lara ilişkin oluşturdukları informal akıl yürütme örüntüleri nedir?, (2) İlkokul öğrencilerinin SBK'lara ilişkin yaptıkları akıl yürütme örüntülerinin niteliği nedir?

Yöntem: Araştırmada temel nitel araştırma deseni kullanılmıştır. Araştırma katılımcılarını belirlemek üzere örnekleme iki aşamada yapılmıştır. Bu amaçla öncelikle tipik durum örneklemesi kullanılarak araştırma verilerinin toplanacağı okullar belirlenmiştir. Bu kapsamda araştırmanın uygulamasının sosyoekonomik düzey bakımından kent ortalamasına yakın üç ilkokulda gerçekleştirilmesine karar verilmiştir. İkinci aşamada ise belirlenen okullarda öğrenim görmekte olan öğrencilerden katılımcıları belirlemek üzere kritik durum örneklemesi kullanılmıştır. Buna göre en fazla bilgiyi verebilecek ve bilgi üretimi konusunda en büyük etkiyi yapacak katılımcıları seçmek üzere kritik durum genel ve fen akademik başarısı yüksek öğrenciler olarak belirlenmiştir. Buna göre sekiz kız ve 11 erkek öğrenci araştırmanın katılımcılarını oluşturmuştur. Araştırma verileri yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Verileri toplamak üzere Organ Nakli, Geri Dönüşüm ve Orman Alanlarının Kullanımı SBK'larını içeren üç adet senaryo ve görüşme sorularını geliştirilmiştir. SBK senaryolarının, bu konuların doğası gereği karşıt fikirler içermesine özen gösterilmiştir. Araştırmada kullanılan görüşme sorular ise katılımcıların iddialarını belirtmeleri, iddialarını gerekçelendirmeleri, olası karşıt iddiaları belirlemeleri ve karşıt iddiaları çürütebilecekleri argümanlar oluşturmalarını sağlamak üzere oluşturulmuştur. Her bir oturumda katılımcılar önce senaryoyu okumuşlardır. Okumalarını tamamladıktan sonra anlaşılmayan bir yer olup olmadığı ve ek açıklama isteyip istemediklerini sorulmuştur. Verilerin analizinde tematik analiz yaklaşımı kullanılmıştır. Analiz sonucunda informal akıl yürütme örüntülerini açıklamak üzere (i) mantıksal informal akıl yürütme örüntüsü, (ii) duygusal informal akıl yürütme örüntüsü ve (ii) sezgisel informal akıl yürütme örüntüsü temalarını oluşturulmuştur. İnformal akıl yürütme örüntülerinin niteliğini açıklamak üzere ise (i) düşük nitelikli informal akıl yürütme örüntüsü ve (ii) nitelikli informal akıl yürütme örüntüsü temaları yapılandırılmıştır.

Bulgular: Araştırmada, katılımcıların en çok sezgisel akıl yürütme örüntüsü oluşturdukları görülmüştür. Bu akıl yürütme örüntüsünü duygusal akıl yürütme örüntüsü izlemektedir. Katılımcıların en az kullandıkları akıl yürütme örüntüsü ise mantıksal akıl yürütme örüntüsüdür. Akıl yürütme örüntüsünün niteliği bakımından değerlendirildiğinde ise katılımcılar daha çok düşük nitelikli düşünme süreçlerini kullanmışlardır. Yani katılımcıların çoğunluğu SSI senaryolarına ilişkin sadece iddia geliştirmişler ve bu iddialarını gerekçelendirmişlerdir. Bununla birlikte az sayıda katılımcının iddia oluşturma, gerekçelendirme, olası karşıt görüşleri belirleme ve bu görüşleri çürütme yeterliğinde oldukları anlaşılmaktadır.

Sonuç ve Öneriler: Araştırmada SBK'ların çözüme yönelik düşünme süreçlerinde sadece bilişsel düşünmenin değil duyuşsal düşünme özelliklerinin de işe koşulduğu belirlenmiştir. Araştırmanın en ilginç sonucu en az kullanılan akıl yürütme örüntüsünün mantıksal akıl yürütme örüntüsü; en çok kullanılan akıl yürütme örüntüsünün ise sezgisel akıl yürütme örüntüsü olmasıdır. Fen ve fen eğitimi çoğunlukla rasyonalist düşünme kalıplarıyla karakterize edilmektedir. Bu durum

daha çok formal akıl yürütme ile ilişkilidir. İnformal akıl yürütme ise formal akıl yürütmeden farklı olarak bilim ve teknoloji tabanlı güncel sorunları tartışırken sosyal, çevresel, etik, ahlaki, ekonomik, politik, duygusal vb. önceliklerin de düşünme sürecini etkilediğini ortaya koymaktadır. Bu nedenle öğretmenler SBK tartışma sürecinde öğrencilerin kullandıkları duygusal ve sezgisel akıl yürütmenin önemini kabul etmeli ve değer vermelidir. Akıl yürütme örüntüsünün niteliği bakımından öğrencilerin zorlandıkları ve çoğunlukla karşıt iddiaları belirleme düzeyine çıkabildikleri söylenebilir. Geleneksel olarak fen öğretimi belirli bilimsel bilgilerin doğrudan aktarımı üzerine odaklanmaktadır. Öğrencilerin bilim temelli sosyal konular üzerine düşünmelerini sağlayacak bağlamlar ise günümüz fen öğretim programlarında yer alsa bile bu bağlamların öğretmenler tarafından işe koşulmadığı bilinmektedir. Dolayısıyla öğrenciler hem SBK'ları tartışma konusunda deneyimsiz hem de içerik bilgisi bakımından yetersiz oldukları için nitelikli argümanlar oluşturmamış olabilirler. Bu nedenle, ilkokul düzeyinde akıl yürütmenin niteliğini geliştirmeye dönük uygulamalı araştırmalar yapılması gerektiği düşünülmektedir.

Anahtar Sözcükler: sosyobilimsel konular, sosyobilimsel konu senaryoları, argümantasyon, informal akıl yürütme, akıl yürütme örüntüleri, akıl yürütme niteliği