

Pre-service Science Teachers' Decisions and Types of Informal Reasoning about the Socioscientific Issue of Nuclear Power Plants

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Abstract

The establishment and use of nuclear power plants to meet the energy need is a controversial socioscientific issue in all the countries of the world; as in Turkey. In this regard, the current study intended to investigate the effect of the socioscientific issue-based instructional activities related to the Nuclear Energy Plants (NEP) that have been attempted to be made widespread in our country on the pre-service science teachers' decisions, positions and types of informal reasoning they use while making their decisions. The current study employed one of the mixed methods; *the data transformative design model*. At the end of the study, it was determined that the pre-service teachers had decided that the establishment of nuclear plants should not continue and that the instructional activities led them to change their positions. Moreover, it was found that while making their decisions, before the application, they were mostly engaged in the ecology-based informal reasoning; after the application, they mostly utilized the social type of informal reasoning. Thus, it was concluded that the pre-service science teachers' engagement in activities related to the socioscientific issue of nuclear energy plants increased their types of reasoning they resorted to and contributed to their sophistication in reasoning. The more types of informal reasoning are used by individuals while making their decisions, the more conscious and reasonable decisions they can make. In this regard, it can be argued that the socioscientific issue-based instructional activities brought social dimensions related to the establishment of nuclear power plants to the fore in the decisions of the pre-service science teachers. Moreover, the opinions of the pre-service science teachers who will take an important role in giving direction to the future of the society about this issue should be taken into consideration by different social associations such as administrators, politicians, non-governmental organizations and particularly by teacher training programs.

Keywords: *Science Education, Socioscientific Issues, Informal Reasoning and Nuclear Power Plants.*

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Introduction

Scientific literacy is an educational goal which all the countries in the world strive to achieve and science educators agree on. Though the definition and dimensions of scientific literacy are controversial, students' consciously addressing and analyzing socioscientific issues is considered to be an important component of scientific literacy (Pouliot, 2008; Sadler, 2004). With the rapid development of science and technology, as the citizens of democratic societies, students may encounter a wide range of socioscientific issues, and they may need to establish positions and decisions, both for themselves and for their parents (Wu and Tsai, 2007).

The term expressed as socioscientific issues refers to social problems, cases or events causing social dilemmas (Sadler, 2004), including more than one point of view and scientists cannot agree on (Kolstø, 2001). According to Simonneaux (2007), socio-scientific issues which are not easy to understand and which have more than one possible solution at the same time can be evaluated on the basis of scientific principles, theories and data. But the solutions cannot be thoroughly examined with scientific evaluations. Behavioral patterns and action plans to solve these problems are related to social factors such as political, economic, moral and ethical. A socioscientific issue in nature involves moral and controversial dilemmas (Kolstø, 2001; Sadler, 2004; Zeidler, Walker, Ackett and Simmons, 2002). Moral limitations are situations that make the solution of a socioscientific problem difficult. For example, many issues ranging from the replacement of human genes in the field of genetic engineering to human cloning involve ethical questions and moral reasoning. For instance, In medical science, questions such as "is it correct to research and reveal all the ways of treatment involving genomic transformations of humans?", "or do families have the right to make gene combinations in unnatural ways to have a baby?", "what kind of role should be played by governments in designs and regulations concerning genetic engineering and who should decide this?" are moral and ethical questions that can be asked within certain contexts (Sadler, 2004).

Reasoning on socio-scientific issues is one of the topics of great interest in science education in recent years. According to Cerbin (1988), reasoning plays a central role in problem solving, making judgments and decisions and in the formation of ideas and beliefs. One of the most important objectives of higher education is to encourage learners to develop their reasoning skills and to be engaged in reasoning. Reasoning is important not only for academic success but also for effective daily life. In this respect, its relations with socioscientific issues are evident because, in general, addressing socioscientific issues involves the processes of argumentation, informal reasoning, and consequently decision-making about these issues (Wu and Tsai, 2007). Researchers have argued that moral and ethical factors associated with socioscientific issues affect informal reasoning and that they are the primary determinant of decision-making (Fleming, 1986; Sadler, 2004).

Formal and informal reasoning can be seen as two different forms of meaning opposite to each other. But in reality there are some common and different aspects between formal and informal reasoning (Wu and Tsai, 2007). While formal reasoning involves the derivation and production of arguments related to formal deductive systems such as logic and mathematics, informal reasoning involves claims and reinforcers supported by some evidence (Cerbin, 1988). Informal reasoning involves cognitive and affective processes employed to evaluate the complicated problems that are devoid of explicit and clear solutions and that are a part of the daily life and to take a position against them (Öztürk and Leblebicioğlu, 2015; Sadler, 2004). For individuals to be able to make decisions and to take positions in relation to socioscientific issues, their informal reasoning and argumentation skills should be enhanced by educators through proper activities. In the literature, there are studies investigating the types of reasoning used by individuals while making decisions about socioscientific issues. In the following section, these studies will be summarized.

Research on the Types of Informal Reasoning pertinent to Socioscientific Issues

When the research on informal reasoning related to socioscientific issues is reviewed, it is seen that though researchers have determined that types of informal reasoning differentiate, as each study is interpreted from different aspects, they make important contributions to the literature of science education. Some of these studies are summarized in Table 1.

Table 1. *Socioscientific Issues and Types of Informal Reasoning Explored by Researchers*

Study	Socioscientific Issue	Main Finding
Fleming (1986)	Nuclear energy and genetic engineering	At the basis of the patterns of reasoning lie ethical and personal factors.
Patronis, Potari and Spiliotopoulou (1999)	Road construction works in their regions	At the basis of the types of arguments lie social, ecologic, economic and practical factors.
Yang and Anderson (2003)	Use of nuclear energy	The modes of reasoning are scientifically, socially and equality-centered.
Sadler and Zeidler (2004)	Gene therapy and cloning	The quality of informal reasoning depends on within-scenario consistency, between-scenarios consistency and noncontradiction, construction of opposite positions and reputations.
Sadler and Zeidler (2005)	Gene therapy, cloning for reproductive and therapeutic purposes	The types of informal reasoning; rational, (logical), intuitive and affective.
Wu and Tsai (2007)	The establishment of 4 nuclear power plants in Taiwan	The modes of reasoning are socially, economically, ecologically, scientifically or technologically-centered.
Liu, Lin and Tsai (2010)	The environmental problem related to the struggle of an exotic, tropical plant species (<i>Mikania micrantha</i>) against invasive seeds	At the basis of the modes of reasoning lie ecologic, ethic, aesthetic, scientific, technologic and socio-economic factors.
Yap (2014)	Genetically-modified organisms, genetic scanning tests, reproduction technology	The approaches of informal reasoning are based on rational (logical), intuitive, affective and ethical factors.

In a study by Fleming (1986) conducted on adolescents aged 17 to 18 to investigate their opinions about nuclear energy and genetic engineering, it was concluded that adolescents define socioscientific issues mostly by focusing on their social aspects and make use of two domains of reasoning being ethical and personal. What is meant by ethical reasoning is the potential of harming everything seen as others. The concern of harm should be given higher priority than all the other domains of reasoning. It goes on being a dominant domain of reasoning while subjects are being examined. What is meant by personal domain of reasoning is defined as efforts invested to protect oneself and one's own interests. In this domain of reasoning, giving harm to others is not seen to be a very important issue; rather, what is important here is one's holding the control of his/her personal, economic and health problems in such a way as to promote his/her own interests. Investigating the qualifications of the arguments produced by 14 year olds in the process of decision making about a socioscientific issue, Patronis, Potari and Spiliotopoulou (1999) stated that the arguments produced have social, economic, ecologic and practical basis. Yang and Anderson (2003) pointed out that while the individuals who are scientifically-centered make their reasoning by using more scientific knowledge; those who are socially-centered put greater emphasis on social factors rather than scientific evidence and those who are equality-centered can adopt different perspectives of more issues. Sadler and Zeidler (2004) explored the quality of university students' informal reasoning about six scenarios related to generic engineering. They evaluated the quality of university students' informal reasoning according to four criteria (within-scenario consistency, between-scenarios consistency and noncontradiction, opposite position and refutation construction). The within-scenario consistency refers to the extent to which the logic presented in scenario having any socioscientific content about cloning and gene therapy is supported; the between-scenarios consistency and noncontradiction mean that a position or an argument presented in a scenario about gene therapy or cloning does not contradict with responses given in some other related scenarios. The opposite position and refutation construction refers to a clear opposite position taken by one of the participants against any of the arguments. Sadler and Zeidler (2005), in another study, investigated the types of informal reasoning engaged in by students in their decision-making process about socioscientific issues. The students resorted to three types of informal reasoning being logical, intuitive and affective. While students are making decisions about genetic engineering scenarios, they use logical processes. They do logical calculations based on many different factors such as patient rights, family responsibilities, alternative treatments, existence of alternatives, side effects, future applications and inconsistencies related to accessibility. Affective informal reasoning can be defined as an apprehensive point of view adopted to empathically direct decisions and behaviors for the wellbeing of others. Intuitive informal reasoning refers to instant reactions towards a scenario. Intuitive informal reasoning is the result of an instinctive reaction or sensation that cannot be explained by logical terms. Wu and Tsai (2007) examined the reasoning modes of students towards the establishment of the fourth nuclear power plant in Taiwan under four categories as social, ecological, economic, scientific or technological. Liu, Lin and Tsai (2010) have extended the classification of Wu and Tsai (2007) to explain the modes of reasoning on an environmental

problem in four categories: ecological, ethical-aesthetic, scientific-technological and social-economic. Yap (2014) examined the types of informal reasoning proposed by Sadler and Zeidler (2005) in four categories by adding ethical informal reasoning. According to the researchers, logical informal reasoning is based on reason, affective informal reasoning is based on worry, intuitive informal reasoning is based on instant reactions related to the content and ethical informal reasoning is based on value and belief-induced thoughts of anyone.

In the some studies directed to the exploration of individuals' types of informal reasoning about socioscientific issues, some factors affecting informal reasoning were also examined. They concluded that informal reasoning and decision-making processes about socioscientific issues are affected from personal content knowledge (Hogan, 2002; Sadler and Zeidler, 2004), personal expertise and experiences (Fleming, 1986), that scientific knowledge is changeable and with its unclear structure, is associated with epistemological components of thinking related to creativity (Liu, Lin and Tsai, 2010).

Significance and Rationale of the Study

Nuclear power plants are a socio-scientific issue that can be seen as a past technology by some nations of the world while as an alternative solution to energy crisis by some others. When the research on nuclear power plants in the literature is reviewed, it is seen that particularly at national level, this issue has been mostly examined within a theoretical framework. Researchers have investigated the aspects of nuclear plants such as historical development, economy, areas of use, effects on environment, society and human health, effects on foreign policies, benefits and harms, factors affecting the decision of possessing them, the public problem of acceptance and the rejection syndrome (Altın and Kaptan, 2006; İmer and Dalbudak, 2012; Kaya, 2012; Köksal and Civan, 2009; Palabıyık, Yavaş and Aydın, 2010; Soykenar and Coşkun 2015; Rebet, 2005; Temurçin and Aliğaoğlu, 2003; Yıldırım and Örnek, 2007). The research on students has been determined to be mostly interested in the description of the current states. For example, Şenyuva and Bodur (2016) explored the pre-service teachers' opinions about nuclear energy and the relationship between these opinions and environmental literacy; Sürmeli, Duru and Duru (2017) investigated the pre-service teachers' attitudes in terms of different variables; Kılınç, Boyes and Stanisstreet (2013) looked into the students' perceptions of the benefits and risks of nuclear power plants; Cansız and Cansız (2015) focused on the students' opinions and knowledge, Aydeniz and Gürçay (2013) investigated the pre-service physics teachers' written argumentation quality; Wu and Tsai (2007) explored the students' informal reasoning and Yang and Anderson (2003) evaluated students' reasoning mode types and preferences. In the current study; on the other hand, the effect of socioscientific issue-based instructional activities on the pre-service science teachers' decisions about the establishment of nuclear energy power plants, their types of informal reasoning in relation to their decisions and informal reasoning levels was examined. As the current study included socioscientific issue-based instructional activities; different from the other research in the literature, it can

provide important insights about how to handle such issues in teacher training for both practitioners and researchers; thus, make important contributions to the literature. Moreover, the issues having a controversial character such as socioscientific issues are widely avoided by teachers in science classes due to concerns about classroom management and etc. Seen from this perspective, the current study can help pre-service teachers develop alternative viewpoints of such issues. In this regard, the problem statements of the current study can be expressed as follows;

- i. What are the pre-service science teachers' decisions about the establishment of nuclear power plants before and after the application of the socioscientific issue-based instructional activities?
- ii. What are the changes taking place in the pre-service science teachers' decision positions after the application of the socioscientific issue-based instructional activities?
- iii. What are the types of informal reasoning engaged in by pre-service science teachers about the establishment of nuclear power plants before and after the application of the socioscientific issue-based instructional activities?
- iv. How did the pre-service science teachers' levels of informal reasoning about the establishment of nuclear power plants change after the application of the socioscientific issue-based instructional activities?
- v. Is there a significant difference between the pre-service science teachers' informal reasoning mean levels about the establishment of nuclear power plants before and after the application of the socioscientific issue-based instructional activities?

Method

The purpose of the current study is to determine the effect of the socioscientific issue-based instructional activities on the pre-service science teachers' decisions about the establishment of nuclear power plants, their positions, types of informal reasoning in relation to their decisions and informal reasoning levels. To this end, one of the mixed methods, *the data transformative design model* as proposed by Creswell, Fetters and Ivankova (2004) was employed. In the data transformative model, researchers collect qualitative data, analyze them on the basis of the previously determined code scheme or the conceptual framework and digitize the codes or themes. In this model, on the basis of a data set, qualitative and quantitative analyses are combined in a study. The goal of the researcher is to turn quantitative data into qualitative themes or codes, or to turn codes and themes in the state of qualitative materials to quantitative numbers (Caracelli and Greene, 1997; Mertens, 2007). In this process defined as quantizing, qualitative data are treated with quantitative techniques to be turned into quantitative data (Sandelowski, 2000). While

in mixed method research binary working model (concurrent or sequential) is viewed to be a traditional approach more widely employed, the transformative model is a relatively new approach still being developed (Creswell, 2003).

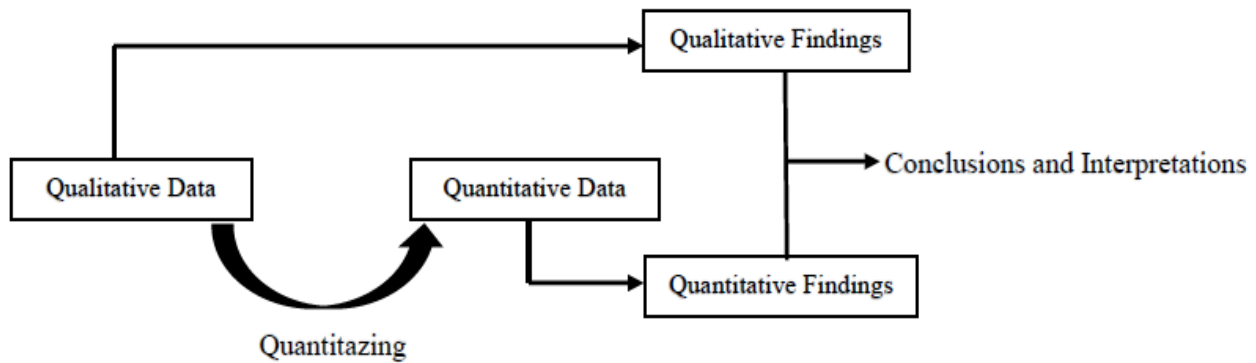


Figure 1. Flow Diagram of the Data Transformative Design Model (Creswell, Fetters and Ivankova, 2004).

The main reasons for the selection of the model based on the transformative paradigm (Mertens, 2007) are that it provides flexibility for researchers, increases the generalizability by transforming qualitative data into quantitative data sets and that the researcher sees both qualitative and quantitative research methods equally valuable.

Study Group

The study group of the current research is comprised of 51 third-year students attending the department of science teaching at the education faculty of a state university located in the Aegean Region of Turkey and taking the course of Special Issues in Chemistry in the fall term of 2016-2017 academic year. The age of the participants varies from 19 to 21. The number of the female students in the group is 43 and the number of male students is 8. Thus, it is clear that distribution of genders is not precisely heterogeneous rather dominated by female participants. The participating students had already studied the topics of nuclear physics, binding energy, natural and artificial radioactivity, nuclear reactions, (fission, fusion) and energy reactors within the context of the required course of General Physics II taken in the fall term of the second year and the topics of structure of the nucleus, radioactivity, nuclear fission and fusion, particle physics and cosmology within the context of the required course of Introduction to Modern Physics taken in the spring term of the second year.

Application Process

The socioscientific issue-based instructional activities were conducted within the context of the course of Special Issues in Chemistry taken by the third-year students attending the department of science

teaching for a total of eight class hours in a four-week period. In the first week of the study, the participating pre-service teachers were instructed about operation principles of nuclear power plants, countries having nuclear power plants, advantages and disadvantages of nuclear power plants and nuclear power plant disasters in the history by means of power point presentations and the question-answer technique. The socioscientific issue-based instructional activities included dilemma cards, problem scenarios, idea production and poster design activities.

Table 2. *Socioscientific Issue-based Instructional Activities Used During the Application*

Activity No	Utilized Method & Technique & Tool	Activity Name
Activity 1	The activity of dilemma cards	Make your choice!
Activity 2	The activity of problem scenarios	Nuclear power plant experts are on the job
Activity 3	The activity of producing ideas	I have an idea!
Activity 4	The activity of poster design	I am walking around the stations, I am designing posters

The dilemma cards are instructional tools through which students arrive at decisions on the basis of their opinions, beliefs and viewpoints about controversial issues bringing about dilemmas in the society. In this sense, they are viewed as suitable instructional tools that can be used in dealing with socioscientific issues by Evren and Kaptan (2014). Within the context of the activity of dilemma cards, cards, as the one given below, were presented to the students.

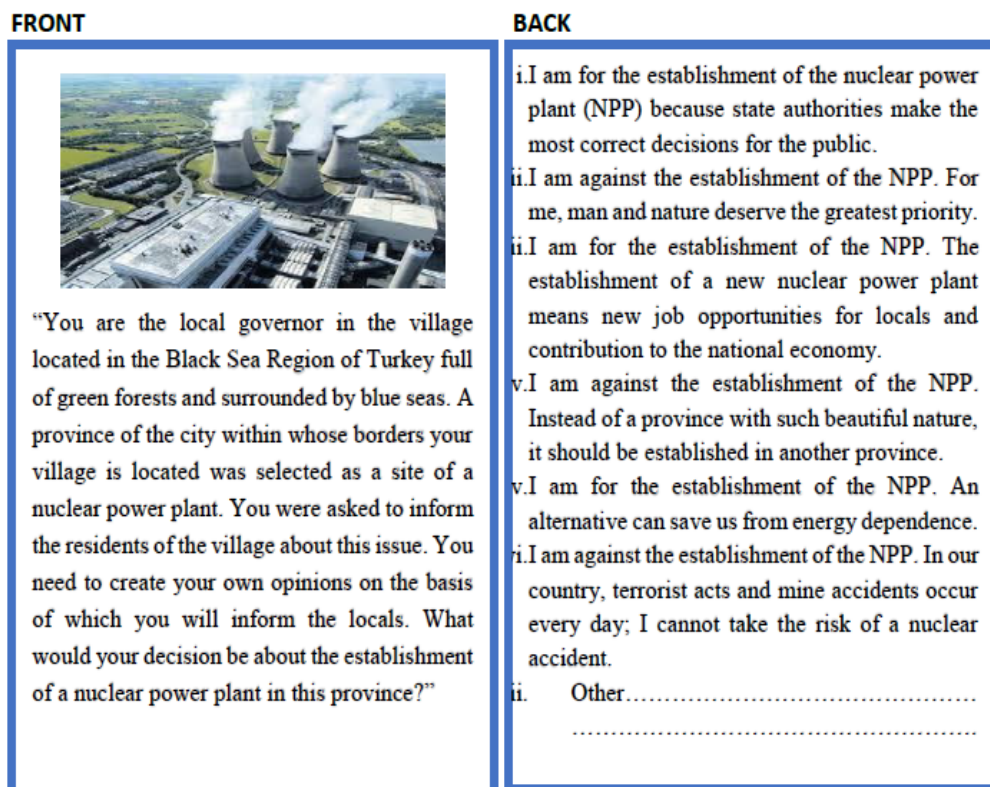


Figure 2. *A sample dilemma card*

Within the context of the socioscientific issue-based activity designed according to the idea producing technique, in every corner of the class, cards reading “I Agree”, “I Disagree”, “I am Undecided” were taped. Each student was distributed small post-it notes. Then each student was instructed to tape the post-it note on the card indicating their opinion and to wait in front of it. After that, the three groups were asked to express their reasons for their selections without initiating any discussion. In the second stage, the members of the two groups were asked to try to persuade the students in the group of “undecided” to join their groups. This stage includes a persuasion process. The role of the researcher throughout the activities is to direct the discussions. The position of the researcher in the class is neutral so as not to influence the opinions of the pre-service teachers about the socioscientific issue in question.

Data Collection Tools

An open-ended question form was developed and administered in order to explore the pre-service science teachers’ decisions and the types of informal reasoning they are engaged in about the socioscientific issue of nuclear energy. The data collection process is comprised of two stages. In the first stage, the pre-service teachers were asked to write their decisions about whether the establishment of nuclear power plants should be continued (their initial decisions about the establishment of nuclear power plants) and their rationales behind these decisions (their initial types of informal reasoning). In the second stage, by reading articles, newspaper news and watching videos broadcast on the media about nuclear power plants, a written text was produced and then a data collection tool consisted of open ended questions was developed. On the front of this data collection tool is there information about the definition of nuclear power plants (238 words), on the back is there information about the positive aspects of nuclear power plants (238 words) and the negative aspects of them (238 words). In order not to affect the pre-service teachers’ decisions, these information sections were kept equal. There are three questions following the written text: 1- Should or shouldn’t the establishment of nuclear power plants be continued?, 2-Explain the rationales (reasons) behind your answer, 3- If you were obliged to persuade a friend disagreeing with your decision about the correctness of your decision, what kind of evidence would you use to persuade him/her?. After the development of the scale, an expert experienced on nuclear power plants was asked to evaluate the scale. In line with the feedback received from the expert, it was decided how the paragraphs explaining positive and negative aspects of nuclear power plants should be placed on A4 paper format (not to affect students) and some corrections were made. Then, three doctoral students from the Natural Sciences Doctoral Program were invited to respond to the scale on a volunteer basis. After the students responded to the scale, their opinions about the scale were gathered (wording, language, comprehensibility, objectivity) and the response time was determined (45 minutes).

Data Analysis

Qualitative data analysis. In the first stage of the analysis process of the current mixed method research employing the data transformative design model, qualitative analysis methods were used. In the analysis of the data, the coding scheme proposed by Wu and Tsai (2007) was used. In this coding scheme, students' types of informal reasoning are classified into four categories as ecologic, social, economic and scientific-technologic. On the basis of these four categories, the codes used by the pre-service teachers were determined. In this stage of the research, the deductive content analysis was used. Following the stage of the deductive content analysis, numerical analysis of the qualitative data was initiated (Yıldırım and Şimşek, 2008). The categories and codes used and the section representing 25% of the raw data set were sent to an expert experienced on qualitative research methods in order to establish scoring reliability. As a result of the calculation made, the coder reliability was found to be 88%. As this value is over the level of the fit stated to be 80% by Miles and Huberman (1994), the reliability of the qualitative data coding is at a good level. In the findings of the research, the names of the pre-service science teachers were coded [PST1: (Pre-service Science Teacher 1), PST2, etc.] and some of the statements they used in deciding were displayed.

Quantitative data analysis. In the analysis of the quantitative data, descriptive and inferential statistical analyses were employed. For this purpose, Microsoft Excel and SPSS 22 program package were used. By using Microsoft Excel program, clustered bar graphs were plotted. Before the initiation of the inferential statistical analyses, the skewness and Kurtosis values of the informal reasoning type scores were examined in order to decide on the analysis test technique and it was determined that they remained within the range of normal distribution (+1, -1). Moreover, according to the results of Kolmogorow-Smirnov test, the distribution of the informal reasoning type scores complies with the normal distribution ($p > 0.05$). As the sample size is higher than 30, it was decided that the use of paired sample t-test; one of the parametric test techniques, would be suitable (Büyüköztürk, Çokluk and Köklü, 2010)

Findings

The codes used by each pre-service teacher while making their decisions about establishment of nuclear power plants were categorized by using Table 3 and frequencies were calculated. The codes determined on the basis of the categorizations in the current study are shown below.

Table 3. *Coding scheme*

Categories	Codes
Ecologic	Global warming, acid rains, nuclear energy, destruction of the environment, endangered species (plants, animals etc.), environmental pollution (water, soil, air and radioactive pollution), destruction of habitats and intervention with living organisms.
Economic	Economic contribution to the nation, contribution to energy production, energy saving, setup cost, making profit, dependence on foreign countries, high cost, reduction in the import of natural gas, uranium-induced dependence on other countries, time saving and gains.
Scientific and/or Technologic	Prevention/evaluation of security threat, implementation of precautions, explosion risk/radiation scattering, evaluation of the establishment and regular control, accident risk evaluation, expert evaluation, reduction of the effect of radiation, past technology, increase in alternative energy sources, use of natural methods/environmental-friendly energies, natural disasters (earthquake etc.) and nuclear leakage, utilization of other scientific disciplines (nuclear medicine etc.) and recycling of nuclear wastes.
Social	Harmful to human health/life, cause of cancer, important for the state, usage of it in many countries, public education, social development, increasing illnesses/health problems, desire to dominate the world, thinking of future generations, terrorist attacks, emigration of people, display of power and production of nuclear weapons.

As can be seen in Table 3, four categories of informal reasoning types which were used in Wu and Tsai (2007) that were applied in study. The findings related to the pre-service science teachers' decisions about the socioscientific issue of nuclear energy before (B.A) and after the application (A.A) of the instructional activities are shown below in the form of a clustered bar graph.

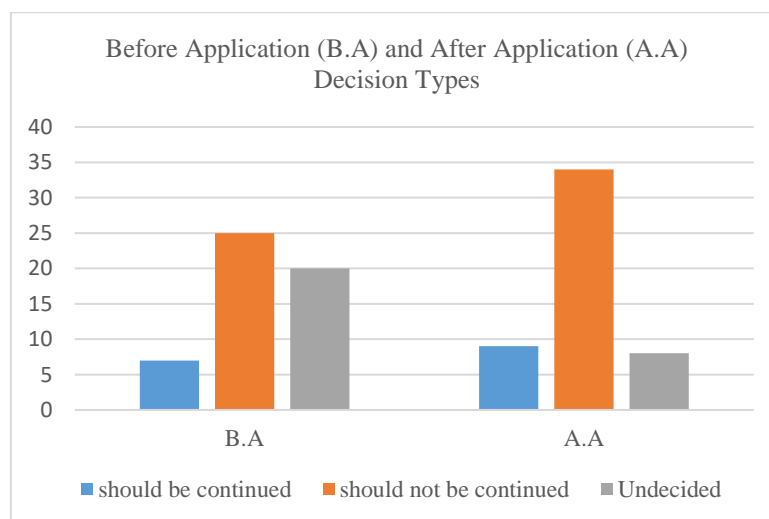


Figure 3. *B.A and A.A Decision Types*

As can be seen in Figure 3, the pre-service science teachers; both before and after the application of the socioscientific issue-based instructional activities, were of the opinion that the establishment of nuclear power plants should not be continued. Most of the pre-service teachers who were undecided about the issue

before the application, decided that the establishment of nuclear power plants should not be continued after the application. The descriptive statistics related to the pre-service teachers changing their positions (from being undecided to being decided or from the existing decision to another decision) or retaining their positions after the application of the socioscientific issue-based instructional activities are presented in Table 4.

Table 4. *Changing or retained positions after the application*

Changing or retained position	f
Undecided → Should be continued	6
Undecided → Should not be continued	9
Should be continued → Should not be continued	5
Should not be continued → Undecided	3
Should not be continued → Should be continued	1
Total Position Changes	24
Total Position Retentions	27
TOTAL	51

As can be seen in Table 4, nearly half of the participating pre-service teachers (f:24) changed their position after the application. Most of the teachers changing their position shifted from the position “undecided” to the position “should not be continued” (f:9). The pre-service teachers’ types of informal reasoning before the application of the socioscientific issue-based instructional activities are shown in Figure 4.

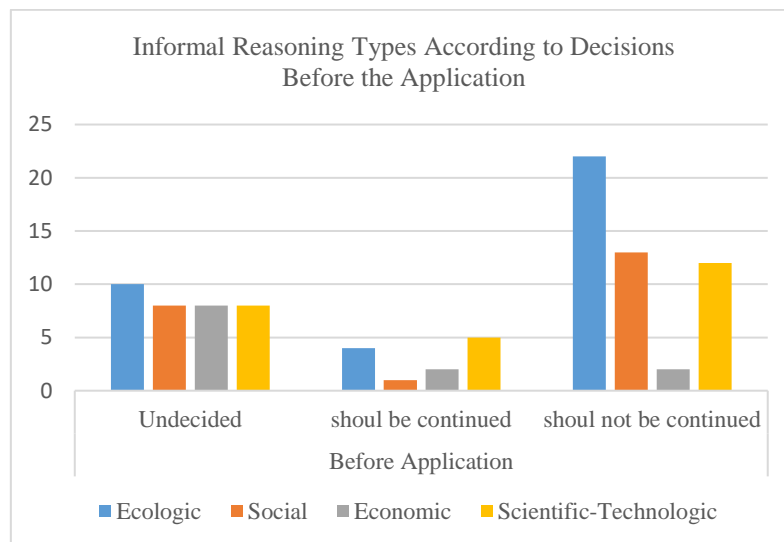


Figure 4. *Informal Reasoning Types according to the B.A Decisions*

As can be seen in Figure 4, before the application of the socioscientific issue-based instructional activities about the establishment of nuclear power plants, the pre-service teachers thinking that it should not be continued resorted to the ecologic type of informal reasoning and the pre-service teachers thinking that it

should be continued resorted to the scientific-technologic type of informal reasoning and the least preferred type of informal reasoning was economic. The pre-service teachers who were undecided about the establishment of the nuclear power plants used the ecologic type of informal reasoning the most and then they equally used the types of social, economic and scientific-technological types of informal reasoning. Some sample descriptions used by the pre-service science teachers while expressing their decisions and types of informal reasoning they were engaged in before the application of the socioscientific issue-based instructional activities are given below.

PST43(Pre-service Science Teacher43): Because I do not think that a power plant posing the risk of explosion and for which many trees must be cut down is good considering that there are many renewable energy sources in the world. Instead of using nuclear energy to develop, environmental friendly energy sources should be used so that we can leave a better world for our children (Should not be continued).

PST25: These power plants can generate high amounts of energy. When the necessary precautions are taken, they will positively affect our social development. While many developed countries utilize these power plants, it seems to be not very reasonable for us to reject them (Should be continued)

PST2: I am undecided; as I do not know what the advantages and disadvantages of nuclear power plants are, I want to say that I am undecided. I can give a better answer to this question, when I am better informed about nuclear power plants (Undecided, lack of information).

When the pre-service teachers' statements uttered before the application of the socioscientific issue-based instructional activities are examined, it is seen that the pre-service teacher coded as PST43 used scientific and technologic types of informal reasoning stating that instead of nuclear power plants, environmental-friendly renewable energy sources should be developed and nuclear power plants pose the risk of explosion and at the same time expressed concern about the destruction of trees to open space for nuclear power plants; thus, resorted to the ecologic type of informal reasoning. The pre-service science teacher coded as PST25 decided that it should be continued on the basis of social and scientific-technologic types of informal reasoning stating that social development is important and developed countries have nuclear power plants thus is it not reasonable to reject them. PST2 stated that the main reason for his/her being "undecided" is lack of information about nuclear power plants.

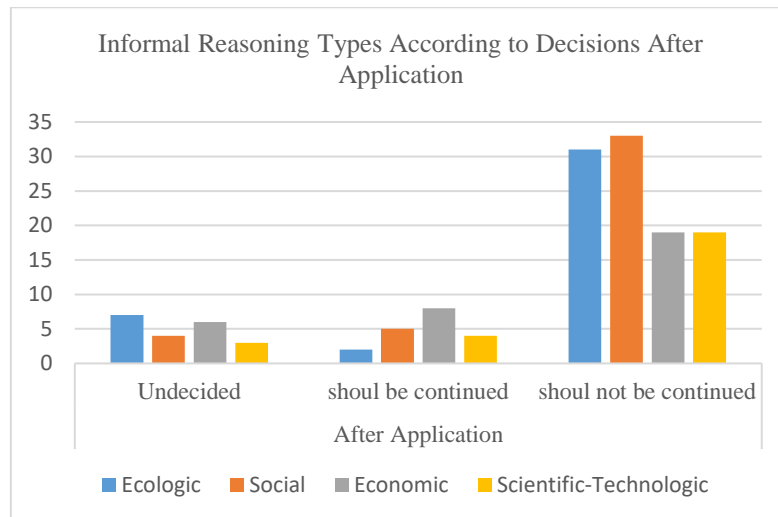


Figure 5. *Informal Reasoning Types according to the A.A Decisions*

In light of the findings reported in Figures 4 and 5, it was concluded that while the pre-service teachers were making their decisions used ecologic type of informal reasoning more before the implementation of the socio-scientific issue-based instructional activities about the establishment of nuclear power plants, they made more use of the social type of informal reasoning after the application. The pre-service teachers who were “undecided” were found to have resorted to ecologic and economic types of informal reasoning about the establishment of nuclear power plants. After the application, some sample descriptions used by them while expressing their types of informal reasoning and decisions are given below.

PST54: Their establishment may help us to get rid of our dependence on foreign countries but the harms brought about by them surpass their benefits. We are already exposed to harmful substances and inorganic foods; thus, their establishment will affect our health negatively. If even the risk of accident is minor, they can be attacked by terrorists, our enemies etc., leading to disastrous results. They can pollute our world and pose a threat to our lives. Our bodies’ indirect exposure to uranium is one of the causes of cancer. It is dangerous for future generations (Should not be continued)

PST19: Nuclear power plants are profitable way of meeting our energy need because with 1 kg U35 atomic fission, 90.000.000 MJ (Mega Joule) energy can be generated. But if we want to obtain this amount of energy from natural ways, it takes nearly ten years. Waiting so long to meet our energy needs may result in technological regression and increasing dependence on other nations (Should be continued)

PST1: Because nuclear power plants have both useful and harmful effects. While they are useful as they decrease global warming and meet our great amount of energy need, they are harmful as their

wastes give serious harms to environment, nature and living things. They make the production of nuclear weapons easier. They cause many disasters. Thus, I am undecided (Undecided)

When the excerpts of the pre-service teachers given above are examined, it is seen that while the pre-service teacher coded as PST54 is of the opinion that their establishment should not be continued due to risk of accident, terrorist attack, harms to human health and causing cancer, the pre-service teacher coded as PST19 stated that the establishment of nuclear power plants should be continued as it takes long time to generate energy by means of others means of energy production and they save us from being dependent on other nations. The pre-service teacher coded as PST1 is undecided as he/she thinks that there is a balance between benefits and harms of nuclear power plants.

Within the context of the third research problem, the change in the numbers of the types of informal reasoning the students were engaged in before and after the application of the socioscientific issue-based instructional activities was investigated (Figure 6).

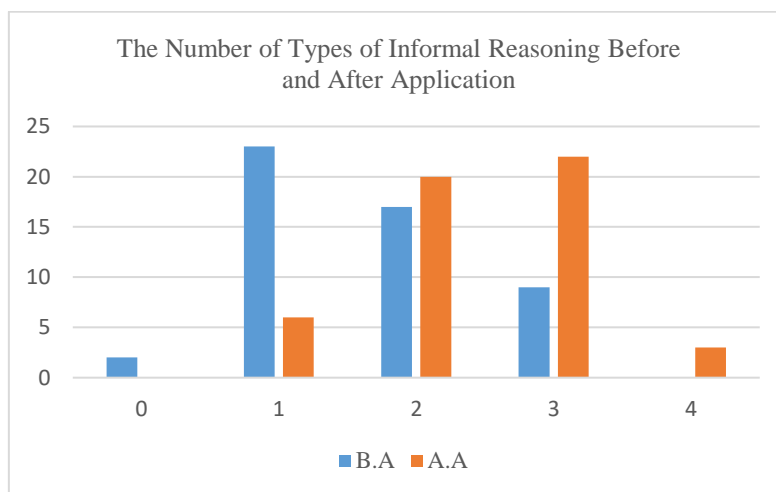


Figure 6. *The number of types of informal reasoning B.A and A.A*

As can be seen in Figure 6, most of the pre-service science teachers were found to utilize one type of informal reasoning before the application of the socio-scientific issue-based instructional activities. After the application, while the number of the pre-service teachers employing one type of informal reasoning decreased to a great extent, an increase was observed in the number of the pre-service teachers using two, three and four types of informal reasoning. Moreover, before the application, there were some students making their decisions without resorting to any type of informal reasoning. Within the context of the fourth research question, the dependent samples t-test was run to investigate the difference between the pre-service teachers' informal reasoning mean scores before and after the application and the results of this test are presented in Table 5.

Table 5. Dependent Samples t-test Results related to the Informal Reasoning Means

	N	X _{mean}	sd	t	df	p
Pretest	51	1.84	0.94			
Posttest	51	2.82	1.21	-5.2	50	.000*

*p < .05

As can be seen in Table 5, there is a significant difference between the informal reasoning mean scores before and after the application ($t = -5.2$; $p < 0.05$). Thus, it can be argued that the socioscientific issue-based instructional activities enhance informal reasoning levels.

Results and Discussions

Today, when science and technology are rapidly developing and changing, energy demand is among the greatest problems of the modern age. The nuclear energy as an alternative source of energy has led to serious disputes in the Turkish society but it has been becoming more and more popular in Turkey in recent years. In the Akkuyu district located in the southern part of Turkey, the government for the establishment of a nuclear power plant signed the treaty. Nuclear energy is among the issues considered to be socioscientific in the field of science. At the local, national and international levels, provision of opportunities for individuals to debate, reason and decide on socio-scientific issues is among the duties and responsibilities of democratic societies. Teaching through socioscientific issues is one of the primary goals of science education and programs.

The current study investigated the effect of the socioscientific issue-based instructional activities on the pre-service science teachers' decisions, positions, types and levels of informal reasoning according to their decisions about the establishment of nuclear power plants. The study revealed that both before and after the application, most of the pre-service teachers decided that the establishment of nuclear power plants in Turkey should not be continued. When the shift or retention of positions was examined, it was found that nearly half of the pre-service teachers changed their positions. Most of the pre-service teachers who were undecided before the applications started to think that it should not be continued and very few of them started to think that it should be continued. In light of these findings, it can be maintained that the socioscientific issue-based instructional activities can make up an effective approach in terms of undecided students to reach a decision and to take a position about the establishment of nuclear power plants. There are some studies reporting findings similar to or different from the findings of the current study. For example, Eş, Mercan and Ayas (2016) conducted a study on senior students and found that high majority of the students do not want to live in a city where there is a nuclear power plant; Şenyuva and Bodur (2016) reported that students have negative attitudes towards the use of nuclear energy; Cansız and Cansız (2015) reported that negative opinions are dominant among students. Kılınç, Boyes and Stanisstreet (2013) stated that the students living in a region where a nuclear power plant is likely to be established tend to believe in

the negative aspects of nuclear energy. Different from these findings, Yener, Aksüt and Somuncu-Demir (2017) reported that as a result of a technical field trip, the pre-service teachers' opinions changed in such a way as to support the establishment of nuclear power plants in Turkey. Moreover, Wu and Tsai (2007) found that the students making evidence-based decisions changed more positions than the students making intuition-based decisions after reading a short report about the use of nuclear energy. Yet, no information was given about the direction of the change.

Within the context of the third research problem, the pre-service science teachers' types of informal reasoning on the basis of their decisions before and after the application of the socioscientific issue-based instructional activities were examined. Before the application of the socioscientific issue-based instructional activities about the establishment of nuclear power plants, the pre-service teachers thinking that the establishment of nuclear power plants should not be continued resorted to the ecologic type of informal reasoning and the pre-service teachers thinking that it should be continued resorted to the scientific-technologic type of informal reasoning and after the application, the pre-service teachers deciding that it should be continued based their decisions on the economic type of informal reasoning and the ones deciding that it should not be continued based their decisions on the social type of informal reasoning. In the current study, it was concluded that the socioscientific issue-based instructional activities resulted in changes of positions and rationales in the students' decisions and types of informal reasoning. This might have been because the socioscientific issue-based instructional activities include both social and communal dimensions and enabled the pre-service teachers to conduct activities in groups. Wu and Tsai (2007) evaluated the high school students' judgments about nuclear energy studied in physics classes before and after reading a short report about it and found that while at first they tended to use ecology-based arguments but then they developed economy-based arguments, concurring with the finding of the current study. Liu, Lin, Tsai (2010); contrary to the current study, found that the pre-service science teachers mostly used science-technology and ecology-based reasoning. This difference might be because of the topics investigated in the studies; in the current study the socioscientific issue is nuclear power plants; however, in the study by Liu, Lin and Tsai (2010), positive and negative sides of the spread of exotic plant species were investigated. Moreover, in their study, there was no instructional process as they aimed to elicit the students' existing types and levels of reasoning. Demircioğlu and Uçar (2014) found that the students most produced ecology-based arguments and least produced social concerns-based arguments. Öztürk and Leblebicioğlu (2015) reported that the students used the socio-economic reasoning the most and ethic and aesthetic reasoning the least while making decisions about hydroelectric power plants.

Within the context of the fourth and fifth research questions of the study, the levels and types of the informal reasoning the students were engaged in before and after the application of the socioscientific issue-based instructional activities were analyzed on the basis of descriptive and predictive statistical findings. As

a result, it was found that while before the application the pre-service teachers used one type of informal reasoning the most followed by two types of informal reasoning, after the application they used three types of informal reasoning the most, followed by two types of informal reasoning. When the mean numbers of the types of informal reasoning found in the pretest and posttest were analyzed through the dependent samples t-test, the difference was found to be statistically significant. Thus, it can be concluded that the socioscientific issue-based instructional activities increased the number of the types of reasoning the students were engaged in while making their decisions about the socioscientific issue of nuclear energy. These findings of the current study concur with the study by Wu and Tsai (2007) reporting that high school students use more than two types of argumentation on average. Liu, Lin and Tsai (2010) conducted a comparative analysis of the number of the types of informal reasoning of the students attending verbal and non-verbal departments and found that pre-service science teachers used one type of reasoning the most, followed by two types of informal reasoning. The main reason for this might be that their study is a comparative study aiming to elicit the existing state. Jho, Yoon and Kim (2014) following the socioscientific issue-based instruction given about the establishment of nuclear power plants in Korea, determined that they continued similar attitudes and decisions. In the current study, contrary to the finding reported by Jho, Yoon and Kim (2014), it was found that while most of the pre-service teachers maintained similar decisions; the pre-service teachers who were undecided created a position and some changes occurred in the primary types of informal reasoning used by them. On the basis of this finding, it can be argued that the application of socioscientific issue-based approach makes students take a position on the socioscientific issues on which they are undecided. Moreover, the socioscientific issue-based activities increase the types of informal reasoning the pre-service teachers are engaged in and also lead to changes in the primary type of informal reasoning employed by the students. Without doubt, an increase in the number of the types of informal reasoning utilized by individuals while making their decisions contributes to the creation of more conscious decisions. Similarly, Gutierrez (2015) concluded that socioscientific issues integrated into classroom discussions and argumentation process result in significant developments in terms of students' generating more detailed, positive and profound explanations for their decisions. As today's pre-service teachers will be the teachers of future (Cansız and Cansız, 2015), their decisions and informal reasoning about socioscientific issues are of great importance in terms of their professional competences because teachers will educate administrators, politicians, doctors, lawyers, engineers, artists and teachers of the future who will make important decisions as responsible, sensitive and conscious individuals by means of science teaching.

Suggestions

Suggestions on the basis of the Findings of the Current Study

As a result of the study, it was found that both before and after the application of socioscientific issue-based instructional activities, majority of the pre-service teachers were of the opinion that nuclear

power plants should not be established in Turkey. Moreover, the pre-service teachers who were undecided before the application were able to reach a decision position after the application. In light of these findings, it can be argued that the socioscientific issue-based instructional activities were effective in the pre-service teachers' making clearer and more conscious decisions because they shifted from an undecided position to a decided position. Furthermore, both before and after the application, majority of the pre-service teachers did not want nuclear power plants to be established in Turkey. The opinions of the pre-service science teachers who hold the potential of giving direction to the future of the society should be taken into consideration by different social communities such as administrators, politicians, non-governmental organizations.

In the current study, the types of informal reasoning the pre-service science teachers were engaged in both before and after the application were also examined and it was found that the pre-service teachers who were of the opinion that the establishment of nuclear power plants should not be continued mostly used the ecologic type of informal reasoning before the application and the social type of informal reasoning after the application; the pre-service teachers who were of the opinion that the establishment of nuclear power plants should be continued mostly utilized the scientific-technologic type of informal reasoning before the application and the economic type of informal reasoning after the application and the pre-service teachers who were undecided about the issue after the application equally benefitted from the ecologic and economic types of informal reasoning. In light of these findings, it can be argued that the socioscientific issue-based instructional activities brought different types of informal reasoning to the fore in the decision-making processes of the pre-service teachers while deciding about the socioscientific issue of nuclear energy. The students who could not reach a decision attached equal importance to the types of informal reasoning they employed. Given that both before and after the application the number of the pre-service teachers deciding that the establishment of nuclear power plants should not be continued, it can be argued that the social type of informal reasoning was employed the most. In this regard, the socioscientific issue-based instructional activities can be suggested for bringing the social considerations to the fore in the decisions taken by students about the establishment of nuclear power plants. The social considerations emphasized in this type of informal reasoning are their harmful effects to human health, the use of nuclear power to dominate the world, the possibility of terrorist attacks and the production of nuclear weapons etc. (Table 2).

As a result of the study, it was found that the number of the types of informal reasoning the pre-service science teachers were engaged in while making their decisions increased. This increase is statistically significant. Thus, it can be argued that the socioscientific issue-based instructional activities make up an approach that can increase the number of the types of informal reasoning used by pre-service teachers. Individuals, the more conscious, utilize the more types of informal reasoning and sensitive decisions they can make.

Suggestions for Further Research

The further research may look into the effect of the socioscientific issue-based instructional approach to be used to teach different socioscientific issues on decision-making and informal reasoning.

The opinions of students from various levels of schooling (elementary, secondary, high school and university) and from different social environments (rural or urban) about the establishment of nuclear power plants can be investigated. Moreover, types of reasoning and decisions of people from different sections of the society living in Mersin Akkuyu district where a nuclear power plant is still being established or in the district determined to be a construction area for a nuclear energy plant in the city of Sinop can be explored by using the socioscientific issue-based instructional activities.

Suggestions for Practitioners

The socioscientific issue-based instructional activities used to address the socioscientific issue of nuclear energy can be used and diversified by teachers working in different educational levels. Within the context of the Course of Special Issues in Chemistry given in the science teacher training program, besides nuclear power plants, other socioscientific issues such as Kyoto Protocol, The United Nations Framework Convention on Climate Change, Greenhouse Effect and Global Warming can be studied by using a similar approach. The socioscientific issue-based instructional approach can be integrated into course contents including socioscientific issues in different disciplines for the training of pre-service teachers.

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