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ARTICLE

Changes in Pre-service Science Teachers' Understandings After Being Involved in Explicit Nature of Science and Socioscientific Argumentation Processes

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Abstract The study explored the changes in pre-service science teachers' understanding of the nature of science and their opinions about the nature of science, science teaching and argumentation after their participation in explicit nature of science (NOS) and socioscientific argumentation processes. The participants were 56 third-grade pre-service science teachers studying in a state university in Turkey. The treatment group comprised 27 participants, and there were 29 participants in the comparison group. The comparison group participants were involved in a student-centred science-teaching process, and the participants of the treatment group were involved in explicit NOS and socioscientific argumentation processes. In the study, which lasted a total of 11 weeks, a NOS-as-argumentation questionnaire was administered to all the participants to determine their understanding of NOS at the beginning and end of the data collection process, and six random participants of the treatment group participated in semi-structured interview questions in order to further understand their views regarding NOS, science teaching and argumentation. Qualitative and quantitative data analysis revealed that the explicit NOS and socioscientific argumentation processes had a significant effect on pre-service science teachers' NOS understandings. Furthermore, NOS, argumentation and science teaching views of the participants in the treatment group showed a positive change. The results of this study are discussed in light of the related literature, and suggestions are

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made within the context of contribution to science-teaching literature, improvement of education quality and education of pre-service teachers.

1 Introduction

Recently, as a result of the development of science and technology, some social dilemmas related to science-technology-society, particularly global warming, genetic engineering practices, and nuclear power plants, have become discussion topics of interest among science teachers and researchers. Within this context, the major role of a science teacher is to prepare students for a rapidly changing world and assist them in becoming scientifically literate citizens (NRC 2013). As a result, the nature of science (NOS) (Lederman 2007), socioscientific issues (SSI) (Herman 2015) and argumentation processes (Erduran et al. 2004) are emphasised as the basic components of science literacy. According to the commonly held definition, science literacy is about people being able to reason, make decisions, and solve problems they encounter in their daily lives using science, and place science, with all its aspects, at the centre of their lives (Roberts 2007). Roberts (2007) stated that science literacy was envisioned in two ways. For vision I, it was claimed that science itself was related to the products and processes of scientific institutions. This vision consists of three concepts: basic scientific terms, NOS, and scientific ethics. Vision II is related to the potential science literacy profiles of future science students, which, according to the author, broadly involves (1) the interaction between science and society, (2) the interaction between science and humans and (3) the interaction between science and technology. According to Roberts (2007), these three issues reveal that NOS, argumentation and socioscientific issues are epistemologically oriented. Most of the researchers who support this claim believe that teachers are responsible for society using these processes as instruments (e.g. Simon et al. 2006; Dawson and Venville 2010). Using this claim as a starting point, this study involved pre-service science teachers (PSTs) in an education process comprising socioscientific issues, argumentation and NOS components.

1.1 Argumentation in Science Education

In science education, argumentation can be defined as the participation of students in the knowledge-structuring process (Ford 2008). However, Berland and Reiser (2011) defined argumentation as a social practice, in which individuals are actively involved because of its nature, attribute meaning to a fact, evaluate their asserted claims through discourse and oppose each other's claims, thus criticising each other. Numerous scientific education researchers have stated that students should be more involved in the process of argumentation, in order for them to have a high level of science literacy (e.g. von Aufschnaiter et al. 2008; Sampson and Clark 2009). These researchers claimed that in this way, students will not only have the opportunity to acquire scientific knowledge but will also learn the epistemology of science, scientific practices and methods, and acquire an understanding of NOS as a social practice (e.g. Tavares et al. 2010; Ryu and Sandoval 2012).

1.2 The Teacher's Role

In traditional science education, students either listen to their teachers' lectures about science-making processes or scientific research results, or follow step-by-step instructions during laboratory activities. In contrast, in the student-centred education process, which relies on constructivist learning theory, students construct knowledge through social understanding and have the responsibility of learning. This theory redefines the roles of teachers and students (Borich 2013); student-centred teaching relies on three core principles:

- Cognitive contradictions or confusion are the stimulus for learning (*question-answer*)
- Knowledge expands through discussion (*collaborative learning groups*)
- Comprehension occurs as a result of the individual's interaction with the environment (*brainstorming*)

For the effectiveness of the process that consists of processes related to the above principles, the role of the teacher has an undeniable importance. However, including argumentation into science classes requires not only a change of the intended learning objectives, but also new and different roles for teachers (McNeill and Knight 2013). Science education was justified more and more on the basis of its relevance to contemporary life and its contribution to a shared understanding of the world on the part of all members of society (DeBoer 2000). According to the contemporary science-teaching approach, an ideal science teacher should take on two roles (Kind et al. 2011). First, a science teacher should support students in being involved in discussions in which they can present their ideas in a critical manner (Simon et al. 2006). Second, a science teacher should be a good role model for students in the argumentation process. Jiménez-Aleixandre and Erduran (2008) described such a person as being a skilled colleague who appropriately uses scientific epistemic criteria qualitatively and persuades students to use them equally well. Zembal-Saul (2009) claimed that including teachers in the process of argumentation not only improves their ability to use argumentation, but also enables them to test their pedagogic skills using the argumentation process. According to this researcher, in-service and pre-service teachers who actively participate in argumentation and learn how to teach this process will have different points of view on issues such as the epistemology of science, verifiability, and the social and cultural dimensions of scientific knowledge. Zeidler and Nichols (2009) stated that for those teachers who want to achieve a high-quality science teaching, their main responsibility is to encourage students' participation in the process of learning, which involves NOS and socioscientific issues, and to prepare a suitable learning environment for the students in consideration with their individual epistemological levels. Therefore, if PSTs have the opportunity to engage in argumentation-related activities during their own education, they will be able to use those activities during their teaching career and encourage students to engage in those kinds of processes (Zembal-Saul 2009).

1.3 NOS and Epistemological Beliefs

Helping students understand NOS is an issue emphasised by all science education programmes that accept scientific literacy as a basic component (e.g. AAAS 2001; NRC 2013; ACARA 2014). While in general, the term NOS (Lederman 2007) refers to the characteristic features and assumptions of scientific knowledge, scientific epistemological beliefs represent beliefs about NOS knowledge (Hofer and Pintrich 1997). Although NOS and scientific epistemological beliefs share some aspects about the nature of scientific knowledge, they also have fundamental differences. For example, while NOS focuses on social and cultural aspects of scientific knowledge, scientific epistemological beliefs concern the justification of scientific knowledge. However, Lederman (2007) claimed that

NOS was one of the components of scientific epistemological beliefs and that it included beliefs about NOS. For this reason, NOS can also be accepted as a part of these beliefs.

Science education researchers have been focusing on the evaluation of students' NOS understanding for over 50 years (e.g. Abd-El-Khalick and Lederman 2000; Abd-El-Khalick 2005). In his research, undertaken to investigate studies conducted about NOS in the last 50 years, Lederman (2007) determined that although these studies had been conducted at different times by different researchers and using different data collection tools, both teachers and students shared a single common point of naive NOS understanding. For this reason, many researchers who support NOS teaching as a useful tool to support students' cognitive development have argued that NOS teaching performed within the context of an explicit approach would be more effective than an implicit approach in terms of improving NOS understanding of individuals (e.g. Abd-El-Khalick et al. 2008; McDonald 2010).

1.4 Socioscientific Issues

It has been shown by many science education researchers that socioscientific issues related to topics such as cloning, stem cells, genome projects, global warming and alternative energy sources would create rich learning contexts for science teaching (e.g. Zeidler and Sadler 2008; Sadler 2009). The inclusion of socioscientific issues in science classes is based on a theoretical framework that draws on the fields of developmental psychology, sociology and philosophy. These subjects also make it easy to engage in argumentation by interrelating cultural and ethical topics. Briefly, socioscientific issues present opportunities for students to assess claims, analyse evidence and assess the multiple perspectives of scientific issues via social interaction and discourse (Zeidler 2014). These opportunities remind us that arguments stated in relation to socioscientific issues have changeable, creative, evidence-based, culture-integrated characteristics that proceed in parallel with the ways of NOS. According to Zeidler (2014), socioscientific issues are tools that support learning outcomes, and as a significant component of science literacy, this is an important area of science education that enables students to learn science by integrating it into their own lives. Within this context, including socioscientific issues in science education is significant for areas such as NOS, epistemology, character education, and scientific literacy (e.g. Lee et al. 2012; Lee et al. 2013). The socioscientific context has an important role in encouraging students to become science-literate individuals, and together with argumentation and NOS, it possesses the following three characteristics of socioscientific issues found in the literature: (1) provides a qualified science-learning context which contains complex social matters involving ethical concerns, (2) offers opportunities to analyse different perspectives of real-world subjects' scientific and social aspects and (3) promotes individuals' science-content understanding and reveals the individual and social repercussions of the belief-based field of knowledge (Zeidler et al. 2009). According to Herman (2015), two significant reasons reveal the importance of the context of socioscientific issues and NOS for educating individuals with scientific literacy. First and foremost is that epistemological characteristics and methodological approaches have the feature of changing scientific ideas and thoughts during the process of decision-making. The second reason is that students rely on their beliefs and epistemological sources more than scientific sources (Herman 2015). Thus, socioscientific issues were used in this study because they offer rich learning environments for argumentation and NOS.

1.5 Socioscientific Argumentation and NOS

To create quality arguments and make effective decisions, students need to possess basic knowledge about the context and about how scientists evaluate claims (Sadler 2004, 2009). For this reason, research aiming at investigating the relationship between argumentation and NOS or epistemological beliefs within the context of socioscientific issues is increasing (e.g. Khishfe 2012a; Cook and Buck 2013). However, there is no unity in the findings presented by researchers investigating the dynamics of these variables. For example, some researchers have claimed that it was inevitable for individuals to change their NOS understanding when they were involved in a socioscientific argumentation processes (e.g. Sadler et al. 2004; Zeidler et al. 2002). This claim means that an individual's understanding of the epistemology of science will affect his/her level of reference to content knowledge. In other words, NOS conceptualisations affect how a person will interpret content knowledge, and this finding shows that NOS implicitly affects the quality of socioscientific argumentation, as numerous studies have shown (Sadler 2004). On the other hand, some researchers claim that NOS understanding does not have significance in the socioscientific decision-making process; rather, individual values and cultural/ethical and social relation factors should be taken into consideration (e.g. Bell and Lederman 2003; Walker and Zeidler 2007).

As stated above, many studies have been conducted with different education levels and various research designs to investigate the relation between socioscientific argumentation and NOS (e.g. Khishfe 2012a, b, c, 2014; Herman 2015). However, there have been only a few studies dealing with the effects of the socioscientific process on NOS or epistemological beliefs. For example, McDonald (2010) involved 17 pre-service teachers in NOS and socioscientific argumentation processes based on the idea that this involvement would help them develop their NOS understandings. The researcher explored the effects of explicit NOS and socioscientific argumentation processes on NOS understanding by administering the Views of Nature of Science questionnaire (VNOS Form C) to five purposefully chosen pre-service teachers both at the beginning and at the end of the process. The results of this qualitative research indicated that the explicit NOS and socioscientific argumentation processes can improve NOS understanding. The study conducted by Cook and Buck (2013) investigated the effects of the socioscientific process on NOS understanding of 24 PSTs. At the end of the study, the researchers found that NOS understandings of the participants had shown a positive change after the socioscientific argumentation processes. The study conducted by Schalk (2012) with 26 university students at various education levels aimed to identify the benefits of a socioscientific argumentation-based education for students' understandings of NOS. The findings of that study evaluated by inductive content analysis of qualitative data indicated that the socioscientific argumentation processes can improve the formal epistemological knowledge of students. Khishfe (2014) investigated the effects of explicit NOS and argumentation teaching, conducted within the context of a socioscientific issue, on NOS understanding and argumentation skills of 121 seventh-grade students. She reported that NOS understanding of the participants who participated in the explicit NOS and argumentation process had improved more than those the other students. Apart from the studies mentioned here, similar results have been obtained from studies, which aimed to investigate the effects of the socioscientific process on the understanding of NOS, conducted with pre-service teachers (Matkins and Bell 2007; Bell et al., 2011; İşbilir et al. 2014) and high school students (Khishfe and Lederman 2006; Eastwood et al. 2012).

1.6 Rationale and Aim of the Study

Understanding an idea in science is directly related to argument-formation skills along with possessing a conceptual and epistemic aspect (Ford and Wargo 2012). Students need to be aware of the context of the encountered problem and to understand how scientists evaluate knowledge claims in order to develop qualified reasoning on socioscientific issues and produce effective judgements (Zeidler 2014). In addition, a person who is aware of the characteristics of scientific knowledge is able to become a qualified decision maker and possesses the qualifications to be an active and affective participant in society (e.g. Lee et al. 2012; Lee et al. 2013). Thus, to improve science literacy, teachers should involve their students in argumentation processes enriched with socioscientific issues and different aspects of NOS (e.g. *tentativeness*, *subjectivity*, *theory and law*, *observation and inference*, *social*, *and cultural embeddedness*) (Karisan and Zeidler 2017). Thus, when the importance of socioscientific argumentation and NOS for scientific literacy in science education is considered, many researchers have emphasised that students must be directly involved in learning situations in which they can present their NOS understanding and socioscientific argumentation skills (e.g. McDonald 2010; Eastwood et al. 2012; Khishfe 2014). However, as stated above, to date, there have been very few research studies pertaining to this issue. As for the research undertaken, none have investigated the changes in pre-service teachers' views. The current research began with the hypothesis that when pre-service teachers take part in activities concerning a socioscientific issue (Zeidler 1997; Zohar 2008), argumentation and NOS, this would make it more likely for them to use such activities in their teaching (Zembal-Saul 2009).

In the present study, we sought answers to the following research questions:

1. Do explicit NOS and socioscientific argumentation processes influence the PSTs' understanding of NOS?
2. How do explicit NOS and socioscientific argumentation processes affect PSTs' views on *NOS*, *science teaching and argumentation*?

2 Method

This study was conducted using an explanatory mixed method (Creswell 2008; Sullivan 2009). In the first phase of this study, quantitative data were collected with the NOS-as-argumentation questionnaire (NSAAQ); in the second phase, qualitative data were collected with semi-structured interviews. The data collection, practice and data analysis processes that were followed for each question are shown in Fig. 1.

2.1 Participants

The participants in this study were 56 third-grade PSTs studying in a science-teaching program of a state university in Turkey. There were two groups: the treatment group with 27 participants (*23 males*, *4 females*) and the comparison group containing 29 participants (*25 males*, *4 females*). This study was conducted in three different classes in the department. The classes of the treatment and comparison groups were decided by the simple random sampling method (Fraenkel and Wallen 2006). To obtain responses to the second research question using semi-

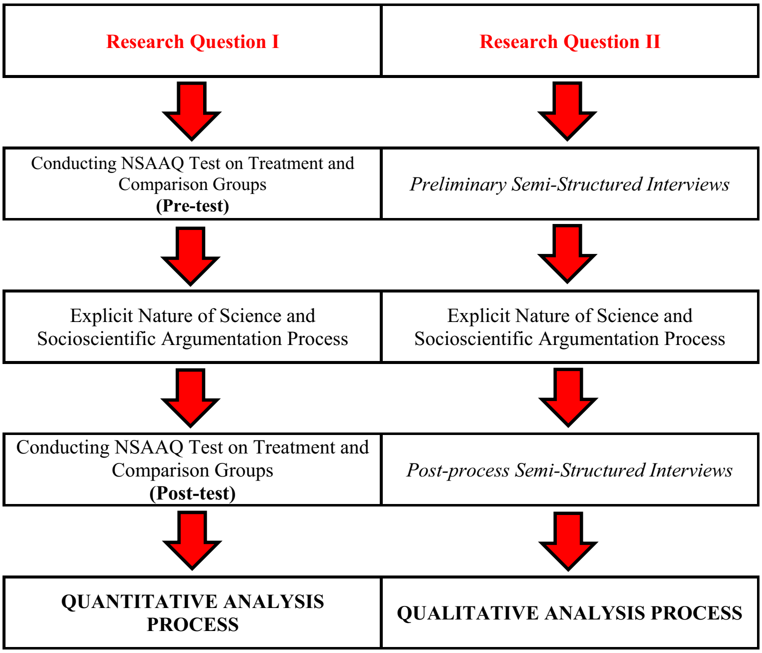

Fig. 1 Overview of the research design

structured interviews, six participants from the treatment group (*25% of the total participant number*) were chosen by the simple random sampling method (Sandelowski 1995).

2.2 Data Collection Tools

In this research, two different data collection tools were used, as detailed below.

2.2.1 The Nature of Science As Argumentation Questionnaire

This test, developed by Sampson and Clark (2006) and translated to Turkish by Cetin et al. (2010), was used to determine participants' understanding of NOS both at the beginning and end of the implementation (Appendix 1). This test was designed to assess an individual's NOS knowledge, the methods they used to generate scientific knowledge, as well as their evaluation of scientific knowledge and of whether science is a socially and culturally embedded practice (Sampson and Clark 2006). During the development of this test, Sampson and Clark (2006) asserted that traditional tests created to define an individual's beliefs on the epistemology of science were either domain-specific (e.g. the Views on Science-Technology-Society) or domain-general (e.g. VNOS), or had been designed only for the evaluation of attitude and beliefs (Views About Sciences Survey). Therefore, Sampson and Clark (2006) needed to develop a quantitative scale to specifically evaluate the role of argumentation in the process of the development of scientific knowledge. As stated in their study, traditional tests developed to define NOS and epistemological beliefs mainly focused outside the scope of NOS; therefore, in this study, the Nature of Science As Argumentation Questionnaire (NSAAQ), which is more appropriate for the nature of argumentation, was used. The Turkish version of the test includes

26 items and a five-point Likert-type scale with a Cronbach's Alpha reliability coefficient of 0.68, calculated in a pilot study with 447 students. For the reliability coefficient of the NSAAQ used in this study, a pilot study was conducted with 254 third-grade PSTs in five different universities, and Cronbach's Alpha was calculated as 0.79. This value indicates that the test has sufficient reliability (Fraenkel and Wallen 2006).

2.2.2 Semi-structured Interview Questions

The semi-structured interview questions, composed of two sets of questions prepared by Sadler (2006), were posed to six participants of the treatment group before and after the implementation. Two experts who specialised in argumentation and qualitative research were consulted to ensure the internal validity of the questionnaire forms, each consisting of four questions (Creswell 2008). Following this validation, a pilot study was conducted with two different pre-service teachers to clarify the clarity of the questions and the results of this pilot study were evaluated by the experts. The final forms of the question sets were created by taking into account the feedback from the pilot study and expert opinions. The characteristics of the question sets are given in Table 1.

As shown in Table 1, different sets of questions were presented to participants before and after the process. To avoid leading the participants or interfering with the teaching process, and to clearly identify the conceptualisations related to argumentation, NOS and science education, the pre-process questions were formulated in a more general manner, and the post-process questions were formulated in a more specific manner. Thus, the two question sets served the same purpose and had the same context, but had different content.

2.3 Procedure

The whole process was carried out over 11 weeks for 2 h each week. All participants were informed about goals of the study before the implementation process. Therefore, all the 56 participants were determined to actively participate in student-centred teaching processes (e.g. *collaborative learning*, *brainstorming*); however, they had not participated in any activities concerning NOS, argumentation or socioscientific issues. The participants of the treatment group were encouraged to discuss their ideas in light of several scenarios. In addition, they were presented with theoretical knowledge about the nature of learning, NOS, argumentation

Table 1 Semi-structured interview topics

	Pre-implementation (question set 1)	Post-implementation (question set 2)
Question 1	Science and its characteristics (NOS)	The impact of the process on opinions about science education (ST)
Question 2	Function of science education (ST)	The relationship between NOS and argumentation (NOS–ARG)
Question 3	The role of argumentation in science (ARG)	Including argumentation in science education environments (ARG–ST)
Question 4	The roles of the teacher and students in science education (ST)	Including NOS in science education environments (NOS–ST)

ARG argumentation, *NOS* nature of science, *ST* science teaching and socioscientific issues. The participants in the comparison group were encouraged to participate in student-centred teaching processes and were presented with superficial theoretical information on NOS and argumentation. The activities of the treatment and comparison groups were performed under the management of the same instructor who had 6 years of experience related to both argumentation and socioscientific issues, and student-centred teaching processes. The instructor encouraged the participants of both groups to express their opinions and to undertake reasoning during the process; however, in order to refrain from deviating from the aim and nature of the study, no data were collected during this process about the reasoning of the participants related to the context of socioscientific issues or the quality or level of their argumentation skills. The implementation-data collection process is comprehensively described in the implementation phases in the sections below.

2.3.1 Weekly Activities

The activity booklets provided to the participants contained three NOS and nine socioscientific argumentation scenarios. Zeidler et al. (2002) stated that the inclusion of scenarios with a socioscientific context, serving the purpose of forming arguments, could be a very beneficial way to reveal the students' understanding of NOS. In accordance with this, the number of scenarios presented in the activity booklet within the context of socioscientific issues was greater than those within the context of NOS. As done in earlier studies, the socioscientific issues used in this study involved factors that encouraged participants to easily apply scientific ideas in the argumentation process when considering informal matters, such as cultural, ethical and social concerns (e.g. Khishfe 2012a; Zeidler et al. 2002). Experts prepared these scenarios using current issues to encourage participants to adopt the scenarios as if they were real. Certain fictional elements and scientific content in relation to the context were used in the scenarios. Three researchers were asked to assess the scenarios in terms of issue context, argumentation, NOS and language adequacy. The scenarios were finalised with these expert opinions. A detailed description of the scenarios used within the data collection process is given in Table 2.

2.3.2 Phase 1 (Week 1)

In the first week of the study, the participants of both the treatment and comparison groups were informed about the implementation process. Then, to determine the pre-implementation views of pre-service teachers about NOS, science teaching and argumentation, semi-structured interviews were conducted with six participants of the treatment group by the first author. Each interview lasted for 12–17 min.

2.3.3 Phase II (Week 2)

In the second week of the study, the NSAAQ (pre-test) was administered to the participants in order to assess their pre-implementation understanding of NOS. In this phase of the implementation, a presentation was delivered concerning the nature of learning and perspectives related to learning to the treatment group participants. In this presentation, the participants were informed about how learning was considered in prominent learning theories, the duties of teachers in a learning environment and the requirements of contemporary science education. In the meantime, the participants of the comparison group were divided into groups of four using

Table 2 Weekly activities

Scenario no	Scenario name	Scenario type	Scenario content	Activity type
1	On Behalf of Environmental Protection	Socioscientific argumentation	Fossil fuels and nuclear power plants and their environmental impacts	Whole-class discussion
2	Science of the 2000s: Biotechnology and Cloning	Socioscientific argumentation	The development of biotechnology and cloning applications in the scientific world	Whole-class discussion
3	Hydroelectric Power Plants	Socioscientific argumentation	Advantages and disadvantages of hydroelectric power plants	Small-group and whole-class discussion
4	Nature and Technology	Socioscientific argumentation	Environmental impacts of biotechnology and genetic engineering applications	Small-group and whole-class discussion
5	Science and its Characteristics	NOS	The social and cultural aspect of NOS	Whole-class discussion
6	The Rats Appeared to be Merciful, not Selfish	NOS	The evaluation and tentativeness of scientific knowledge	Small-group and whole-class discussion
7	Is it Scientific Freedom Limited?	NOS	The values of the scientific method and results	Small-group and whole-class discussion
8	Electric Car Production	Socioscientific argumentation	Energy sources used by electric and petrol cars and their environmental impacts	Small-group and whole-class discussion
9	Smart Phones are Threatening Human Life	Socioscientific argumentation	Benefits and losses of mobile phones	Small-group and whole-class discussion
10	Golden Rice	Socioscientific argumentation	Genetically modified organisms (GMOs)	Small-group and whole-class discussion
11	Biofuel Production	Socioscientific argumentation	Advantages and disadvantages of biofuel production	Small-group and whole-class discussion
12	Scientists Discuss	Socioscientific argumentation	Environmental impacts of nuclear power plants	Small-group and whole-class discussion

the simple random sampling method; thus, the 29 participants were divided into 7 groups. In this phase, each group was asked to devise a lecture in relation to the curriculum for the sixth, seventh and eighth grades. The groups that carried out the teaching process determined that the relevant learning outcomes were not the same between groups. The subject contents of learning outcomes selected by groups are given in below.

- Force and motion (group I) (6th grade)
- Electric energy (group II) (7th grade)
- Force and energy (group III) (7th grade)
- Light and sound (group IV) (6th grade)
- Electricity in our lives (group V) (8th grade)
- Electrical conduction (group VI) (6th grade)
- Reflection and light absorption in the mirror (group VII) (7th grade)

2.3.4 Phase III (Weeks 3 to 6)

In this phase, on the basis of the data obtained from the NSAAQ, implementation groups were formed and announced. Then, participants were given a presentation consisting of basic information about argumentation, and a video containing a sample of socioscientific argumentation was presented. The participants were asked to structure this video according to the Toulmin argument model. The target of this practice was to improve participants' basic argumentation skills by internalising the argumentation components of the model. It was hypothesised that participants would have sufficient argumentation skills for them to become involved in the argumentation process (Kuhn 2010; Zohar and Nemet 2002).

In the fourth and fifth weeks of the study, whole-class discussions were conducted by the researcher between the aforementioned presentations related to the first two scenarios of the activity booklet. The whole-class discussions lasted 20 min on average. This practice was based on the rationale given by Lin and Mintzes (2010) that, in order to improve students' argumentation skills, they should be directly involved in the argumentation process. In addition to the studies conducted by these authors, many other researchers have concluded that the involvement of learners in explicit argumentation processes, in small groups or as a whole class, can help them improve their argumentation skills (e.g. Osborne et al. 2004; von Aufschnaiter et al. 2008). In accordance with this claim, the participants should be included in small-group discussions to provide them with the opportunity to make use of their different cognitive levels in the same pool of knowledge and develop their learning outcomes (Dawson and Venville 2010). Therefore, in the last week of this phase, small-group discussions took place after the whole-class discussions and presentations. In this context, the groups were directed to engage in small-group discussions related to the third and fourth scenarios in the activity booklet. On average, the small-group discussions lasted 10 min. The inclusion of the participants in small group discussions was based on four factors which were considered by Dawson and Venville (2010) to affect argument-formation skills and argumentation quality. These factors are as follows:

- Teachers' roles in coordinating small-group and whole-class discussions,
- Use of written frames to support student ideas,
- Suitability of the context to the argumentation process and class level,

- Enabling students' active participation in the argumentation process.

After the small-group discussions, whole-class discussions were practised with each scenario, in which groups who had opposing or alternative views were encouraged to thoroughly discuss them. In contrast, the participants of the comparison group produced lectures about the learning outcomes that they had learned in the previous phase. From the seven groups, each week two groups created lectures that lasted for a class hour. The aim in this phase was to improve the basic pedagogical skills of the science teachers in the comparison group. The teaching process of a four-person group is given under these headings:

- All four participants took an equal share in the teaching process.
- One participant from the group took the role of the teacher, whereas the others acted as students.
- Every group performed its teaching process in accordance with a lesson plan (Figure 2).
- Each group used constructivist science-teaching methods and techniques during their teaching process.
- After an hour of teaching (40 min), the entire class gave their opinions about the performed methods and techniques.

SAMPLE COURSE PLAN	
Subject Content	Light and Sound
Class	6th grade
Student Outcomes / Goals and Behavior	He/she learns situations that may arise because of interaction with sound waves. He/she makes predictions to prevent the spread of a voice and tests these predictions.
Teaching Strategies	Question-answer Brainstorming Concept mapping Discovery learning approach Experiment
COURSE FLOW	
The teacher begins the lesson with the question "How Does Sound Occur?" The students brainstorm about the question. After the brainstorm, the definition of sound is given. A sample concept map is prepared with the students. In order to better consolidate knowledge about the subject, students are allowed to experiment in groups. The results of each group in the experiment are explained and compared in class. The entire class reaches a collective result.	
Assessment and evaluation	What is sound? Why does sound not emerge in space?

Fig. 2 Sample course plan

2.3.5 Phase IV (Weeks 7 and 8)

In the fourth phase, the small-group and whole-class discussions concerning socioscientific issues were finalised, and the participants moved on to implementations related to NOS. After a short review and evaluation of the previous week, a presentation was delivered concerning NOS and its perspectives. Many researchers who have conducted studies about NOS have argued that teaching NOS explicitly is the best method for all age levels in order to develop an effective understanding of NOS (e.g. Khishfe and Abd-El-Khalick 2002; Schwartz and Lederman 2002). After the small-group discussions, whole-class discussions were practised in relation to the fifth scenario and groups who had opposing or alternative views were encouraged to thoroughly discuss their ideas. Within the second week of this phase, the small-group and whole-class discussions were practised using the sixth and seventh scenarios. In addition, a short presentation containing basic information about argumentation and NOS was delivered to the comparison group; thus, its participants were not deprived of the basic skills that the treatment group participants had received. Then, in the second week of this phase, group presentations about physics special topics were delivered (e.g. *nuclear power plants and superconductivity*). In these presentations, the groups used student-centred learning techniques as in the previous step and prepared the materials for this purpose. In these presentations, the participants gave information about topic content and fields of application.

2.3.6 Phase V (Weeks 9 to 11)

In the last phase of the implementation, activities were finalised with the small-group and whole-class discussions using the last five scenarios in the activity booklet. During this time, the lecture activities of the comparison group were finalised. Then, to determine the post-implementation opinions of pre-service teachers concerning NOS, science teaching and argumentation, semi-structured interviews were conducted with six participants of the treatment group by the first author, as it was undertaken in the first phase. Each interview took 12–17 min. Additionally, in this phase, the NSAAQ was administered to the comparison and treatment groups to assess their post-implementation NOS understanding. Finally, the data collection process ended after a general evaluation of the implementation with the participants.

2.4 Data Analysis

2.4.1 Research Question I

In order to test whether the NSAAQ test scores of the members of the treatment and comparison groups show normal distribution, the Shapiro–Wilk Test was used (because *the number of the participants in both groups was less than 50*). Thereafter, to compare participants' *NSAAQ test* results, paired sample *t* tests and independent sample *t* tests were performed comparing:

- Pre-test scores of treatment and comparison groups' participants,
- Post-test scores of treatment and comparison groups' participants,
- Pre-test and post-test scores of treatment group's participants,
- Pre-test and post-test scores of comparison group's participants were compared.

2.4.2 Research Question II

The data gathered with the semi-structured interviews was analysed with the inductive content analysis method. This method allows concepts behind the data to be revealed together with the relationship among these data using coding (Strauss and Corbin 1990). In the constant comparative method (Glaser and Strauss 1967), the responses given by the participants during the interviews before and after the implementation process were comprehensively analysed and a ‘coding key’ including analytical assessment choices was formed by the authors and academic peers. Both authors were involved in all processes of qualitative data analysis. Before forming the coding key, a general briefing template was developed to determine the evaluation criteria (NOS, argumentation, socioscientific issues, science teaching) of the interview questions used in the question sets, and the responses were placed under definite themes in accordance with the transcription of voice records. Another expert was involved in the formation of the template. That expert also participated in the data analysis process to provide external supervision and peer debriefing. For the process of placing the obtained codes under conceptual themes that best represented these codes, we referred to the related literature. For example, the analysis of the answers to the questions about NOS was undertaken in accordance with science myths (McComas 2002), and the characteristics of science and those related to the questions about science education were analysed in keeping with teacher-centred (Van Driel et al. 2007) and student-centred teaching processes. After reaching a consensus on the method of analysis, four of the 12 forms (*two forms for each process*) that contained the responses to the interview questions were sent to the same researcher, and the analysis of the forms, undertaken at different times and places, were compared. In this way, the required inter-coder reliability for the process was achieved (Lincoln and Guba 1985). As stated by Lombard et al. (2002), this value must be at least 70%, and it was found to be 81% in our study. Additionally, as recommended by Cresswell (2008), a limited part of the analysis made was sent to an outside expert, and his opinion was taken for the purpose of external auditing. After establishing the reliability standard for the coding, the remaining eight forms were analysed, and the process of the determination of coding and themes was completed.

3 Findings

In this section, the findings of the study are presented under two main headings. The first concerns the findings of the quantitative analysis undertaken to determine the change in PSTs’ NOS understanding according to the explicit NOS and socioscientific argumentation processes, and the second presents the findings of the qualitative analysis carried out to determine the change in participants’ perceptions about the NOS and socioscientific argumentation processes.

Table 3 Pre-test scores of the treatment and comparison group participants

	Number	$\overline{X}$	*SD*	df	*t*	*p*
Treatment group	27	84.22	6.25	54	.455	.651
Comparison group	29	83.34	7.99			

$p > .05$

Table 4 Post-test scores of the groups

	Number	$\overline{X}$	*SD*	df	*t*	*p*
Treatment group	27	106.70	12.94	54	8.03	.000
Comparison group	29	84.06	7.62			

$p < .05$

3.1 The Effect of Explicit NOS and Socioscientific Argumentation Processes on NOS Understanding

To determine whether the pre-test and post-test NSAAQ scores obtained from the participants of the treatment and comparison groups showed a normal distribution, a Shapiro–Wilk test was performed. The test results indicated that the data had a normal distribution ($p > .05$) and were suitable for parametric tests.

3.1.1 Comparison of Pre-test Scores Between the Two Groups

To compare the pre-test scores of the treatment and comparison groups that were administered the NSAAQ, an independent sample *t* test was used. The results of this test are given in Table 3.

The data presented in Table 3 revealed that there was no significant difference between the pre-test results of the treatment and comparison groups. This finding indicates that both groups had the same level of NOS understanding before the study process.

3.1.2 Comparison of the Post-test Scores Between the Two Groups

To compare the post-test NSAAQ scores of the treatment and comparison groups, an independent sample *t* test was used. The results of this test are given in Table 4.

According to the data presented in Table 4, there was a significant difference between the post-test results of the two groups. This finding indicates that the explicit NOS and argumentation process is more effective than the student-centred science-teaching process for improving NOS understanding of the participants.

3.1.3 Comparison of the Pre-test and Post-test Scores of the Comparison Group Participants

To compare the pre-test and post-test NSAAQ scores of the participants in the comparison group, a paired sample *t* test was used. Table 5 shows the results of this test.

Table 5 Pre-test and post-test scores of comparison group participants

	Number	$\overline{X}$	*SD*	df	*t*	*p*
Pre-test	29	83.34	7.99	28	− .425	.674
Post-test	29	84.06	7.62			

$p > .05$

Table 6 Pre-test and post-test scores of treatment group participants

	Number	$\overline{X}$	*SD*	df	*t*	*p*
Pre-test	27	84.22	6.25	26	− 7.54	.000
Post-test	27	106.70	12.94			

$p < .05$

The data presented in Table 5 show that there was no significant difference between the pre-test and post-test results of the comparison group. This finding indicates that the student-centred science-teaching process has no significant impact on improving NOS understanding of the participants.

3.1.4 Comparison of Pre-test and Post-test Scores of Participants in the Treatment Group

A paired sample *t* test was used to compare pre-test and post-test scores of treatment group participants, taken from the NSAAQ test. The results of this test are given in Table 6.

The data presented in Table 6 reveal that there was a significant difference between the pre-test and post-test results of the treatment group. This finding indicates that the explicit NOS and socioscientific argumentation processes had a significant impact on improving participants' NOS understandings.

3.2 The Impact of the Explicit NOS and Socioscientific Argumentation Processes on Understanding of Argumentation and NOS

This section presents the inductive content analysis of the answers given by the six pre-school science participants of the treatment group to the semi-structured interview questions performed before and after the implementation. The viewpoints and themes which were obtained after the inductive content analysis are presented in detail in Table 7. The findings related to the characteristics of each question in the pre-implementation and post-implementation question sets are presented under specific sub-headings. Additionally, extracts from participants' responses are provided together with the related question characteristics in order to clarify the results of the analysis. In order to ensure confidentiality, these extracts were labelled using letters followed by numbers, e.g. A_1, B_1 for the pre-implementation answers and A_2, B_2 for the post-implementation answers. Here, A_1 and A_2 notations were chosen to clearly distinguish between the pre-implementation and post-implementation answers of the same teacher and allow comparisons to be made.

3.2.1 Science and Its Characteristics

The participants responded to two main questions: 'What is science to you?' and 'What separates a scientific branch like physics or biology from other study branches like psychology or philosophy?' The second question was asked in order to increase the depth of the answers. Table 7 presents the findings of the inductive content analysis carried out on the answers given by the PSTs to the question of science and its features. The participants' responses were categorised under the headings of 'Science Myths' for scientific misconceptions and 'Characteristics of Science' for summarising NOS. The participants responded with more science myths than characteristics of science. In particular, their responses about the relation between theory and law were remarkable, and there was no consensus on the idea that science provides absolute proof.

Table 7 Viewpoints and themes from the inductive content analysis

Questions		Themes	Concepts[a]	*n* (total 6)
Pre-implementation	Science and its characteristics	Science myths	Hypotheses become theories that in turn become laws	5
			A general and universal scientific method exists	4
			Science and its methods provide absolute proof	6
			Scientists are particularly objective	3
			Science and technology are identical	3
		Characteristics of science	Science is an attempt to explain natural phenomena	6
			Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and scepticism	3
	Function of science education	Definition of natural cases in the universe	To make life easier	3
			Explanation/understanding of natural cases	2
		Teacher-centred teaching	Laboratory practices	6
			Lecture	2
	Role of argumentation in science	Argumentation nation	A motivation tool for students	3
			Information sharing	2
			A kind of common speech-form	4
		Teacher-centred teaching	Lecture	5
	The roles of the teacher and students in science education	Teacher-centred teaching	Lecture	4
			Information transfer	5
			Laboratory experiments	3
Post-implementation	The impact of implementation on the opinions about science education	Generally positive change		6
		Student-centred teaching	The argumentation process	4
			NOS process	2
			From teacher centred to student centred	5
	The relationship between NOS and argumentation	Gordian knot		4
		Scientific literacy	Direct to research	3
			Promotes the ability to grasp information	2
			Improves decision-making skills	2

Table 7 (continued)

Questions	Themes	Concepts[a]	*n* (total 6)
Including argumentation in science education environments	Positive response		6
	Student-centred teaching	For students to grasp information themselves	4
		Developing curiosity	3
		Argumentation	3
	Scientific literacy	Expression skills	3
		Scientist-like behaviour	5
Including NOS in science education environments	Positive response		6
	Scientific literacy	The change of scientific ideas over time	4
		History of science	2
		Thinking like a scientist	4
	Student-centred teaching	Rich learning experiences	5
		Meaningful learning	2
		Scientific thinking	3
		Developing curiosity	2

[a] The quotations relating the highest frequency (*n*) themes and concepts are given under each subheading below

For instance, the analysis of the answers to this question showed that all participants supported the viewpoint that 'Science and its methods provide absolute proof', categorised under science myths.

Here is a participant's response related to this topic:

> A_1: Physics and biology are more concrete, instead philosophy is more abstract. When a physicist or biologist makes a research or investigation, s/he reaches a result and gets a concrete record. A philosopher thinks, but s/he does not experiment. S/he just makes a suggestion about something and it stays there. For instance, Einstein found different formulas in physics like mc^2.

In the excerpt above, participant A_1 chose to explain the idea that science and its methods provide absolute proof by referring to Einstein's theory of relativity. This participant's claim was that physics and biology, which have more positivist approaches, present more solid proofs than philosophy. Moreover, A_1 claimed that while it is possible to prove an idea in disciplines such as physics and biology, this is not the case for philosophy.

Another viewpoint under the science myths theme was that most participants stressed is, 'Hypotheses become theories that in turn become laws'. Another participant, C_1, who responded in accordance with this viewpoint also chose to explain an idea by referring to a scientist. This teacher argued that a scientist proves his/her theory by undertaking experiments with reference to Newton and Edison. The participant stated that a scientist should start the research process with a theory and try to prove it as a law by conducting experiments. S/he also claimed that a precondition for science is that the scientist should be open to new ideas:

> C_1: A scientist must have an inquisitive spirit. S/he must search for something all the time. Before turning an idea into law, s/he should keep it as a theory so that s/he can be open to new ideas. For example, Newton found the gravity by exploring and making research. At first, he formed his theory, and then he could reach the law by disproving his theories. Or Edison, he did the same. I mean, scientists had always worked and researched until they reached a law.

There were fewer participant answers related to the features of science category than the science myths category. All the participants especially argued that science is an attempt to explain natural phenomena. For example, participant C_1 stated that science could not be thought of as being separated from everyday life and asserted that science exists to make life easy.

> C_1: In my opinion science is everything that we see around. Simply, when we wear a jumper in the winter charging by friction occurs, and that is related to science. Or when we call out to a friend our voice echoes: why? I mean, science exists in every stage of life. Friction between our feet and the ground when we are walking is related to science.

3.2.2 Function of Science Education

When asked 'Why is science education important?' and 'What do you expect your students to learn from your lessons', five of the six PSTs stated that science education is significant in helping students in their ordinary lives. For example, one participant's response to this question was

> A_1: Science education is important for making our lives easier. One simple example is cars: life would be much harder for people without cars. Cars are related to physics and science and they help us to make our lives easier. Without science lessons, people would do everything according to themselves. But, with science lessons they learn from outside sources.

In answers to this question, most teachers referred to a teacher-centred education method in science classes. Within this context, one participant stated that s/he would teach the lesson in accordance with laboratory practices:

> D_1: I expect students to do some of the things themselves while I am teaching them a practice. I mean I can teach them better in a laboratory, and they can improve themselves by using what I teach them in their lives. Let's think about a construction worker: if he uses a machine to carry the construction materials instead of carrying them on his back, it means that he had learned something from me.

The responses given by above two different participants were from two different perspectives revealing that they conceptualised science education as teacher centred. For example, half of the participants stated that science was necessary to make life easy and science education should be integrated with everyday life, just as stated by A_1. However, their responses to the question of how to teach science effectively contradicted this view. The response of D_1 has evidential value for this claim. This PST claimed that a student should be able to use their knowledge in real life and asserted that this goal could be achieved through a rhetorical (teacher-centred) process.

3.2.3 Role of Argumentation in Science

None of the six participants gave a clear answer to the question 'What should the role of argumentation be in science?' or 'What should be the role of argumentation in primary, secondary and high school education?'. Thus, it was concluded that the participants had no opinion about the meaning of argumentation, and four of the six participants conceptualised argumentation as a form of speech.

> C_1: The way of speaking and rhetoric are very important for me. A teacher's style can increase or decrease a student's interest for the lesson. For primary school or at the university, we study more for a lesson if we like the teacher.

The response given by C_1 reveals the erroneous conception of argumentation before the implementation process as a rhetorical form, which possibly affected the participants' ideas concerning science education.

> F_1: It depends on my teaching ability. It is more important for students to be talking to me. It is highly unlikely for me to give them false instructions because my knowledge is much different than theirs. If argumentation occurs among them, that may lead to misconceptions.

As shown in the response given by F_1, five of the six participants referred to a teacher-centred (rhetorical) process. F_1 stated that the role of argumentation depended on the teacher's teaching style.

3.2.4 The Roles of the Teacher and Students in Science Education

Following the analysis, all PSTs were found to refer to laboratory studies in their responses to 'How should science education be in its most ideal circumstances?' and, 'What should the role of the teacher and students be in science education?'. The analysis of responses showed that five of the six participants claimed that science education had to be conducted using a teacher-centred transfer of knowledge.

> D_1: In the most ideal circumstances we should have proper laboratory equipment. To do any kind of experiment, we should have proper technological devices.

When the same pre-service teacher, who had emphasised laboratory experiments, was asked, 'What should be the roles of the teacher and students?', his/her answers referred to teacher-centred teaching.

> D_1: First, I would teach the subject, and then I would ask as many questions as I could, in order to see how much they understand. After that I would make them practice and experiment on the subject. The

teacher's role should be to teach correct information and communicate with the students. The role of students should be mostly listening to the teacher and explaining their ideas about the subject.

The response of participant D_1 summarises the conceptualisation of the PSTs concerning science education before the implementation process. This understanding represents traditional science education; in this kind of teaching, the teacher has an active role while the students have passive roles.

3.2.5 The Impact of Implementation on the Participants' Opinions About Science Education

Following the implementation process, our first question for the participants was 'After your experiences during this process, did your opinions about science education change?' When the answers were analysed, all the participants stated that there was a positive change. When they were asked in-depth about the reasons for this change, most participants emphasised the argumentation process.

C_2: I had a positive change. I learned new ideas. Honestly, I learned to look at things with a different point of view. For example, when one of our friends elucidated a subject, contrary to what I had thought before, I agreed with him/her. I learned how to debate and share ideas in a class environment. I have learned scientific thinking.

For this question, the response of C_2, which represents the inclinations of the PSTs, revealed that the implementation process had a positive impact on the aspect of scientific thinking with different perspectives. One of the findings obtained from these responses was participants' reference to student-centred teaching. One of the participants, who expressed a positive change after the implementation, stated:

F_2: It is a positive change indeed. Previously I had thought that as teachers we were supposed to teach a lot more. I am more relieved now. Now, I can say that my opinion about the students has changed. If my opinions had not changed, I would teach students more than they needed, and this would not benefit them. Now, I do not think that the teacher as the only authority in the classroom. Both the teacher and students have responsibilities. For example, you told us that students should be more active in the class, and the teacher must be more like a mentor. It was new for me; my opinion changed on the issue.

F_2 stated that before the implementation process her/his ideas were more teacher-centred; after the implementation process, s/he no longer thought that the teacher should be the sole authority in the classroom. According to this participant, students should be encouraged to be more active. This proves that the teachers who participated in the implementation process started to have a more student-centred approach.

3.2.6 The Relationship Between NOS and Argumentation

Although there was no complete consensus among the participant responses to the question, 'What should be the role of socioscientific argumentation and NOS in science education?', they stated that both implementations were necessary for quality science education. A response within this context was

B_2: I think they are used together. Because, I mean, with socioscientific argumentation we have use them together, because they proceed together. How have we reached it … while we were engaging in socioscientific argumentation, we were in a society. There were things in the NOS that had an impact on us; it was different for each of us. What happened was we internalised that we are all together, when we engaged in an argumentation together.

B_2 claimed that NOS and argumentation proceeded together, and, in fact, the participants engaged in the NOS process while performing argumentation without being aware of it. This situation demonstrates that the participants referred to NOS and argumentation as having similar bases. On the other hand, four participants claimed that NOS and argumentation had a Gordian knot-type relationship. The teacher candidate who saw argumentation and NOS as a tangled knot explained this as follows:

> D_2: I think they should be performed together. They are like key and lock, because you lead students to perform research rather than memorise. I mean, if they are not used together, it will proceed like memorisation. Done this way, knowledge can stay fresh for students. If a student learns something by memorisation s/he will forget it the next year; however, if s/he learns it by conducting research, it will be harder to forget.

D_2, who claimed that NOS and argumentation had a lock-and-key relationship, stated that these two concepts would lead an individual to research and serve a meaningful learning process.

3.2.7 Including Argumentation in Science Education Environments

All the participants gave a positive response to the question, 'As a teacher, would you use (socioscientific) argumentation in your classes?' The responses were recorded, and when the participants were asked to explain further, different rationales were given. Some participants argued that socioscientific argumentation is good in order for students to reach information on their own:

> A_2: Students reach a conclusion through discussion in socioscientific argumentation. Students understand their environment with the help of science. For example, from the lesson in which we studied benefits and harms of nuclear power plants, students may gain a different point of view. They find the truth themselves. I would make them engage in argumentation as we did in your lesson. I had little knowledge about genetically modified organisms; but when we started to discuss it, I used my knowledge related to the issue and I learned something from the other group members. I mean, I had a new point of view about the issue.

A_2, who believed that the inclusion of argumentation in science education would provide benefits for acquiring knowledge, preferred to give examples about genetically modified organisms, which is a socioscientific issue. This participant asserted that after the implementation process, s/he not only learned more about genetically modified organisms but also had a changed perspective. On the other hand, the most stressed point by the participants concerning this question was that the inclusion of argumentation in science education would be useful for educating science-literate individuals. C_2, who supported this claim, stated that individuals participating in argumentation process would be more skilful in expressing their ideas:

> C_2: I will definitely use it. As I said before, by engaging in argumentation, students learn to listen to each other. They can state their opinions easily. Usually a student gets nervous when s/he is asked a question, but in an argumentation process s/he can express his/her ideas more easily because it is like a normal social engagement, in which they talk about current social matters.

3.2.8 Including NOS in Science Education Environments

All participants gave a positive response to the question, 'As a teacher, would you use NOS in your classes?' When we asked them 'Why?' in order to clarify their answers, they mostly referred to the changes in scientific ideas over time. E_2 also held a supporting view and stated that the inclusion of NOS in science education would help students to engage in qualified conceptualisations about the changeable nature of scientific knowledge. In addition, this participant claimed that although s/he did not participate explicitly in NOS activities, since s/he performed argumentation, s/he would implicitly improve from the perspective of NOS. This situation, as revealed by the analysis of the other responses, reflects that NOS and argumentation have a similar basis.

> E_2: I will use it. When I use argumentation in my class, NOS comes naturally with it. For example, while arguing for something people may change sides with each other. I changed my ideas, which I thought to be unchangeable, after my discussions with my friends, and the same can happen with the students.

C_2 was another participant who believed that NOS presented meaningful and rich learning experiences and stated that NOS would lead students to research and increase their curiosity in the same way as argumentation. In addition, this participant claimed that students would have rich learning experiences and that NOS would help them to create links between their lessons and modern daily life.

> C_2: I will definitely use it, because it encourages students to engage in research and increase their sense of wonder. It ensures building ties between lessons and real life. In this way, they will learn about current issues and they will be more successful at expressing their thoughts among friends.

4 Discussion and Conclusions

This study investigated the change that occurred in NOS understanding and opinions about science education of PSTs who had participated in the explicit NOS and socioscientific argumentation processes. In this section, the findings are discussed under separate sub-headings in accordance with the literature.

4.1 The Change of PSTs' NOS Understanding During the Explicit NOS and Socioscientific Argumentation Processes

The first research question was whether the explicit NOS and socioscientific argumentation processes affected PSTs' NOS understanding. The NSAAQ was administered to all participants at the beginning of the implementation process in order to determine their NOS understanding. As shown in Table 3, there was no significant difference between the pre-test scores of the participants of the two groups. Not only was their NOS understanding very similar but their scores were also very low, indicating that participants' NOS understanding was insufficient. This result conforms to the findings of other studies conducted to investigate NOS understanding (e.g. Abd-El-Khalick and Lederman 2000; Lederman 2007). Many science education researchers (e.g. Khishfe and Abd-El-Khalick 2002; Schwartz and Lederman 2002) are in agreement that the teaching of explicit NOS is the most effective method for individuals to develop a better NOS understanding. This consensus and the results obtained can be considered as the rationale for teaching explicit NOS and the socioscientific argumentation processes, which was implemented in this study. That there was no significant difference between the pre-test scores of the comparison and treatment groups meant that both groups started the process with an equal understanding of NOS.

However, the results after the implementation process were different. As shown in Table 4, the NOS understanding of the treatment group participants was significantly higher than that of the comparison group. This result indicates that the explicit NOS and socioscientific argumentation processes were more effective than a student-centred science-teaching process in terms of developing the NOS understanding of individuals. This result is corroborated by most of the results of the studies in the literature (e.g. Khishfe and Lederman 2006; Bell et al. 2011; Eastwood et al. 2012). This result showed, once again, that explicit NOS teaching is the most effective method in developing NOS understanding (e.g. Khishfe and Abd-El-Khalick 2002; Abd-El-Khalick 2005). Another interesting result is that the post-test scores of the participants in the comparison group did not show a significant increase compared to the pre-test scores (Table 5). This result showed that a student-centred science-teaching process without the intervention of any NOS-related activity will be inadequate in developing NOS understanding. This situation indicated the need for additional teaching interventions for the development of NOS understanding (Driver et al. 1996; Abd-El-Khalick and Lederman 2000). Furtheromore, the post-test scores of the treatment group participants significantly and positively changed compared to the pre-test scores (Table 6). This result revealed that the explicit NOS and socioscientific argumentation processes significantly improved the participants' NOS understanding, similarly to other studies (Matkins and Bell 2007; McDonald 2010; Cook and Buck 2013; Schalk 2012; İşbilir et al. 2014). Many science education researchers contributing to the NOS literature have claimed that performing argumentation-based education together with an explicit NOS approach helps students to conceptualise NOS (e.g. Lederman 2007; Abd-El-Khalick et al. 2008). These claims support the findings of the current study, which shows that the explicit NOS and socioscientific argumentation processes is an effective method to improve NOS understanding.

4.2 The Change of PSTs' Views on NOS, Science Teaching and Argumentation After the Explicit NOS and Socioscientific Argumentation Processes

The aim of the second research question in this study was to investigate the characteristics of the changes which would occur in relation to PSTs' ideas of NOS, science education, and argumentation after the explicit NOS and socioscientific process. The results of this section also made it possible to more clearly analyse the results of the first research question. To answer this question, semi-structured interviews were performed before and after the explicit NOS and socioscientific argumentation processes with six participants of the 27 treatment group members, chosen by simple random sampling method. The results of the interviews undertaken to determine the changes that stemmed from the explicit NOS and socioscientific argumentation processes are presented below. From the participants' answers to the first question, the PSTs believed in science myths, which included common scientific misconceptions as described by McComas (2002). McComas claimed that there were 15 science myths, based on the rationale that it would be an obstacle for students to experience real science situations if they had been taught science subjects, unrelated to the philosophy of science, in teacher education programmes. In the current study, the participants possessed some of the following myths:

- Hypotheses become theories which in turn become laws.
- A general and universal scientific method exists.
- Science and its methods provide absolute proof.
- Scientists are particularly objective.
- Science and technology are identical.

This result explained the low NSAAQ scores before the implementation of explicit NOS and socioscientific argumentation. This situation also revealed that the PSTs had naive views about NOS. Maybe the most important finding in this case was that the participants shifted from a teacher-centred (rhetorical) to a student-centred approach, as they referred to teacher-centred science education in their responses to the second, third and fourth questions. For example, all participants underlined the importance of laboratory lessons in their answers for the question about the roles of the teacher and students within the context of science education; however, they referred to the rhetorical (teacher-centred) education in their answers to the sub-question which was posed to deepen their responses. When asked about the same issue after the implementation, their answers revealed a positive improvement. For example, participant A_1 initially stated the importance of laboratory lessons along with rhetorical teaching, but his/her answer after the implementation revealed a great change. Among the responses to the second questions, A_2 particularly referred to the process of argumentation. Participant F_2 clearly stated that the teacher should not be the single authority; rather, s/he should be a mentor in the classroom. As a result, it can be said that the explicit NOS and socioscientific argumentation processes brought about a positive change on the views of PSTs about science education. This result indicated that the NOS and socioscientific argumentation processes could be a good method for raising individuals with scientific literacy within a socioscientific context (NRC 2013; ACARA 2014).

Many of the results from various studies conducted within the context of science teacher education supported the results of the current study (e.g. Sadler 2006; Iordanou and Constantinou 2014; Vieira, Bernardo, Evogorou, and de Melo 2015). As revealed in this paper, the PSTs' involvement in the argumentation process as students resulted in an improvement in their perceptions of science education; this improvement, as predicted by many science education researchers (e.g. Kuhn 2010; Herman 2015) and contemporary science education programmes (e.g. AAAS 2001; ACARA 2014), may increase the possibility that PSTs will use explicit NOS and socioscientific argumentation processes in their lessons to raise students with scientific literacy. To place these claims on more solid ground, the participants were asked two questions about argumentation before the implementation. According to the analysis of the answers given to these questions, an improvement was seen in participants' views about argumentation, who had considered argumentation either as a kind of one-sided speech or had no clear idea about it. When the pre-implementation and post-implementation answers of participant C_1 were compared, it was seen that s/he had thought, before the implementation, that argumentation was a method that benefited teacher-centred science education:

> C_1: The way of speaking and rhetoric are very important for me. The diction of a teacher can increase or decrease a student's interest for the lesson. For primary school or at a university, we study more for a lesson if we like the teacher.

However, after the implementation, C_1 defined argumentation as a method used to raise students with scientific literacy. This result clearly shows the change caused by the direct involvement of teachers in the explicit NOS and socioscientific argumentation processes (Ryu and Sandoval 2012; Cook and Buck 2013). It is expected that these participants would use explicit NOS and socioscientific argumentation during their teaching careers.

> C_2: I will definitely use it. As I said before, by engaging in argumentation, students learn to listen to each other. They can state their opinions easily. Usually a student gets nervous when s/he is asked a question, but in an argumentation process s/he can express his/her ideas more easily because it is like a normal social engagement, in which they talk about current social matters.

In her study conducted with six science teachers and 568 students, McNeill (2009) argued that teachers strongly affect the argumentation and learning levels of their students. Thus, increasing science teachers' argumentation skills and making them aware of the importance of these skills for quality science teaching will affect their students' understanding in the future. The change that occurred in the science-teaching perspectives of the participants after the implementation process can be evaluated as beliefs. These are accepted as psychological constructions including the understanding, presupposing, images or propositions that an individual accepts to be real and true (Richardson 1996). According to Pajares (1992), a person's belief directs their future actions. Van Driel et al. (2007) considered that most teachers have either teacher-centred or student-centred belief systems, and they project these systems into their classrooms. However, Patchen and Crawford (2011) claimed that because teachers' beliefs are always inclined to change, it is hard to divide them into two categories. On the other hand, Saban (2006) claimed that any teaching activity might affect belief systems, but he asserted that these systems were very resistant to change. This claim relates to the results of the current study. The participants' shift from teacher-centred to student-centred teaching can be related to the change of their belief systems as claimed by many researchers studying these changes (e.g. Van Driel et al. 2007; Saban 2004). In the research, the results obtained show that the explicit NOS and socioscientific argumentation processes positively changed NOS understanding, which have quantitative characteristics, and NOS, science education, and argumentation, which have qualitative characteristics. However, the explicit NOS and socioscientific argumentation processes may go beyond this and lead to a change in the students' belief systems as well. In addition, this shows that implementations based on NOS and socioscientific argumentation may even cause changes in change-resistant belief systems.

After engaging in the explicit NOS and socioscientific argumentation processes, the PSTs referred to *the tentative NOS* in their responses and also stated that the explicit NOS process could provide rich learning experiences for their students. This result is in agreement with the results reported in the literature (e.g. Sadler et al. 2004; Khishfe and Lederman 2006). With their post-implementation NSAAQ scores, it was shown that the PSTs' NOS understandings improved significantly after their participation in the explicit NOS and socioscientific argumentation processes. This means that our research hypothesis is supported. Many science education researchers suggested that apart from the scientific knowledge that they produced, individuals with a developed NOS understanding are expected to realise that science is dynamic, strictly tied to culture, a product of imagination and creativity, and has a subjective and experimental nature (Bell, Lederman, and Abd-El-Khalick 2000; Lederman 2007). From their responses to the second question of the post-implementation interview, it was clearly seen that the PSTs' NOS understanding had improved, as was expected. On the other hand, McComas et al. (2002) stated that individuals who understood the dynamic NOS would be interested in science more as a process and they would make healthier decisions about the issues related to themselves. Therefore, their reference to the dynamic and changing NOS in their responses revealed that the PSTs had also improved their decision-making abilities during the study.

5 Implications and Recommendations

As stated above, this study shows that the explicit NOS and socioscientific argumentation processes improves PSTs' NOS understanding. In addition, a positive change occurred in NOS, socioscientific argumentation and the science education perspectives of the participants who were interviewed after the study. A discussion of the findings in light of the current literature indicates that future studies can be undertaken to investigate the impact of the NOS process on PSTs' decision-making skills, with the participation of different grade levels, to further contribute to their science education. Furthermore, different studies can be conducted concerning the individual or joint impact of NOS and socioscientific argumentation on the belief systems of different age levels. For the qualitative improvement of education environments and to present rich learning environments for the students in science classrooms, these three basic elements of science education should be better encouraged and supported. Lastly, in the context of PST education, educational environments that can help them to improve their pedagogical skills in relation to NOS, socioscientific issues and argumentation can be enhanced.

Compliance with ethical standards

Conflict of Interest The authors have no conflict of interest to declare.

Appendix 1: The Nature of Science as Argumentation Questionnaire (NSAAQ)

Read the following pairs of statements and then circle the number on the continuum that best describes your position on the issue described. The numbers on the continuum mean:

1 = I completely agree with viewpoint A and I completely disagree with viewpoint B.
2 = I agree with both viewpoints, but I agree with viewpoint A more than I agree with viewpoint B.
3 = I agree with both viewpoints equally.
4 = I agree with both viewpoints, but I agree with viewpoint B more than I agree with viewpoint A.
5 = I completely agree with viewpoint B and I completely disagree with viewpoint A.

	Viewpoint A	A	A > B	A = B	B > A	B	Viewpoint B
1	Scientific knowledge describes what reality is really like and how it actually works.	1	2	3	4	5	Scientific knowledge represents only one possible explanation or description of reality.
2	Scientific knowledge should be considered tentative.	1	2	3	4	5	Scientific knowledge should be considered certain.
3	Scientific knowledge is subjective.	1	2	3	4	5	Scientific knowledge is objective.
4	Scientific knowledge does not change over time once it has been discovered.	1	2	3	4	5	Scientific knowledge usually changes over time as the result of new research and perspectives.
5	The concept of "species" was invented by scientists as a way to describe life on earth.	1	2	3	4	5	The concept of "species" is an inherent characteristic of life on earth; it is completely independent of how scientists think.
6		1	2	3	4	5	Scientific knowledge is best described as an attempt to

	Viewpoint A	A	A > B	A = B	B > A	B	Viewpoint B
	Scientific knowledge is best described as being a collection of facts about the world.						describe and explain how the world works.
7	Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued.	1	2	3	4	5	Scientific knowledge can be considered trustworthy if it is well supported by evidence.
8	The scientific method can provide absolute proof.	1	2	3	4	5	It is impossible to gather enough evidence to prove something true.
9	If data was gathered during an experiment it can be considered reliable and trustworthy.	1	2	3	4	5	The reliability and trustworthiness of data should always be questioned.
10	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles.	1	2	3	4	5	Scientists know that atoms exist because they have seen them using high-tech instruments.
11	Biases and errors are unavoidable during a scientific investigation.	1	2	3	4	5	When a scientific investigation is done correctly errors and biases are eliminated.
12	A theory should be considered inaccurate if a single fact exists that contradicts that theory.	1	2	3	4	5	A theory can still be useful even if one or more facts contradict that theory.
13	Scientists can be sure that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	1	2	3	4	5	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never work that chemical.
14	Experiments are important in science because they can be used to generate reliable evidence.	1	2	3	4	5	Experiments are important in science because they prove ideas right or wrong.
15	All science is based on a single scientific method	1	2	3	4	5	The methods used by scientists vary based on the purpose of the research and the discipline.
16	The methods used to generate scientific knowledge are based on a set of techniques rather than a set of values.	1	2	3	4	5	The methods used to generate scientific knowledge are based on a set of values rather than a set of techniques.
17	In order to interpret the data they gather scientists rely on logic and their creativity and prior knowledge.	1	2	3	4	5	In order to interpret the data they have gather scientists rely on logic only and avoid using any creativity or prior knowledge.
18	Scientists are influenced by social factors, their personal beliefs, and past research.	1	2	3	4	5	Scientists are objective, social factors and their personal beliefs do not influence their work.
19	Successful scientists are able to use the scientific method better than unsuccessful scientists.	1	2	3	4	5	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists.
20	Two scientists (with the same expertise) reviewing the same data will reach the same conclusions.	1	2	3	4	5	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions.
21		1	2	3	4	5	What counts as evidence is the same for all scientists.

	Viewpoint A	A	A > B	A = B	B > A	B	Viewpoint B
	A scientist's personal beliefs and training influences what they believe counts as evidence.						
22	The observations made by two different scientists about the same phenomenon will be the same.	1	2	3	4	5	The observations made by two different scientists about the same phenomenon can be different.
23	It is safe to assume that scientist's conclusions are accurate because they are an expert in their field.	1	2	3	4	5	A scientist's conclusion can be wrong even though scientists are experts in An experiment is used to test an idea. Their field.
24	The concept of density is an invention of scientists to represent a property that physical objects might possess.	1	2	3	4	5	The concept of density is an inherent property of physical objects; it is completely independent of how scientists think.
25	Science is best described as a process of exploration and experiment.	1	2	3	4	5	Science is best described as a process of explanation and argument.
26	An experiment is used to test an idea.	1	2	3	4	5	An experiment is used to make a new discovery.

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