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Examination of Training on Pre-Service Science Teachers' Views on Socio-Scientific Issues and Nature of Science

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Abstract

Science continuously interacts with the social environment. Science develops with social needs, and society develops and changes with scientific advances. These changes and developments may cause dilemmas in society. Thus, the purpose of this study is to investigate the improvements among pre-service science teachers in terms of socio-scientific issues and nature of science after explicit theoretical and practical training. The participants in this case study were 16 voluntary pre-service science teachers. In-depth views of the pre-service science teachers on nature of science and socio-scientific issues were examined with open-ended questions and reflective diaries. After the training, the understanding of the pre-service science teachers for nature of science and socio-scientific issues was improved, and they learned various approaches for teaching nature of science and socio-scientific issues.

Keywords: *socio-scientific issues, nature of science, training, pre-service science teachers*

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Introduction

The main goal of science educators is to train students who are scientifically literate and help them adapt to the rapid development of science and technology. This development is also associated with changing the nature of knowledge and science. In school, science education programs are designed in line with this changing nature. The reason for this is that the main objectives of science education are the development of students' 21st-century skills and training scientifically literate students (McComas et al., 2000; Karışan & Zeidler, 2017; Ma et al., 2021). Additionally, science education has adopted as a goal the resolution of social problems by inquiry. Science continuously interacts with the social environment. This leads us to socio-scientific issues, which have conceptual relationships with science (Abd-El-Khalick et al., 1988; Türkmen et al., 2017; Ke at al., 2021). Science develops with social needs, and society develops and changes with scientific

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developments. These changes and developments may cause dilemmas in society. Complex scientific issues containing dilemmas are defined as socio-scientific issues (Topçu, 2015). Thus, this study investigated the influence of socio-scientific issues and nature of science training on pre-service science teachers' views on socio-scientific issues and nature of science.

Socio-Scientific Issues

Socio-scientific issues are defined as controversial and uncertain issues on which society may have different views and difficulty arriving at a definite decision (Lee & Donnely, 2006; Ke et al., 2021). In other words, socio-scientific issues are issues that often do not result in a clear decision, where the ultimate decision is very difficult to reach, and at the same time, ethical principles and scientific inquiry are present (Lee et al., 2006; Zeidler & Nichols, 2009). The basis of socio-scientific issues involves multiple perspectives (Owens et al., 2021), reasoning, and inquiry, confronting ethical issues, and understanding and explaining scientific process skills with justification (Simonneaux, 2001; Lee et al., 2013). Teaching socio-scientific issues with science education is the ideal method (Friedrichsen et al., 2016). While learning socio-scientific issues, students will make connections between science and social life, and develop inquiry skills, critical and analytical thinking skills, and communication skills (Simonneaux, 2007; Susilawati et al., 2021). Additionally, teaching socio-scientific issues facilitates the teaching of nature of science and its components (Sadler et al., 2004). socio-scientific issues are complicated and include multiple disciplines that students may find difficult to understand.

Nature of Science

Nature of science, which has become one of the basic components of science education, includes knowing and the way of knowing, the meanings that are given to scientific knowledge, and the processes of scientific knowledge and its characteristics (Lederman, 1992; Meichtry, 1993; Brunner et al., 2020). Others have stated that nature of science is meaningful with epistemological support (Abd-El-Khalick et al., 1998; Akgün & Kaya, 2020). Science educators define nature of science as the epistemology of science and science as a way of knowing (Lederman, 1992; Yeh et al., 2019). Although scientists have not adopted a common definition, they do agree on common features. Nature of science is widely defined as the values and beliefs that are inherent to the development of scientific knowledge (Lederman, 2007). The general dimensions of nature of science are: scientific knowledge is (a) tentative, i.e., subject to change; (b) empirically based, i.e., based on observations of the natural world; (c) theory-laden, i.e., subjective; (d) derived in part from human inference, imagination, and creativity, and se) surrounded by social and cultural aspects of society (Abd-El-Khalick et al., 1998; Lederman, 2007; Duc Dat et al., 2023).

Lederman (1992) and Duc Dat et al. (2023) revealed that teachers and pre-service teachers may possess inadequate conceptions of the nature of the scientific endeavor. For example, Lederman (1992) reported that most teachers did not believe in the tentative nature of scientific knowledge, and fewer teachers believed in positivism. Duc Dat et al. (2023) stated that pre-service teachers hold misconceptions about nature of science. They mentioned that students' understanding of "the function of scientific theories and the logic of testing them" (p. 19) was not adequate. Aslan et al. (2009) stated that science teachers possessed insufficient knowledge related to the meaning of science, the nature of observations, the tentativeness of scientific knowledge, the structure of hypotheses, theories, and laws, and the scientific method. Yalvac et al. (2007) also found that pre-service teachers did not have coherent ideas for understanding the differences between hypotheses, laws, and theories. Lederman et al., (2002) argued that teachers should design instruction in line with students' nature of science misconceptions. In order to develop the conception of pre-service science teachers on nature of science and help them become scientifically literate, science curricula in teacher training programs have been revised in many countries, including Turkey.

Cofre et al. (2019) stated that although the understanding of nature of science is important for the development of scientific literacy in students, few studies exist on the understanding and teaching of nature of science. They also proposed that, as Herman (2018) stated, nature of science teaching will require researchers to perform more studies on teaching pre-service teachers in informal learning environments, outside of science classes. Nouri et al., (2021) stated that science educators are still in favor of the requirement of efficient nature of science instruction for pre-service teachers. Thus, this study is vital for determining the characteristics of nature of science instruction.

Socio-Scientific Issues and Nature of Science

Teaching socio-scientific issues and nature of science to pre-service science teachers is important. Researchers have stated that there is a relationship between socio-scientific issues and nature of science, but that this relationship has not been completely clarified (Leung, 2020). For example, some studies reported that there is a relationship between some nature of science aspects and socio-scientific issues (Sadler et al., 2004; Wu and Tsai, 2011), and some others reported a weak relationship (Leung et al., 2015; Khishfe, 2012). Thus, this study will be helpful in filling this gap in the literature. This study investigated both theoretical and practical training processes.

Purpose of the Study and Research Questions

The purpose of this study is to investigate pre-service science teachers' development of an understanding of socio-scientific issues and nature of science after explicit theoretical and practical training. The research questions were:

1. How should nature of science be taught?
2. How should socio-scientific issues be taught?
3. What is the relationship between nature of science and socio-scientific issues?
4. What are the views of pre-service science teachers on nature of science and socio-scientific issues?

Methods

This is a case study (Stake, 2006) that was planned to develop an in-depth understanding of the view of pre-service science teachers on nature of science and socio-scientific issues.

Participants

The participants were 16 (12 females, 4 males) voluntary pre-service science teachers. These participants were in different years of study at different universities in Turkey. These participants would be teaching at elementary schools of grades five to eight. They are training to become teachers of elementary science topics including earth and universe, living things and life, physical events, and matter and change. All of them are enrolled in elementary science education departments. Their mean age was 20. The participants were selected based on their status of having participated in a training program before.

Data Collection

In order to examine the participant's views on nature of science and socio-scientific issues in depth, open-ended questions and reflective diaries were used. Open-ended questions were given both at the beginning and at the end of the training. These questions were:

1. What do you think about science? What comes first to your mind when you hear the word science? Explain.
2. Have you heard of nature of science before? Would you briefly describe?
3. Do you think a science teacher should understand nature of science and its components? Is this helpful for the teacher, in what ways?
4. Please explain the importance of nature of science in terms of science education.
5. What are socio-scientific issues? Have you heard about this before?
6. How are socio-scientific issues related to science?
7. What are the advantages/disadvantages of teaching socio-scientific issues in science education?
8. What are the advantages/disadvantages of teaching nature of science in science education?
9. When you are a teacher, how will you teach nature of science and socio-scientific issues in your classes? Could you briefly describe?

Students wrote reflective diaries each day, and they wrote four diary entries in total. The tasks for each entry were:

1. Explain the importance of socio-scientific issues in science education;
2. Explain the importance of nature of science in science education;
3. Comment on the relationship between socio-scientific issues and nature of science.

Implementation

This was a 5-day training program with a total duration of 40 hours. In the study, the participants were given theoretical and practical training on nature of science and socio-scientific issues. They usually studied as a group. In the training, academics who are experts on these topics were included as the training instructors. These academics had conducted studies on socio-scientific issues and nature of science. The purpose of the training was to develop the views of the participants regarding nature of science and socio-scientific issues. The topics in the training were the definition of socio-scientific issues and their characteristics, the definition of nature of science and its components, the relationship between socio-scientific issues and nature of science, and how these concepts could be taught in classes. Each training class lasted 45 minutes. The participants actively participated in the classes. Each day, they discussed and used different methods and approaches while learning socio-scientific issues and the nature of science. The training steps for the 5-day program were as follows:

Day 1: In the morning, the participants were introduced to each other by drama activities because they were from different universities all around Turkey. Then, pre-test open-ended questions on nature of science and socio-scientific issues were asked. In the afternoon, the participants were introduced to the concept of socio-scientific issues, followed by argumentation regarding socio-scientific issues. There were 8 classes on this day.

Day 2: In the morning, the participants were introduced to the concept of nature of science and the family resemblance approach: what nature of science is, its characteristics, the objectives and values of science, and scientific practices and their characteristics. A related activity was carried out. In the afternoon, instructors introduced reasoning in socio-scientific issues and the concept of socio-scientific issues in science. Then, the participants took part in an activity on these socio-scientific issues through group work. There were 9 classes on this day.

Day 3: In the morning, the scientific method and its characteristics and the definition of scientific knowledge and its characteristics were discussed, followed by a related activity. In the afternoon, topics that could be

considered socio-scientific issues were discussed, and a related activity was held. The teacher's role in socio-scientific issues was determined through this activity. There were 8 classes on this day.

Day 4: In the morning, instructors presented scientific explanations and how to teach these explanations, and a related activity was held. In the afternoon, nature of science teaching activities with case stories were conducted. The roles of the teacher and the students, as well as the characteristics of the cases, were discussed. There were 7 classes on this day.

Day 5: In the morning, the use of socio-scientific issues in teaching nature of science and the relationship between nature of science and socio-scientific issues were discussed, followed by a related activity. In the afternoon, the definition of epistemological beliefs and their components, their relationship to the nature of science, and the relationships of socio-scientific issues with epistemological beliefs were discussed, and a related activity was held. There were 8 classes on this day.

The participants worked as a group while performing activities related to these topics.

Data Analysis

The responses of three pre-service science teachers to the open-ended questions and their reflective diaries were examined by the author and a researcher, other than the author. Each rater created codes. The interrater reliability coefficient was calculated as 93%. The remaining responses of the remaining participants were coded by the author.

Results

Results on Reflective Diaries

We examined students' reflective diaries in terms of knowledge, skill, and application to determine the participants' understanding regarding nature of science and socio-scientific issues. The responses of the participants were examined as follows:

- The knowledge includes the terms: I learned, we prepared, we saw.
- The skill includes the terms: My skills developed, this developed … skills.
- The application includes the terms: I will apply this in my future class, this could be applied in science classes.

Importance of Socio-Scientific Issues

Some participant responses were as follows:

> Today, we performed an activity concerning whether the use of antibiotics is useful or harmful. We learned the historical development of socio-scientific issues. [We learned] the 5E model and the socio-scientific issues teaching model. We learned learning and teaching activities. We learned socio-scientific issues and their teaching. (knowledge, P3)

> We saw that socio-scientific issues caused dilemmas due to the lack of clear answers. I saw that these dilemmas could be resolved by our thinking skills. This way, we gain the habit of reasoning and scientific thinking. (skill, P5)

> It makes students look through multiple perspectives and transfers real-life applications to the classroom, and so, students could develop critical thinking skills. For example, in the class, in the bacteria topic, the use of antibiotics could be more deeply examined. (application, P4)

The participants often considered the importance of socio-scientific issues from a knowledge perspective. However, there were some participants who stated that socio-scientific issues cause skill development in students and themselves and mentioned the application of socio-scientific issues in science classes. The responses of the participants in the reflective diaries on socio-scientific issues are given in Table 1.

Table 1. *Responses of Participants in the Reflective Diaries on Socio-Scientific Issues*

	Day 1		Day 2		Day 3		Day 4	
	N	%	N	%	N	%	N	%
Knowledge	9	**56**	4	25	10	**63**	9	**56**
Skill	4	25	11	**69**	4	25	2	13
Application	3	19	1	6	2	12	5	**31**

Importance of Nature of Science in Science Education

Some responses of the participants were as follows:

> We learned what the benzene ring is, how it is used. We reinforced ou[r] knowledge of the method in the activity we held. (knowledge, P13)
>
> The purpose of science education is not to transfer scientific knowledge and principles to students but to help the development of inquiry and reasoning skills using scientific knowledge with experiments and observations. (skill, P14)
>
> In science education, we can design the materials that will enable students to learn the values so that the students could reach the objectives of the course. (application, P16)

The participants explained the importance of nature of science in science education from a knowledge perspective on the first day. However, on the following days, they explained it as that nature of science causes skill development and mentioned applications of nature of science in science classes. Table 2 presents the distribution of the responses of the participants in the reflective diaries.

Table 2. *Responses of Participants in the Reflective Diaries on Nature of Science*

	Day 1		Day 2		Day 3		Day 4	
	N	%	N	%	N	%	N	%
Knowledge	15	**94**	5	31	4	25	5	31
Skill	1	6	6	**38**	4	25	6	**38**
Application	0	0	5	31	8	**50**	5	31

Relationship Between Socio-Scientific Issues and the Nature of Science

After the second day, the participants stated that there is a relationship between socio-scientific issues and nature of science. Most of them explained this as socio-scientific issues include scientific knowledge, the nature of science is a piece of scientific knowledge, and the characteristics of these two concepts are related.

Some participants (two) stated that these two concepts are related to the family resemblance approach. Some (three) stated that their scientific method steps are common. Some (four) stated that their reasoning is

common. Table 3 shows the responses of the participants on the relationship between the nature of science and socio-scientific issues.

Table 3. *Responses of Participants in the Reflective Diaries on the Relationship Between Socio-Scientific Issues and Nature of Science*

	Day 1		Day 2		Day 3		Day 4	
	N	%	N	%	N	%	N	%
No answer	10	**63**	0	0	0	0	0	0
Knowledge	5	31	16	**100**	16	**100**	16	**100**
Skill	1	6	0	0	0	0	0	0

Views of Pre-Service Science Teachers on the 5-Day Training Program

The responses of the participants on the 5-day training program were examined in terms of knowledge, skill, and application.

Some responses of the participants were as follows:

> I learned that science emerged with curiosity, Lederman's nature of science model, the implicit approach and the open reflective method for nature of science teaching, and use of socio-scientific issues in relation to nature of science. (knowledge, P4)

> We performed group work on antibiotic usage in animals. We conducted a literature review, made inferences, and this is helpful for the development of our communication skills. (skill, P5)

> Well, how can I use it and how can I explain it in the lesson? First of all, I talk about science. In the engage step, which is the first step of the 5E method, I start with a remarkable presentation, video, or newspaper article on socio-scientific issues. Then I talk about social interactions in the explore, explain, and elaborate steps. I create an environment where the students can actively participate in scientific ideas. In the evaluation part, I ask the students to prepare a poster. I determine a topic and prepare a poster according to the thesis they accept. (application, P7)

The participants explained their views on the 5-day training program from a knowledge perspective. However, there were also those who mentioned them from a skill and application perspective. Table 4 shows the responses of the participants in the reflective diaries on the 5-day training.

Table 4. *Responses of Participants in the Reflective Diaries on the 5-Day Training*

	Day 1		Day 2		Day 3		Day 4	
	N	%	N	%	N	%	N	%
Knowledge	12	**75**	11	**69**	15	**94**	16	**100**
Skill	3	19	2	12	0	0	0	0
Application	1	6	3	19	1	6	0	0

Results of Open-Ended Questions

The responses of the participants to the pre-test and post-test open-ended questions were examined in terms of the characteristics of socio-scientific issues, examples of socio-scientific issues, students' thinking skills when they learn about the nature of science, students' thinking skills when they learn socio-scientific issues, nature of science misconceptions, dimensions of nature of science, pre-service science teachers' understanding of nature of science, teaching ways of socio-scientific issues and nature of science, teaching ways of socio-scientific issues, and teaching ways of nature of science.

The Characteristics of Socio-Scientific Issues

According to the participants, socio-scientific issues include characteristics that cause dilemmas in society, cause ethical debates, and do not have definite correct answers.

> Socio-scientific issues are issues that cause dilemmas in society and controversy due to different perspectives and ethical issues, and they there is no clear consensus on them. (pre-test, P4)
>
> According to the participants, socio-scientific issues cause dilemmas in society, they deal with social life and science, they do not have definite correct answers, and their discussion takes place on social media.
>
> Socio-scientific issues are a concept that includes both science and society. For something to be socio-scientific, it must deal with both society and the environment, and it must also deal with scientific knowledge that has a background. socio-scientific issues are issues that are controversial and uncertain, and dilemmas that take place on social media. (post-test, P13)

In the pre-test, the participants stated the characteristics of socio-scientific issues mostly in relation to social life and science. In the post-test, in addition to this, they mentioned that socio-scientific issues cause dilemmas in society and that they are open-ended. The responses of the participants on the characteristics of socio-scientific issues are given in Table 5.

Table 5. *Responses of Participants on the Characteristics of Socio-Scientific Issues*

The characteristics of SSI	Pre-test N	Post-test N
They cause dilemmas in society.	3	14
They cause ethical discussions.	1	0
They do not have definite correct answers (open-ended).	2	10
They deal with social life and science.	10	12
Their discussion takes place on social media.	0	1

Examples of Socio-Scientific Issues

In the pre-test, the responses of the participants on examples of socio-scientific issues were generally those stated in textbooks. In the post-test, they stated examples of socio-scientific issues that the instructors used in their activities in the training program.

> I can define them as topics that are open to discussion and attract different views. Nuclear power plants, cloning, genetically modifies organisms, gene therapy, etc. come to my mind. (pre-test, P15)
>
> [Some] socio-scientific issues are nuclear power plants, global warming, hydroelectric power plants, vaccines, pesticides in agriculture and drug use in animal husbandry, organ donation. (post-test, P8)

At the end of the training program, the participants mentioned various examples related to socio-scientific issues. The responses of the participants on examples of socio-scientific issues are given in Table 6.

Table 6. *Responses of Participants on Examples of Socio-Scientific Issues*

Example	Pre-test (N)	Post-test (N)
Global warming	1	6
Nuclear power plants	3	5
Organ donation	1	2
GMO	3	4
Natural disasters	1	0
Environmental pollution	1	0
Cloning	2	0
Gene therapy	1	0
Hydroelectric power plants	1	1
Wearing/not wearing a mask	1	0
Vaccination/COVID-19	0	3
Space technologies	0	1
Drones	0	1
Stem cell therapy	0	1
Drug use in agriculture and animal husbandry	0	1

What Thinking Skills Do Students Develop When They Learn about Nature of Science?

In the pre-test, the participants stated that learning nature of science mostly improves students' critical thinking skills. In the post-test, in addition to critical thinking skills, they stated that this learning improves students' reasoning and creativity skills.

> Because when students learn about nature of science, they will gain a new perspective, and they will be able to build new experiences and knowledge in their daily and academic lives based on data, supported by justifications, and based on well-founded ideas. (pre-test, P15; This is an example of argumentation skills.)

> The teacher, who has mastered these components, develops students' imagination, creativity, and different ways of thinking. They raise individuals who are open to questioning, can adapt to changes, and make inferences. (post-test, P1; This is an example of creative thinking, critical thinking, and reasoning skills.)

The responses of the participants on the thinking skills students develop when they learn nature of science are given in Table 7.

Table 7. *Responses of Participants on the Thinking Skills Students Develop When They Learn Nature of Science*

Thinking skills	Pre-test (N)	Post-test (N)
Critical thinking	4	6
Analytical thinking	1	1
Creativity	1	2

Argumentation	1	0
Reasoning	0	3

What Thinking Skills Do Students Develop When They Learn Socio-Scientific Issues?

In the pre-test, the participants did not write anything about which thinking skills students would develop on socio-scientific issues. However, in the post-test, the majority stated that socio-scientific issues develop critical thinking skills.

> When students learn socio-scientific issues in science education, they develop reasoning skills, base their preferences on scientific sources and data, develop decision-making skills, and acquire analysis skills. This concept enables students to question their actions in depth for their future lives. They interpret the information they have learned in a cause-effect relationship. (post-test, P4; This is an example of analytical thinking and argumentation.)

The responses of the participants on the thinking skills students develop when they learn socio-scientific issues are given in Table 8.

Table 8. *Responses of Participants on the Thinking Skills Students Develop When They Learn Socio-Scientific Issues*

Thinking skills	Pre-test (N)	Post-test (N)
Critical thinking	0	12
Analytical thinking	0	1
Creativity	0	2
Argumentation	0	3
Reasoning	0	1

Nature of Science Misconceptions

In the pre-test, two participants had misconceptions about nature of science. In the post-test, they did not report misconceptions.

> Science: I think science is everything that is objectified. Science is a collection of knowledge that has been researched by high-level people and turned into an objective phenomenon. (pre-test, P16)

The responses of the participants on nature of science misconceptions are given in Table 9.

Table 9. *Responses of Participants on the Nature of Science Misconceptions*

Misconceptions	Pre-test (N)	Post-test (N)
The emergence of proven information is science.	1	0
Science is everything objectified. Science is a collection of knowledge made into an objective phenomenon.	1	0

Dimensions of the Nature of Science

In the pre-test, the participants did not mention nature of science dimensions, but in the post-test, they mentioned some nature of science dimensions. Nevertheless, they mostly stated that scientific knowledge is phenomenological.

> It argues that scientific knowledge consists of uncertain and changeable processes and that it is acquired not only by experiments but also by observation and thinking. (post-test, P6; It is an example based on the view that scientific knowledge is open to change, and it is phenomenological.)

The responses of the participants on nature of science dimensions are given in Table 10.

Table 10. *Responses of Participants on Nature of Science Dimensions*

Nature of science dimensions	Pre-test (*N*)	Post-test (*N*)
Scientific knowledge is open to change.	0	4
Scientific knowledge involves subjectivity.	0	3
Science and culture interact with each other.	0	1
Scientific knowledge is phenomenological	0	8

Pre-Service Science Teachers' Understanding of Nature of Science

While only some participants described nature of science in the pre-test, most of them described it in the post-test.

> What nature of science reminds me of is the mixing of science with nature. For example, the production of GMO plants is a product of this. (pre-test, F5) This is an example of the relationship between science and nature.

> It is the sum of answers to questions such as what science is, how it works, how scientists organize their scientific research, how scientific knowledge emerges and develops, and what factors are affected by it. (post-test, F3; This is an example of what science is, how it works, how scientists work.)

The participants' responses regarding their understanding of nature of science are given in Table 11.

Table 11. *The Participants' Understanding of Nature of Science*

	Pre-test (N)	Post-test (N)
What is science? How does it work?	1	7
How has scientific knowledge developed in history?	2	6
How do scientists work?	1	3
It is the relationship between science and nature.	2	0

How Do You Teach Socio-Scientific Issues and Nature of Science?

In the pre-test, the participants wrote their teaching preferences for both nature of science and socio-scientific issues in general. On the other hand, in the post-test, they proposed separate models/methods and techniques for socio-scientific issues and nature of science.

> I want them to learn by doing and applying in the laboratory. I want them to learn the plants by seeing and touching the soil, by taking them out to nature. (pre-test, P5; This is an example of doing experiments and the constructivist approach.)

The responses of the participants regarding their teaching preferences for socio-scientific issues and nature of science are given in Table 12.

Table 12. *Responses of Participants on Their Teaching Preferences for Socio-Scientific Issues and the Nature of Science*

	Pre-test (N)
Conventional approach (lecturing, timeline, writing)	7
Experimentation	2
Conceptual change texts	2
Discussion	5
Constructivist approach	2
No idea	3

How Do You Teach Socio-Scientific Issues?

The participants mostly stated that they would prefer the 5E Model while teaching socio-scientific issues.

> When I become a teacher, I use the 5E teaching method, family resemblance approach, benzene ring analogy, Brandon's matrix according to the topic of socio-scientific issues. (post-test, P11)

The responses of the participants regarding their teaching preferences for socio-scientific issues are given in Table 13.

Table 13. *Responses of Participants on Their Teaching Preferences for Socio-Scientific Issues*

Model/Method/Technique	Post-test (N)
5E Model	7
Argumentation	3
Discussion	5
Six Thinking Hats technique	1
Experimentation	1
Benzene ring analogy	2
Family resemblance approach	1
Brandon's matrix	1
Other	2

How Do You Teach Nature of Science?

> I use the 5E learning model, I have posters prepared, and provide student-centered interaction by making use of teaching principles and methods. (Pre-test, F4)

Participants mostly preferred the 5E model while teaching nature of science. The responses of the participants regarding their teaching preferences for nature of science are given in Table 14.

Table 14. *Responses of Participants on Their Teaching Preferences for Nature of Science*

Model/Method/Technique	Post-test (N)
5E Model	5
Open reflective method	1
Experimentation	1
Family resemblance approach	1
Benzene ring analogy	1
Brandon's matrix	1
Other	3

Discussion and Conclusion

This study investigated developments in pre-service science teachers' nature of science and socio-scientific issues understanding with a 5-day practical and theoretical training program on nature of science and socio-scientific issues. After the training, the participants' understanding of nature of science and socio-scientific issues was improved, and they learned various teaching approaches for teaching nature of science and socio-scientific issues. The reason for this could be that in the training, the participants got involved in both theoretical and practical work. They worked in groups and discussed the issues with each other. As in this study, Leung (2020) found that with a socio-scientific issues intervention program, undergraduate students developed an understanding of nature of science and evaluated socio-scientific issues from multiple perspectives.

In this study, with the socio-scientific issues and nature of science training, the participants explained the importance of socio-scientific issues mostly in terms of knowledge, but they explained nature of science in terms of skill and application. They described the relationship between socio-scientific issues and nature of science in terms of knowledge, and they mostly explained this perspective by considering that socio-scientific issues include scientific knowledge, and nature of science is a piece of scientific knowledge and related to the properties of scientific knowledge. With the training on nature of science and socio-scientific issues, the participants of this study showed that they developed their nature of science and socio-scientific issues knowledge. After the training, most participants stated multiple characteristics of socio-scientific issues such as that socio-scientific issues cause dilemmas in society, they do not have a consensus on correct answers, and they deal with social life and science. Furthermore, before the training, most participants gave socio-scientific issues examples presented in textbooks, but after the training, they gave examples discussed in the training. This result was also supported by the findings of Kinskey & Zeidler (2021) and Loughran (2007), who stated that pre-service elementary school teachers mostly rely on textbooks. After the training, most participants in this study reported that socio-scientific issues develop critical thinking, argumentation, creativity, reasoning, and analytical thinking skills. This result was similar to the results reported by Kinskey and Zeidler (2021), who reported that with pedagogy and practice, pre-service teachers developed their skills.

In this study, at the beginning of the 40-hour (5-day) training program, the participants had some misconceptions about the characteristics of nature of science. However, after the training, they resolved these misconceptions. As in Kutluca and Aydın (2017), participants in this study improved their nature of science-related understanding. At the beginning of the training, some participants had misconceptions about nature of science. For example, they stated that science includes proven information, and science is a collection of

objective phenomena. These results were similar to those reported by Mesci and Schwartz (2017) and Cofre et al. (2019), who stated that the tentative and subjective nature of knowledge could make learning more difficult than some other aspects of nature of science do. Nevertheless, after the training in this study, these misconceptions were eliminated, and no misconceptions were observed. This result was in agreement with those reported in the studies conducted by Mesci (2020), Bilican (2018), and Bell et al. (2011).

At the beginning of the training, the participants of this study did not mention any nature of science dimensions or aspects, but after the training, they mentioned some nature of science dimensions. Following the training, most participants had developed an understanding of nature of science. They defined nature of science as what science is, how it works, how scientific knowledge has developed in history, and how scientists work. This result was compatible with the result reported by Mesci (2020). Mesci (2020), Clough (2018), and Lederman and Lederman (2014) stated that it is important to investigate learning environments for an in-depth understanding of the nature of science, and this study, including a 5-day theoretical and practical training program, improved the understanding of pre-service science teachers regarding nature of science.

While most of the participants of this study stated that they would teach socio-scientific issues and nature of science with the conventional approach at the beginning of the training, some reported that they would use methods such as discussion, experimentation, conceptual change texts, and experimentation. On the other hand, some participants said they did not have an idea regarding this issue. These teaching approaches and methods are generally taught in methods courses (Herman et al., 2013; Nouri et al., 2021). In this study, after the training, the participants proposed different teaching methods or approaches for socio-scientific issues and the nature of science. For example, most preferred the 5E learning cycle model for teaching socio-scientific issues. The participants also preferred methods such as discussion, argumentation, benzene ring analogy, family resemblance approach, and Brandon's matrix. Moreover, most participants preferred the 5E learning cycle model for teaching the nature of science. Others preferred the open reflective method, experimentation, the family resemblance approach, the benzene ring analogy, and Brandon's matrix. The results of this study showed that, as stated by Cofré et al. (2019), Nouri et al., (2021), and Kruse et al., (2022), explicit nature of science and socio-scientific issues instruction is effective for the development of an understanding of nature of science and socio-scientific issues among pre-service science teachers.

Implications for Theory and Practice

The findings of this study have implications for educators who train science teachers. For example, explicit nature of science and socio-scientific issues instruction is important for the development of pre-service teachers' views on nature of science and socio-scientific issues. The length of the explicit nature of science and socio-scientific issues training program could be extended, and adding information about conducting quantitative studies could be very useful. In this study, it was concluded that the explicit 5-day theoretical and practical training program improved the pre-service science teachers' understanding of nature of science and socio-scientific issues.

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