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A Mixed-Method Study on Pre-Service Teachers' Informal Reasoning Regarding Nuclear Energy Use

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ABSTRACT
The aim of this study was to reveal pre-service teachers' informal reasoning regarding nuclear energy use in terms of informal reasoning modes, decision modes, and argument types. The exploratory sequential mixed method was used to collect data. The informal reasoning of pre-service teachers was investigated thoroughly and holistically by examining the qualitative data first, and then by making qualitative findings quantitative. The findings revealed that pre-service teachers adopted social and ecological-oriented informal reasoning more. As far as argument modes are concerned, the number of supportive arguments was higher compared to rebuttal arguments. The study further revealed that most of the pre-service teachers had a high level of informal reasoning. Our study showed that pre-service science teachers used multiple informal reasoning modes and demonstrated high-quality informal reasoning. Integrating socio-scientific issues in the curriculum may help pre-service teachers improve the quality of their informal reasoning and produce more arguments. Teachers can relate a subject in their lessons to a socio-scientific issue, which can help enhance students' use of arguments and the quality of informal reasoning.

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Introduction

It is a well-known fact that science and society have been interacting with each other for a long time now, meaning that as society started to exist, the need for science emerged, and society has been affected by scientific developments directly since then (Topçu, 2015). Nowadays, people are taking more active roles in social problems, which causes some dilemmas about public issues. These dilemmas are called socio-scientific issues, in which social or scientific factors have a central role (Sadler, 2003). These issues connect society and science (Sadler, 2004).

According to Sadler (2004), socio-scientific issues can be defined as ill-structured, complex, and open-ended issues with no clear-cut solutions. Global warming, biotechnological applications, nuclear energy use, and cloning can be given as examples of socio-scientific issues. Because of the nature of the socio-scientific issues, people can hardly achieve reconciliation about them (Sadler & Zeidler, 2005a). According to Sadler and Zeidler (2005a), a socio-scientific issue has a scientific basis and includes argumentation and dilemmas in its nature.

According to many of the research studies on learning contexts, which take socio-scientific issues as a basis, using these issues in classrooms helps develop students' understanding about

scientific issues, provides additional motivation for learning, and affects students' epistemological developments and attitudes towards science positively (Akşit, 2011; Dolan et al., 2009; Topçu et al., 2014). When the socio-scientific issues are integrated into the curriculum, they affect the cognitive, emotional, and social development of students and teachers. Furthermore, socio-scientific issues can promote students' decision making processes and critical thinking (Turan, 2012).

Due to the nature of socio-scientific issues, informal reasoning is often used in reasonings that both support and object to the conclusion. As opposed to formal reasoning, the problem structure of informal reasoning is different; it does not have poorly structured and shortcut solutions (Shaw, 1996). For this reason, we can say that informal reasoning and socio-scientific issues can adapt to each other. As Tweney (1991) argued, the results of scientific processes can be presented via formal reasoning although they are based on informal reasoning. Revealing individuals' informal reasoning can be a proper way to reach their thoughts about socio-scientific issues. Also, argumentation, which is a process to support or disprove a social, mental, and verbal idea, can serve as an active process to reach people's informal reasonings (Sadler, 2003). The argumentation process seeks to find a logical solution to debates, problems, and questions (Driver et al., 2000).

When the studies on informal reasonings and socio-scientific issues are examined, it is seen that researchers have particularly focused on the factors that affect the modes, qualities, and patterns of informal reasonings for evaluation purposes. The studies conducted so far show great diversity in terms of study groups, selected socio-scientific issues, and educational levels. For example, Patronis et al. (1999) carried out a study in Greece with 14-year-old students to reveal which arguments they use in the decision-making process, while Wu and Tsai (2007) conducted a study with high school students about building nuclear power plants in Taiwan. In addition, Grace et al. (2015) carried out a study with 16 and 17-year-old science students from a different country, while Witzig et al. (2011) analyzed 143 college students' research reports about stem cell research.

In the literature, we can also see some studies conducted with pre-service science teachers. These studies were conducted to reveal the conceptual understanding and knowledge levels about nuclear issues (Küçük et al., 2015), examining argumentation skills about genetically modified foods (Demiral & Çepni, 2018), the informal reasoning patterns and the relationship between reasoning patterns and reasoning qualities (Topçu, 2008), to present belief systems about a socioscientific issue (Kılınç et al., 2014), to reveal the effect of content knowledge on the informal reasoning process (Topçu et al., 2010), and to present the impact of the nature of science on informal reasoning and argumentation skills (Acar, 2008). Also, some studies were conducted to investigate the decision making and argumentation skills of middle school and high school students about the waste problem (Kortland, 1996) and genetic dilemmas (Zohar & Nemet, 2002).

If we examine the role of socio-scientific issues in the classroom from a general perspective, we can say that teachers need to provide students with learning environments in which they can easily express their ideas, support their thoughts with different justifications, and rebut their classmates' ideas with opposing arguments. Akşit (2011) argued that pre-service teachers (PSTs) have insufficient knowledge about how they can teach socio-scientific issues and which methods they can use to guide the argumentation process. There is a limited number of studies in the literature investigating the experiences of PSTs about socio-scientific issues, the argumentation process, and informal reasonings. Thus, it is believed that the investigation of the informal reasonings and decision-making modes of PSTs who will most probably implement socio-scientific issues in their classrooms in the future may fill this gap and make a contribution to the literature. This study was conducted for this purpose, and the following main question and sub-questions were addressed:

- What kind of informal reasoning modes do PSTs have about nuclear energy use?
- What kind of decision-making modes do PSTs have?
- What positions do PSTs have about nuclear energy use?
- Are there any significant differences in PSTs' informal reasoning modes depending on their departments?

- What is the relationship between argument and informal reasoning modes of PSTs about nuclear energy use?
- What are the informal reasoning levels of PSTs about nuclear energy use?

Method

During the data collection process, we firstly reached qualitative findings, and then we used those findings to reach quantitative ones. In other words, the qualitative phase was used to build a basis for the quantitative data (Creswell, 2014a). The study is an exploratory mixed-method research study (Creswell & Plano Clark, 2011) conducted to reveal pre-service science, primary school and social sciences teachers' informal reasonings about nuclear energy use in a rich and integrated context. First, the researchers made a content analysis on open-ended questions to reach the informal reasoning modes. Then, quantitative analysis was conducted with these findings to answer the research questions.

Participants

This study was conducted in a state university in the central Anatolia region of Turkey. The university had about 2000 undergraduate students in the 2015-2016 semester. During the study, there were 230 students in the department of science teacher education (SCITE), 238 students in the department of primary school teacher education (PRISTE), and 226 students in the department of social science teacher education (SOCSTE). A total of 100 senior students from these three departments (31 from SCITE, 41 from PRISTE, and 28 from SOCSTE) constituted the research sample.

Selection of the Participants

The purposeful sampling method (Creswell, 2014b) was used to select participants whose undergraduate education directly or indirectly included topics about nuclear energy. Senior students were selected because they have taken all the courses about environmental education issues that can be related to nuclear energy and the use of nuclear energy.

Analytical Framework

In this study, the analytical framework developed by Wu and Tsai (2007) was used. This framework is based on the two systems of thinking in Dual-Process Theories, which are called System 1 and System 2 (Evans, 2002). The definitions of System 1 and System 2 are given in Table 1 (Evans, 2002, p.989). As seen, while System 1 represents intuitive, System 2 represents evidence-based decision-making mode.

Table 1

Characteristics Attributed to the Two Systems of Thinking in Dual-Process Theories

System 1: Implicit	System 2: Explicit
Unconscious	Conscious
Automatic	Controllable
Evolved early	Evolved late
Shared with other animals	Uniquely human
Independent of language	Related to language
Pragmatic/ contextualized	Logical/abstract
High process capacity, parallel	Constrained by working memory, sequential
Driven by learning and innate modules	Permits hypothetical thinking
Independent of general intelligence	Correlated with general intelligence

According to this framework, firstly, we reached the qualitative indicators which are decision-making modes (intuitive or evidence-based), reasoning modes (social-oriented, economic-oriented, ecological-oriented, science or technology-oriented), and reasoning levels according to argument modes (supportive arguments, counter-arguments, and rebuttals). Then, quantitative measures were created drawing on the findings of the content analysis about decision-making modes, reasoning modes, and reasoning levels. According to the analytical framework proposed by Wu and Tsai (2007), if the participants develop only supportive or counter-arguments, they are considered to have a low level of informal reasoning quality; on the other hand, if they also present a rebuttal argument, then they are considered to have a high level of informal reasoning quality. In this study, if the participants used only supportive or counter-arguments or both, their informal reasoning level was considered low. On the other hand, if the participants used rebuttals in addition to supportive and counter-arguments, their informal reasoning was evaluated as high.

Exploratory sequential mixed method design was used in our research. First, qualitative data collection and analysis was conducted, followed by quantitative analyses (Creswell, 2014b). For content analysis, two researchers separately created codes and themes. The procedure is explained in detail in the "data analysis" section.

Within the scope of this analytical framework, it is useful to give brief information about nuclear energy and its usage, which is the subject of this research. A huge amount of energy is released when heavy radioactive (uranium) atoms split into smaller atoms (fission) by the impact of a neutron or when light radioactive atoms combine to form heavier atoms (fusion). This energy is called nuclear energy. In nuclear reactors, the energy obtained by the fission reaction is converted into electricity (Turkish Electricity Transmission Corporation [TEİAŞ], 2011).

Nuclear energy meets about 17% of today's electricity needs. Some countries generate most of their energy from nuclear power plants. For example, according to the data of the International Atomic Energy Agency (IAEA), France provides 75% of its electrical energy from nuclear energy. There are more than 400 nuclear power plants worldwide, of which more than 100 are located in the United States alone (TEİAŞ, 2011).

While some want the establishment of nuclear power plants in the world and Turkey, some do not. There are many different arguments put forward in this regard. Those who view nuclear power plants positively put forward their high energy efficiency, reduction of greenhouse gas and their reserves that will last for many years. They also show nuclear energy as advanced technology. Those who approach the establishment of nuclear power plants negatively, on the other hand, emphasize the risk of radiation, which may occur as a result of an accident, and argue that this is a factor that will threaten the environment and human health. The number of nuclear accidents in the world has increased their concerns (Kaya, 2012, p. 88).

While the world is looking for new ways of energy production, nuclear energy has been determined as the best alternative for many countries. In this process, Turkey started its nuclear power experience in the 1960s and established a 1 MW research reactor in Küçükçekmece in 1962 (Yıldırım & Örnek, 2007, p.35). The power plant projects that are the subject of our research are located in the cities of Sinop in the north of Turkey and Mersin in the south.

Data Collection Tools

To collect data, first, a passage of 601 words was prepared in which both the benefits and harms of nuclear energy and nuclear facilities were stated. While the positive aspects of nuclear energy and facilities were defended in 219 words in the passage, the negative aspects were explained in 296 words, and finally, the reports were summarized in 86 words. These passages were adopted from some environmental science resources in the literature and were edited by the researchers. The passages were examined by three experts in terms of content and grammar and were finalized by the researchers.

Following the preparation of the passages, open-ended questions were adapted from the study conducted by Wu and Tsai (2007). These questions were used to reveal the informal reasoning modes of the PSTs in our study.

Data Collection Process

After the passages and the questions were finalized, a pilot study was conducted to determine the clarity of the statements in questions and the time required for answering the questions prior to the main study. The pilot study was conducted with eight PSTs who were not included in the main study. The pilot study showed that it took 50 minutes for the participants to read the passages and answer all the questions. When the research questions shared above were re-examined, it was seen that the questions mainly focus on the "use" of nuclear energy; however, in open-ended questions, the focus was on "building" nuclear power plants. During the time of the research, the construction of nuclear power plants was a much-debated scientific issue in Turkey. Thus, it was believed that posing a question about "building" nuclear power plants could provide rich data about either thoughts about building nuclear power plants or using nuclear energy, and consequently, the term "building" was used in open-ended questions.

After the pilot study, the main study was conducted in three stages. Firstly, the PSTs were informed about how the study would be carried out. There were ensured that confidentiality would be kept at all times. Then, they were asked the first open-ended question: "What do you think about the construction of nuclear power plants in Turkey? How did you reach this decision?". In the second stage, the passage about the advantages and disadvantages of nuclear energy and nuclear power plants was shared with the participants. After reading the passages, the participants were posed four questions adapted from Wu and Tsai's study (2007) in the third stage. The questions are listed below:

1- Do you support the building of nuclear power plants in Turkey? Why? (Assessing possible position changes of PSTs about nuclear power plants)

2- If you want to convince your friend about your position, what arguments will you propose to convince them? (Evaluating PSTs' ability to generate supportive arguments)

3- If someone holds an opposite position with you on this issue, what arguments may they have? (Evaluating PSTs' ability for counter-argument construction)

4- According to the arguments you have proposed in question 3, can you write down your opposing ideas to justify your position? (Evaluating students' ability for rebuttal construction).

Data Analysis

Data analysis began with qualitative analysis, followed by quantitative data analysis. The participants were coded during the research process. For example, "SCI PT 1" means "first pre-service science teacher". The meanings of the abbreviations are as follows:

SCI PT: Pre-service science teacher
PRI PT: Pre-service primary school teacher
SOC PT: Pre-service social science teacher.

The written answers were transferred to the Microsoft Word 2016 software and then content analysis was performed (Neuendorf, 2002; Yıldırım & Şimşek, 2013) via the QDA Miner Lite software. Before the study, there were a priori themes (mentioned in the "analytical framework section," i.e. "ecological-oriented reasoning mode"), and during the analysis process, new codes were obtained.

According to Wimmer and Dominick (2011), to ensure intercoder reliability, researchers should code the 10-25% data separately and then must reach a consensus. In this study, the researchers coded 25% of the data individually and then reached .67 consistency according to the formula provided by Miles and Huberman (1994). Then, they had discussions about their independent coding processes until they reached 100% agreement about their coding results.

Quantitative data were obtained by analyzing the answers given to the open-ended questions through content analysis. To exemplify, as a result of the content analysis, the number of informal

reasoning modes of PSTs was determined (quantitative analysis). With the qualitative results, it was possible to put forward the underlying elements of the informal reasoning modes, argument modes and informal reasoning qualities of the PSTs.

According to the results of the Kolmogorov-Smirnov test, nonparametric tests were performed for the analysis of the quantitative data. In this study, for internal validity, an expert who has already published a considerable number of quantitative and qualitative studies in this area reviewed the raw data and the rationality of the findings to ensure internal reliability. For external validity, the researchers informed the readers about the steps of the study for the transferability of the findings of this study to real-world issues.

Findings

First, we revealed the PSTs' informal reasoning modes. Since informal reasoning modes are the basic elements of this research, other elements (decision making modes, argument modes, and informal reasoning quality) were interpreted according to the informal reasoning modes given in Table 2 according to the departments.

Table 2

The Informal Reasoning Modes of Preservice Teachers

Department	N	Informal reasoning modes			
		Social	Economic	Ecological	Science or technological
SCITE	31	104	79	108	60
SOCSTE	28	76	57	54	38
PRISTE	41	95	73	95	43
Total	100	275	209	257	141

As seen in Table 2, the most commonly used modes of informal reasoning are social-oriented and ecological-oriented. It has been determined that the science or technology-oriented informal reasoning mode is the least commonly used mode. The frequency of social and economic informal reasoning modes in SCITE are close to each other.

The PSTs' decision making modes were either "intuitional" or "evidence-based". Their position statements were "changed" or "not changed", and their perspectives about the construction of the nuclear power plants were rated as "indecisive", "positive" and "negative". The findings pertaining to the decision-making modes can be seen in Table 3. Here are some samples of informal reasoning modes of participants.

SCI PT 4: *"With the establishment of a nuclear power plant, job opportunities will be opened for many people". (social-oriented)*

SOC PT 16: *"The establishment of a nuclear power plant will also be positive for the country's economy. Having a nuclear power plant makes us, our country, strong." (economic-oriented).*

SCI PT 20: *"In this respect, I state that the waste materials that come out as a result of the transfer of a nuclear power plant near water sources can be collected in another area"(environmental-oriented).*

PRI PT 33: *"I would say that from a very small atom of uranium it produces too much electricity than normal and that everything is a danger. I would say that there is no harm in establishing nuclear power plant since the necessary precautions are taken" (science or technological-oriented).*

Table 3

PSTs' decision-making modes and their perspectives about the building of nuclear power plants

Decision-making mode	Indecisive		Positive		Negative		Total	
	N	%	n	%	n	%	N	%
Evidence-based	9	10	63	70	18	20	90	90
Intuitional	2	20	5	50	3	30	10	10
Total	11	11	68	68	21	21	100	100

As seen in Table 3, 90% of the PSTs made evidence-based decisions, while 10% made intuitive decisions. 70% of the PSTs who already made evidence-based decisions were found to have a positive stance about nuclear energy and its use. According to the findings, 30% of the PSTs who made intuitive decisions and 13% of the PSTs who made evidence-based decisions changed their positions. It was also found that most of the evidence-based decision-making modes remained unchanged.

Table 4 below shows the Kruskal-Wallis test results concerning pre-service science teachers' informal reasoning modes according to departments.

Table 4

Kruskal-Wallis Test Results Regarding PSTs' Informal Reasoning Modes According to the Departments

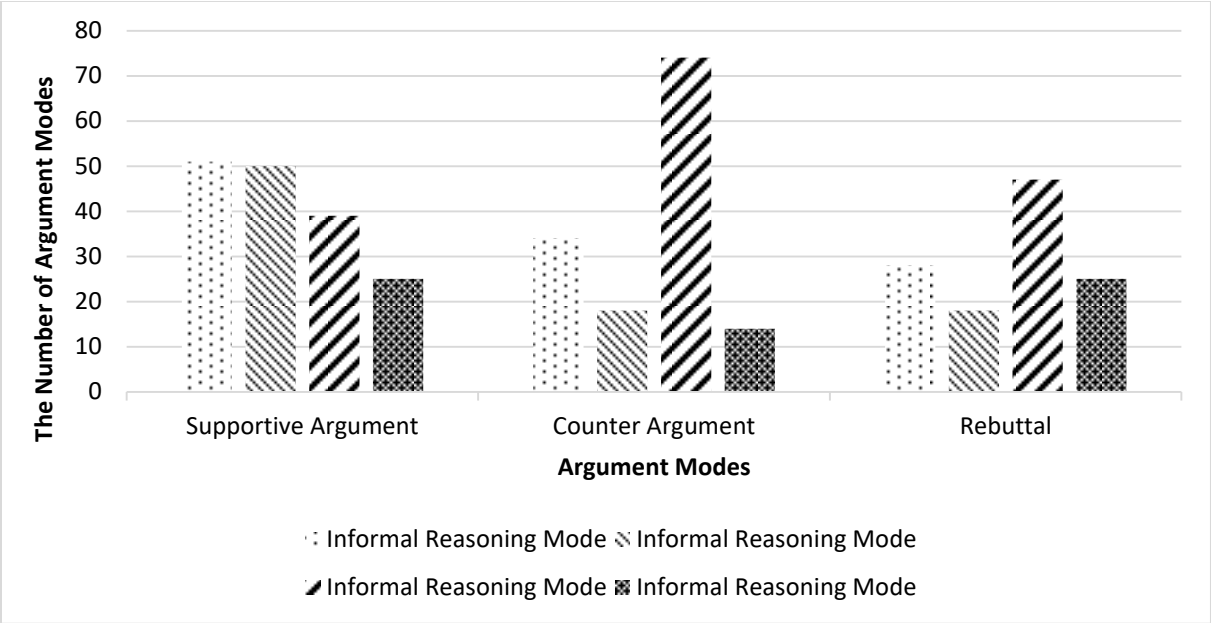
Reasoning Mode	Department	n	Mean rank	df	x^2	P	Sd.
Social-oriented	SCITE (1)	31	59.03				
	SOCSTE (2)	28	49.77	2	4.588	.101	
	PRISTE (3)	41	44.55				
Economic-oriented	SCITE (1)	31	59.00				
	SOCSTE (2)	28	49.23	2	4.410	.110	
	PRISTE (3)	41	44.94				
Ecological-oriented	SCITE (1)	31	63.53				
	SOCSTE (2)	28	42.38	2	9.801	.007	1-2, 1-3
	PRISTE (3)	41	46.20				
Science or technology-oriented	SCITE (1)	31	63.10				
	SOCSTE (2)	28	48.57	2	9.966	.007	1-2, 1-3
	PRISTE (3)	41	42.29				

As revealed in Table 4, there is no significant difference in social-oriented [x^2 (sd=2, n=100)= 4.588, p>.05] and economic-oriented arguments among departments [x^2 (sd=2,n=100)= 4.410, p>.05]. However, there is a significant difference in ecological-oriented [x^2 (sd=2, n=100)= 9.801, p<.05] and science or technology-oriented arguments [x^2 (sd=2,n=100)= 9.966, p<.05] among the three departments. Based on the mean ranks results in Table 4, it can be stated that SCI PTs produced more ecological and science or technology-oriented arguments than the other PSTs in other two departments.

The relationship between the argument modes and informal reasoning modes was also investigated. As seen in Figure 1, when the PSTs produced supportive arguments, they mostly used a social-oriented argument. As far as producing counter-arguments is concerned, they mostly used ecological-oriented arguments, and when they produced rebuttals, they mostly used ecological-oriented reasoning modes. For all the three-argument modes, they used the science or technology-oriented informal reasoning mode.

Figure 1

The Relationship between Argument and Informal Reasoning Modes



According to the framework developed by Wu and Tsai (2007), PSTs' argument modes were also investigated in terms of reasoning quality. As seen in Figure 1, most of the argument mode produced by PSTs in terms of reasoning quality is supportive arguments, and rebuttals are produced the least.

Figure 2

The Frequencies of the Argument Modes According to Departments

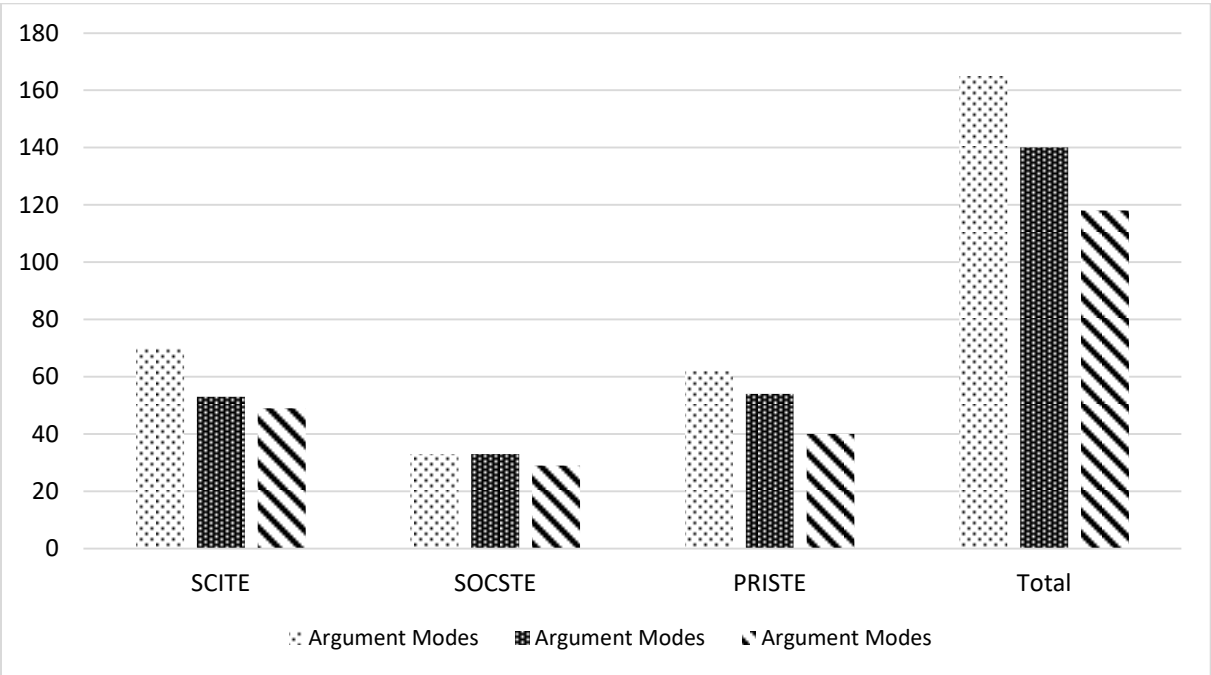


Figure 2 presents the frequencies of the argument modes according to the departments As seen in Figure 1, most of the arguments produced by three departments are supportive arguments by the SCITE, followed by supportive and counter-arguments by the SOCSTE, and supportive arguments by the PRISTE.

Finally, we investigated PSTs' informal reasoning levels. The results revealed that more than half of the PSTs (62%) had a high level of informal reasoning. Most of the PSTs in the department of SCITE (77%) had a high level of informal reasoning. The PSTs in the department of PRISTE had informal reasoning levels that were very close to each other (49% high level and 51% low level).

Result, Discussion, and Recommendations

Results about Informal Reasoning Modes of Preservice Teachers

Our study revealed that the PSTs mostly produced social-oriented and ecological-oriented informal reasoning modes, while science or technological-oriented informal reasoning modes were produced the least. When the issue of nuclear energy is examined from an environmental perspective, it is seen that the pre-service science teachers use ecology-oriented informal reasoning frequently. When the course contents of the SCITE, SOCSTE, and PRISTE undergraduate programs are examined, it is seen that there are topics related to nuclear energy and the environment.

However, as it was revealed, the PSTs could not use science or technological-oriented informal reasoning mode about nuclear energy at the expected level. Similar findings can be found in the literature. In the study conducted by Demircioğlu and Uçar (2014), the PSTs mostly used ecological-oriented informal reasoning modes, while they used scientific or technological oriented informal reasoning mode the least. Another study conducted by Liu et al. (2010) with 177 first-year university students in Taiwan showed that half of the participants used ecological and science or technological oriented informal reasoning modes. The study conducted by Öztürk and Leblebicioğlu (2015) revealed similar findings. The participants in their study made ecological and socioeconomic evaluations frequently, while they presented fewer scientific or technological evaluations. Wu and Tsai (2007) found in their study that students used very few science or technological oriented informal reasonings. According to the researchers, this is because students cannot make a connection between the socio-scientific issues they encounter and the content knowledge they have learned in science classes. Science should not be seen only as a course, but students should be taught how to use science and technology to produce solutions to social problems.

Results about Decision Making Modes of Preservice Teachers

When we examine the results about decision-making modes, we can say that 90% of the PSTs used evidence-based mode, while 10% used the intuitive one. The study conducted by Wu and Tsai (2007) in Taiwan revealed similar results about the decision-making modes. They revealed that 72% of the high school students made evidence-based decisions. We argue that PSTs are more sensitive about the welfare of society and energy independence. For this reason, further studies could be carried out about nuclear energy and its use as it is a popular subject nowadays in Turkey. In our study, we found many evidence-based decisions, and these decisions are related to the number of informal reasoning modes and informal reasoning qualities in a way. We can say that if teachers can include any popular science subject in their classes as a socio-scientific issue, students may be more interested in that particular science subject and may produce more informal reasoning modes.

Results about Positions of Preservice Teachers

When we examined the perspectives of the PSTs about the construction and use of nuclear power plants, we found that 68% of them approached it positively, while 21% had a negative

perspective. The participants who had a positive perspective justified their decisions by saying that nuclear energy is productive; less terrain is used to produce energy; there is less greenhouse gas emission; as a country, we may have a say in the region; and our dependence on external sources may be reduced.

On the other hand, accident risks in plants, the harms of the radiation leak on nature, the huge cost of building nuclear power plants, and continued external dependence because of uranium used are the negative perspectives regarding nuclear power use and construction of power plants. The review of the literature about socio-scientific issues related to nuclear energy use or building nuclear power plants reveals the same negative and positive arguments (Ateş, 2013; Ateş & Saraçoğlu, 2013; Çavuş, 2013; Yapıcıoğlu & Aycan, 2018).

Based on the findings, we can also say that PSTs who used evidence-based arguments about using nuclear power plants are more positive than those who used intuitive argument modes.

Results about Informal Reasoning Modes of Preservice Teachers According to the Departments

When we examine the informal reasoning modes according to departments, it is seen that the pre-service science teachers used social and economic oriented informal reasoning modes more than other departments, and also pre-service primary school and social science teachers used social and economic-oriented informal reasoning modes almost at an equal rate. Ecological and science or technology-oriented informal reasoning modes showed a significant difference in favour of the pre-service science teachers. This may be attributed to the fact that environmental courses are frequent in the undergraduate programs of pre-service science teachers compared to the other two departments.

When we investigate the argument modes according to reasoning quality, it is seen that supportive arguments showed significant differences based on departments, and pre-service science teachers used supportive arguments more than other departments. They are followed by pre-service primary school and social studies education teachers. One of the possible reasons for this is that pre-service science teachers might have encountered nuclear energy issues more than other departments because of the undergraduate curriculum of the science teacher education department.

There is no significant difference between the departments in terms of counter-arguments. Pre-service science teachers used more counter-arguments than the pre-service primary school and social science teachers. Furthermore, pre-service primary school and social science teachers were close to each other in terms of using counter-arguments. It was revealed that PSTs used mostly "ecological-oriented" arguments as counter-arguments. This may be because content knowledge based on undergraduate lessons can be linked with producing arguments.

As far as rebuttals are concerned, it can be stated that pre-service science teachers produced more rebuttals than the other departments, which may be due to content knowledge that can affect the number of constructed arguments and the number of informal reasoning modes. The findings of some studies in the literature coincide with the findings of our study (Acar, 2008; Sadler & Zeidler, 2005b; Zohar & Nemet, 2002). Sadler (2004) found that knowledge about socio-scientific issues has a central role in informal reasoning. In the study conducted by Soysal (2012) and Kutluca (2012), it was revealed that content knowledge is a useful variable for determining the quality of socio-scientific arguments. Zohar and Nemet (2002) found that when the argumentation process is integrated into the courses, it positively affects scientific knowledge and the reasoning quality of the students. The study conducted by Demircioğlu and Uçar (2014) revealed that PSTs are competent in expressing and defending their ideas; however, they are weak at producing counter-arguments and rebuttals.

Topçu (2008) revealed that all of the pre-service science teachers involved in the study could easily express their claims and the arguments supporting their claims. However, they produced fewer counter-arguments and rebuttals. There is a similar finding that while pre-service science teachers can defend their claims with reasons, they put forward a small number of counter and rebuttal arguments (Topçu et al., 2011). Similarly, Kortland (1996), who conducted a study with 13-14-year-old students,

revealed that the students produced simple arguments and a limited amount of upper-level arguments. According to Kortland (1996), there may be two reasons behind that: lack of knowledge about socio-scientific issues and being inexperienced about expressing arguments clearly.

Results about the Relationship between Argument and Informal Reasoning Modes of Preservice Teachers

Here, it must be noted that informal reasoning modes are the components of the arguments (supportive, counter, and rebuttal). In other words, when the informal reasoning modes (ecological, economic, social, science or technology-oriented) come together, they construct all of the argument modes. The PSTs in our study mostly used social-oriented and economic-oriented informal reasoning modes to support their views. They may have resorted to these informal reasoning modes due to their sensitivity to reducing economic dependence and political power arguments.

Since the nuclear energy issue in this study is related to the environment, we can say that ecological-oriented informal reasoning was used mostly as the counter-argument and rebuttal. The social-oriented informal reasoning mode decreased from the supportive arguments to the rebuttals. Demircioğlu and Uçar (2014) found that PSTs mostly used ecological justifications on pre-tests and economic ones on post-tests. Here we can see that our results coincide with the findings of another study on a different socio-scientific issue in terms of the informal reasoning modes chosen by PSTs.

Results about Informal Reasoning Levels of Preservice Teachers

The findings further revealed that PSTs developed supportive arguments more than the other modes of argument. This may be attributed to the fact that supportive arguments have a permanent place in their minds and they do not want to refute these arguments with counter-arguments; thus, they use counter-arguments less. It is not clear whether they do this based on evidence or intuitively; however, it seems that they have strong supportive arguments which prevent the formation of counter-arguments. In theory, the curriculum includes exercises through which students can easily express their ideas, defend their ideas effectively giving different reasons, and perform tasks where classmates can develop counter-arguments to rebut their claims. However, in practice, the level of informal reasoning is almost always low. In other words, students are frequently at the level of producing supportive arguments and cannot reach the counter-argument and rebuttal levels.

In this study, it was found that 62% of the PSTs had high and 38% of the PSTs had low levels of informal reasoning. It was seen that most of the pre-service science education teachers and more than half of the pre-service social science teachers are at a high informal reasoning level, while half of the pre-service primary school teachers are at a high informal reasoning level. The study conducted by Wu and Tsai (2007) demonstrated the same rates, although in opposite directions (38% high and 62% low level). The reason why our results contradict those of Wu and Tsai's (2007) study is that college students may have a more advanced level of reasoning than high school students.

In Turkey, nuclear energy use and the construction of power plants are popular scientific issues. It is planned to build two nuclear power plants to meet energy needs in Turkey. It was thought that the popularity of the issue may attract PSTs' attention. Our findings revealed that the pre-service science teachers in this study used multiple informal reasoning modes and have high-quality informal reasonings. Integrating socio-scientific issues in the curriculum may help PSTs improve their informal reasoning qualities and produce more arguments. Teachers can also relate a subject in their lessons to a socio-scientific issue. In this way, students' use of arguments and informal reasoning qualities may be improved. In this study, the science-oriented informal reasoning mode was used the least. Educators may give more importance to socio-scientific issues in classrooms to receive feedback from students about using informal reasoning modes.

As human beings, we are afraid of what we do not know. In this research, it is thought that content knowledge and informal reasoning modes can have a positive relationship. Content

knowledge is a barrier to the emergence of reasoning flaws (Sadler & Zeidler, 2005a). We share the same thoughts with Sadler and Zeidler (2005a) about content knowledge and informal reasoning quality. Thus, it is believed that more research should be conducted about the relationship between content knowledge and informal reasoning modes. Moreover, the relationship between undergraduate courses and content knowledge level may be investigated in the informal reasoning literature. The effects of media on negative perspectives about nuclear energy use can also be investigated because Kılınç, Boyes, and Stanisstreet (2013) found that most middle school and high school students have negative perspectives about nuclear power plant construction due to the negative popular media news.

In this study, we analyzed the written answers of PSTs about a socio-scientific issue. The skill of revealing ideas in writing is a critical one. For this reason, writing exercises (e.g. short stories, composition, etc.) about scientific issues would be more helpful to present the ideas in writing. Through such exercises, both teachers and researchers can acquire more information about the participants' reasoning modes for other socio-scientific issues.

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