ISSN: 2148-9955

International Journal of Research in Education and Science (IJRES)

www.ijres.net

Analysis of Pre-service Science Teachers' Understanding of Nature of Science and Proposed Arguments on Socio-scientific Issues

Kader Bilican
Kırıkkale University

To cite this article:

Bilican, K. (2018). Analysis of pre-service science teachers' understanding of nature of science and proposed arguments on socio-scientific issues. *International Journal of Research in Education and Science (IJRES), 4*(2), 420-435. DOI:10.21890/ijres.410632

IJRES International Journal of Research in Education and Science
Volume 4, Issue 2, Summer 2018 DOI:10.21890/ijres.410632

Analysis of Pre-service Science Teachers' Understanding of Nature of Science and Proposed Arguments on Socio-scientific Issues

Kader Bilican

Article Info

Article History

Received:
10 December 2017

Accepted:
07 March 2018

Keywords

Nature of science
Socio-scientific issues
Justification
Argumentation
Teacher education

Abstract

The purpose of current research is to explore the influence of a science teaching method course incorporating explicit reflective NOS instruction on pre-service science teachers' views of NOS and justifications in their arguments related to their decision-making on socio-scientific issues. This study is a case study and the participants were 5 pre-service science teachers who were enrolled in elementary science teaching program. To track changes in participants' NOS views, the Views of Nature of Science Questionnaire was administered as pre- and post- test. To examine students' source of justifications, the decision-making questionnaire was administered as pre- and post-questionnaire. The research questions of the study were examined for each participant and presented to include the change in participants' NOS views, change in participants' source of justifications, and the relation between participants' views of NOS and their justifications in their arguments on SSI. The results of the study did not show a clear relationship between improved NOS views and the shifts in the sources of justifications used to make decisions on socio-scientific issues.

Introduction

Science teaching has not only related to teaching of scientific events, objects or abstract and theoretical concepts but also developing knowledge through why and how enquiry related to scientific facts ((Erduran, Simon, & Osborne, 2004; Kolsto, & Mestad, 2005; Millar & Osborne, 1999). Achieving scientifically literate citizens is one of the agreed goal of science education globally. That is possible if science education includes teaching of practice and methods of science equally to teaching of science concepts (Driver, Newton, & Osborne, 2000). Additionally, science education need to provide opportunities for learners to interpret and evaluate evidence, construct claims and support them with warrants or justifications, and develop appropriate understanding of science to achieve scientifically literate citizens (Lin & Mintzes, 2010).This claim brings out that, scientifically literate citizen could be able to interpret and evaluate evidence, construct claims and support them with warrants or justifications, have an understanding of science as a human enterprise (Lin & Mintzes, 2010).Therefore, having students appropriate understanding of nature of science as well as being able to evaluate evidence and construct claims have been always taken attention of science educators. Although there is no clear direct relationship between NOS views and ability to construct arguments, some studies suggested an interplay between NOS views and argumentation (McDonald, 2010; Sampson &Clark, 2006; Yerrick, 2000). That is learners with more developed views on NOS are likely to realize claims are refutable, and require support of evidence (Sampson &Clark, 2006). Additionally, practice of engagement in argumentation would better support improvement of NOS views as reflected in their arguments (Yerrick, 2000).

Science educators suggest the inclusion of socio Scientific issues (SSI) in science classrooms with the purpose of educating responsible citizens who have an understanding of scientific evidence and scientific knowledge as a product of human enterprise as well as moral and ethical values with respect to others and the environment (Driver, Newton, & Osborne, 2000; Hodson, 2003; Mun, et al., 2015; Roth & Lee, 2004). The claim is that a person's belief and understanding regarding what science is, how science operates and the limits of science, that is epistemology of science, have a profound impact on his/her decision-making related to SSI (Kolsto, 2001a, Sadler, 2004; Sadler, Chambers, & Zeidler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002). It is claimed that, thinking of socio-scientific issues would serve as an ideal context for NOS views development (Zeidler, 2014). On the other hand, appropriate understanding of NOS will make individuals be able to make informed decisions on socio-scientific issues (Driver, Leach, Millar, &Scott, 1996). Considering argument construction, SSI is believed to provide a context which people with argumentation skills justify their positions through valid evidences and acceptable warrants.

However, some research supported this claim that learners, who hold naïve views of NOS, think scientific knowledge irrelevant for decision-making or have misunderstanding or misinterpretation of data (Cook & Buck, 2013; McDonald & McRobbie, 2012; Sadler, 2004; Zeidler, et al., 2002). Whereas, Bell and Lederman (2003) reported non-significant results with the participants, who are university professors, in their decision making on SSI, though they hold different views of NOS. This conflicting result made us wonder the situation with pre-service teachers in terms of how they justify their positions on socio-scientific issues with respect to their NOS understanding. Pre-service science teachers were chosen for this study in refer to the literature asserting that teacher is an important factor in promoting discourse. When the teacher creates a meaningful context of learning, the number and level of wide-ranging and multi-voiced dialogic interactions increase significantly (Saglam, Kanadli, Karatepe, Gizlenci, & Goksu, 2015). Teacher should challenge students to evaluate alternative ideas and analyse the rationale of their own positions (Sadler, Chambers, & Zeidler, 2004). For example, teachers may compel students to consider particular positions and the nature of science that utilizes combinations of evidence in the form of quantitative, descriptive, and casual observations of data or information (Zeidler, et al., 2002). However, when dealing with controversial socio-scientific issues, the discussions about nature of science, the meaning and role of evidence, and the ways science communities work to establish knowledge are very important, yet difficult. Teachers need to question their own views of science and scientific knowledge, and compare these views with their teaching practice; a process which is usually uncomfortable for them (Albe, 2008).There are few studies stating that learners' understanding of science might affect their engagement in argumentation (Sandoval &Millwood, 2007).Thus the purpose of current research is to explore the influence of a science teaching method course incorporating explicit reflective NOS instruction on preservice science teachers' views of NOS and warrants in their arguments related to their decision on socio scientific issues. We know from past research that the explicit teaching of NOS in pre-service teacher education yielded positive results in terms of improving PST's views of NOS (Abd-El Khalick & Lederman, 2000; Cook & Buck, 2013). The question is whether this positive change will provide a ground for improved justifications in the decision making with regard to socio-scientific issues. The research questions of the current study are as following:

1- How do pre-service science teachers' views of nature of science change over the course of explicit nature of science instruction?
2- How do the pre-service science teachers' justifications of socio-scientific issues change over the course of explicit nature of science instruction?

Justifications of Socio-scientific Issues

Socio-scientific issues are described as the social dilemmas with a scientific content (Sadler, Chambers, & Zeidler, 2004). Cloning, stem cells, alternative energy sources, global warming, genetically modified foods are some examples of socio-scientific nature which has links with science and technology as well as society (Sadler, 2004; Albe, 2008). The inclusion of these issues into science curricula has found proponents from science educators due to the central role SSI plays in educating responsible citizens who can apply scientific knowledge and habits of mind (Sadler, 2004; Driver, Newton, & Osborne, 2000).

The quality of argumentation on scientific and socio-scientific issues has been directly related to the reasoning and to the use of justifications (Erduran, Simon, & Osborne, 2004). Based on the sociology of justification framework, Simonneaux (2001) makes the claim that "The crucial point in justification processes is the 'orders of importance' that are attached to objects of debate." (p. 906) The justifications, for example, in the form of warrants and backings in Toulmin's model (1958), help students establish the links between concepts and subjects (Cinar & Bayraktar, 2014). In the evaluation of written arguments, Kelly et al. (2007) focused on the structure of reasoning (convergent, sufficient and valid or not) besides the structure of thesis (solvable and supportable or not). Using this model, Karisan and Topcu (2016) observed that although all preservice teachers posed solvable and researchable thesis statements, the group, who wrote high quality papers on global warming issue, were able to support their arguments with proper evidence and develop complex reasoning mechanisms. This complexity in socio-scientific reasoning is theoretically situated in terms of four aspects in a study by Sadler, Barab, and Scott (2007). The aspects are "recognizing the inherent complexity of SSI, examining issues from multiple perspectives, appreciating that SSI are subject to ongoing inquiry, and exhibiting skepticism when presented potentially biased information" (p.387).

Zohar and Nemet (2002) explored the learning outcomes resulting from explicit teaching of reasoning patterns incorporated into the teaching of scientific content within the context of controversies involved in human genetics. The participants were divided into two groups: experimental (N=99) and comparison (N=87). All the

participants in the study learned basic concepts in genetics before the study began and additional, advanced concepts in genetics during the study. However, while those in the comparison group were provided with a special booklet that presented the genetic information in a traditional textbook approach, those in the experimental group learned the concepts within a unit called "Genetic Revolution" with explicit instruction on socio-scientific argumentation skills. It was found that the learning context of SSI in human genetics had boosted students' performance in both biological knowledge and argumentation skills. The results obtained from the experimental group indicate that students had the ability to transfer their reasoning abilities taught in the context of dilemmas in genetics to dilemmas emerging in everyday life. An increase in the number of justifications and the complexity and quality of the arguments produced by the students was also observed (Zohar & Nemet, 2002).

Another study, carried out with Turkish pre-science teachers (PST), aimed to examine their informal reasoning in terms of SSI and the factors impacting their informal reasoning (Topçu, Yılmaz-Tüzün, & Sadler, 2011). Interviews were held with 39 participants. Seven SSI scenarios, which were taken from previous studies of SSI and informal reasoning, were used in the interviews. Data collection was made through the Informal Reasoning Interview (IRI) and Moral Decision-Making Interview (MDMI) protocols, which are specifically designed for the exploration of informal reasoning and the factors manipulating informal reasoning. Findings demonstrated that the informal reasoning presented by the participants to both the genetic engineering and global warming issues included both cognitive and affective domains. That is, participants resorted to their 'reason' to comprehend the issue and then arrived at a decision based on motions in most of the scenarios. However, there were those who relied solely on reason to defend their claims or solely on emotive reasoning, using emotions such as empathy and sympathy to resolve problems. In some other cases, participants provided instant responses, which is a pattern of thinking termed intuitive informal reasoning. However, it was found that despite the variety, rationalistic informal reasoning was more frequently employed. When analyzed closely, it was found that the context or nature of the different SSI had an impact on what type of informal reasoning was employed. Furthermore, the study found that personal experience also played a critical role in the decision-making process regarding SSI as participants who had familiarity with certain topics and unfamiliarity with others provided responses with varying patterns of informal reasoning (Topçu, Yılmaz-Tüzün, & Sadler, 2011).

The availability of multiple perspectives in justifications is also emphasized in studies. For example, Sampson and Clark (2008), in their analysis of the studies for the evaluation of argumentation, reported three focal issues to be considered: the structure of argument, the scientific accuracy or adequacy of the content and the nature of the justifications. Based on these criteria, a higher quality argument would be the one with backings, qualifier and rebuttals as well as types of reasons that reflect multiple and relevant perspectives and scientifically correct reasons (Dawson & Carson, 2016). The scientific knowledge may exist in different representational modes in a variety of ways in an argumentation on SSI (Namdar & Shen, 2016). When the consideration is on a socio-scientific controversial issue, the students' justifications may be sourced from a complex interrelation of contextual, epistemological and social factors (Albe, 2008). For example, in a study related to human carcinogenesis and doping effects by Albe (2008), students justified their claims with reference to their personal experience and to "cultural truisms" as called by Billig (1987). Zeidler and Sadler (2008) indicated that standard argumentation frameworks may be sufficient in scientific contexts, but they may not function well to explain the moral aspect of argumentation in socio scientific contexts because the moral duties, obligations, commitments and the like must be considered in SSI, in addition to the technological decisions made upon scientific information. If morality is not included in discussions, the functional understanding of science literature may not be fully realized (Zeidler & Sadler, 2008).

Nature of Science in Relation to Socio-Scientific Issues

Nature of science has been in the centre of discussions for science education researchers for a long time. While some researchers confirm that there are common aspects of sciences such as the tentative nature of scientific knowledge, the empirical based nature of conclusions, and science as a product of human imagination, creativity and subjectivity (Abd-El-Khalick, 2014; Khishfe, 2012; Lederman & Lederman, 2014), others think that science should not be represented as a distinct category of natural sciences, but should be illustrated as a connected model of systems that are interrelated, comprehensive and more representative (Allchin, 2011; 2012; Erduran, 2014; Erduran & Dagher, 2014). Although we accept the criticisms about the consensus view of NOS, we agree with Kampourakis (2016) in that this way of conceptualizing NOS serves an effective initiation for discussions related to the epistemology of science. Therefore, we preferred to stick with the examples of explicit instruction

of NOS found in the literature to provide an introduction to the discussions of NOS. Our hypothesis was that improved views of NOS will lead to varied and valid justifications of SSI.

Indeed, several research reported significant relationships between NOS and SSI. One way of looking at this relationship is to explore the impacts of SSI as learning contexts on developing learners' science content knowledge and nature of science understandings (Sadler, Barab, & Scott, 2007). For example, Cook and Buck (2013) investigated the ways in which pre-service teachers reflected their understanding of NOS in a socio-scientific inquiry. They studied with twenty-four undergraduate students enrolled in a university science class. The researchers engaged students in authentic scientific inquiry with integrated socio-scientific environmental science concepts and provided them opportunities for reflection on NOS aspects. At the end of a semester, participants demonstrated understanding of the subjective, culturally-embedded and empirical-based nature of science along with multiple perspectives in SSI. Overall, Cook and Buck (2013) reported that students' views became more specific and descriptive of NOS. Their results displayed that contextualized NOS instruction within SSI helped pre-service teachers meta-cognitively reflect on the applications of several NOS aspects. The only aspect that the participants had difficulty in was the consideration of data (Cook & Buck, 2013).

Another similar experimental study was carried out by Khishfe (2014), which aimed to (a) explore the impact of explicit nature of science (NOS) and explicit argumentation instruction in the context of a socio-scientific issue on the argumentation skills and students' understandings of NOS, and (b) examine the skills of students in terms of transferring NOS understandings and argumentation skills learned in one socio-scientific context into other similar, familiar and unfamiliar contexts. A total of 121 seventh grade students from two schools in the city of Chicago in the USA participated in the study. There were two intact experimental groups, which underwent an intervention involving an eight-week unit about the water usage and safety. Explicit NOS instruction, which lay emphasis on empirical, tentative, and subjective NOS aspects, was integrated into the teaching of all groups. However, only Treatment I groups additionally received explicit instruction on argumentation. Each participant was administered a questionnaire and the data obtained from these questionnaires were analyzed and categorized into three as naïve, intermediary, or informed arguments. Moreover, the progress in participants' responses for each of the three components of argumentation (argument, counterargument, and rebuttals) was evaluated. Participants were also interviewed and administered pre- and post-test employing open-ended items on two socio-scientific issues to assess their learning and transfer of argumentation skills and NOS understandings. According to the findings, there were significant improvements in the learning of argumentation practice and NOS understandings of the participants in Treatment I group. Further, the participants in this group had made connections to argumentation when displaying their NOS understandings by the end of the study. On the other hand, even though improvements were also observed in the learning and transfer of NOS understandings of the participants in Treatment II group, there was only some improvement regarding argumentation practice (Khishfe, 2014).

The research confirms that reasoning on SSI requires understanding the content, evaluating the available information, referring to the moral and ethical ramifications, and decision-making on the issue (Sadler, Chambers, & Zeidler, 2004). The decision-making on SSI issues necessitates students to master scientific models, concepts and skills, together with knowledge about science (Erduran & Jiménez-Aleixandre, 2012) since many of the studies in related literature support the fact that conceptual understanding of the context or material that underlies socio-scientific issues is crucial and a prerequisite for informal reasoning of the issues in subject (Sadler, 2004). We know from the research that the process would benefit from the epistemological representations that the students have, as well. There is enough evidence of that naïve views of NOS lead to ignorance of scientific knowledge in socio-scientific reasoning, and misinterpretation of data and claims because of poor understanding of what constitutes data and how to use data when interpreting scientific knowledge (Cook & Buck, 2013). Therefore, another aspect of the relationship is the impact of NOS conceptualizations on informal reasoning regarding SSI. For example, Sadler, Chambers and Zeidler (2004) investigated high school students' conceptualizations of NOS and the ways in which they interpret and evaluate conflicting evidence in the context of SSI. Studying with eighty-four students, the researchers provided a learning context in which students read contradictory reports about the status of global warming and respond to several questions. The researchers focused on three aspects of NOS displayed by participants: empiricism, tentativeness, and social embeddedness. They concluded that "In terms of the manner in which individuals interpret and evaluate conflicting evidence regarding socio-scientific issues, results indicate that negotiation of conflicting evidence in a socio-scientific context is influenced by a variety of factors related to NOS such as data interpretation and social interactions including individuals' own articulation of personal beliefs and scientific knowledge" (Sadler, Chambers, & Zeidler, 2004, p. 405).

Albe (2008) investigated adult students' (22 to 43 years old) opinions on the effects of mobile phone use as a socio-scientific topic. Participants were engaged in an activity which involves first, examination of contemporary discussions about the effects of mobile phone use on health effects and training on evaluating the validity and reliability of research results. Next, they were asked to review some research papers and make selection among that supports their own point of view. The researcher also documented aspects of nature of science realized while participants were interpreting available evidence and making decisions. Similar to Sadler et al. (2004), the discussions before the activity resulted with students' justifications based on personal experience and values. Whereas, the justifications after the classroom activity were rather "epistemological based on the notion of scientific evidence" and in a few cases, on "sociological aspects by identifying an influence of a social actor on scientific practice" (Albe, 2008, p. 824). Hence, teachers need to be aware of their students' understanding of the nature of science and be able to provide explicit instruction in order to help their students develop their understanding of the nature of scientific claims (Albe, 2008; Kolsto & Ratcliffe, 2008; Simonneaux, 2008). Thus, they might need to provide learners with guidance in referring their understanding of NOS aspects during decision-making process and help them learn to critically evaluate scientific claims even they are in contrast to their own positions (McDonald & McRobbie, 2012).

The only contradictory research with those reviewed above was conducted by Bell and Lederman (2003). In their study, the researchers investigated the role of nature of science in decision-making on socio-scientific issues and the justifications in decision-making regarding these issues. They studied with twenty-one faculty of universities, and asked them to complete a decision-making questionnaire, which is also used in this study, and participate to a follow-up interview. The researchers did not find any difference between the decisions of the faculty, despite their views of the nature of science diverge. The justifications made by the participants on their decisions were based on personal values, morals and ethics, and social concerns. Scientific evidence, even though it is not absolute as they indicated in their conceptions of the nature of science, was prioritized by the participants in their decision making. The results of the study showed that the nature of science views not necessarily figure the decisions on socio-scientific issues (Bell & Lederman, 2003). In summary, the research is not concluded in terms of the influence of learners' views of nature of science on their reasoning when debating on socio-scientific issues. There is still need for more research that questions the relationship between NOS views in decision-making on socio-scientific issues. Therefore, we investigated the justifications made by the pre-service teachers on socio-scientific issues when their views of NOS improved with explicit nature of science instruction.

Method

Participants

Participants of the study were 5 pre-service science teachers (4 females and 1 male) who are enrolled in elementary science teaching program. The participants were chosen voluntarily basis. They were in their 3rd year of 4-year undergraduate education. In their first three years, they took basic science and mathematics courses, like calculus, general chemistry, physics, and biology; science courses with a specific focus, such as optics and modern physics, fundamentals of analytic, organic and inorganic chemistry, astronomy, physiology, and molecular biology; as well as pedagogical courses, like educational psychology, instructional principles and methods, measurement and assessment, instructional technology and material development. Therefore, they are considered to have their own view of nature of science due to the intense theoretical education and laboratory training in university level science courses. However, before the intervention, the pre-service teachers stated that they occasionally encountered the concept of nature of science, but they were not taught what it is in any course they took. The course, therefore, in which the intervention of this study took place was their first formal introduction to the views of nature of science.

Context of the Study

This study is a case study conducted to explore the influence of a science teaching method course incorporating explicit reflective NOS instruction on pre-service science teachers' views of NOS and justifications in their arguments on socio scientific issues. Case study was defined as "an empirical inquiry that investigates a contemporary phenomenon within its real life context especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2008, p. 18). Therefore, case study design for the present study would allow in-depth exploration of NOS understandings of pre-service science teachers and their reflection of these

views in justifications of their arguments on socio scientific issues in which socio scientific issues served as a base to provide meaningful connections between science and one's life directly over explicit reflective NOS embedded science method course.

The intervention was carried on as part of a science teaching method course during a fall semester. The author and another instructor gave the course jointly. The overarching goal of the course was to provide participants with theoretical framework for teaching science at elementary level, and developing desired attitudes toward science and science teaching as well as having a deeper understanding of some science content and nature of science concepts. During the course, the participants were exposed to explicit reflective NOS instruction by means of several content-generic and content-embedded activities, reading samples, and discussions. Each activity had been undertaken through single class sessions which held weekly in 3-hour blocks throughout the semester. First, pre-service science teachers were introduced to the related concepts such as what science is, and what scientists do through an interactive discussion. Then, the difference between science and non-science was discussed through hands-on/minds on activities. The activities of "Tricky tracks", "Young? Old?", "The aging president", "Real fossil real science", "An activity for the first day of class", "Sequencing events", and "Black box" served to address the difference between observation and inference, the empirical basis of scientific knowledge, imaginative, subjective and tentative nature of scientific knowledge taken from the book "The nature of science in science education: Rationales and strategies" (McComas, 2006). In addition to these, the function of theories and laws were emphasized during the activities explicitly.

Data Collection

Merriam (2009) suggested to use, interviews, document analysis and observation as data collection tools in basic qualitative studies. Thus, data were collected by means of open ended questionnaires and interviews in this qualitative study.

The Views of Nature of Science (VNOS-C) Questionnaire

To track changes in teachers' NOS views, modified version of The Views of Nature of Science Questionnaire – Form C (VNOS-C) was administered as before and after the intervention followed by interviews for validity (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). VNOS-C contains 10 open ended questions addressing each NOS aspect. Through VNOS-C questionnaire, participants' views about what science is, subjectivity of science, tentativeness, creativity and imagination, scientific methods, empirical basis, socio cultural embeddedness were assessed. In addition, participants' views on the distinction between observation and inference as well as between theories and laws were assessed.

The Decision -Making Questionnaire (DMQ)

To examine students' justifications of socio scientific issues, the decision-making questionnaire by Bell and Lederman (2003) was administered as pre- and post-questionnaire. The questionnaire included three scenarios concerning science and technology issues; fetal tissue implantation, global warming, and the relationship between cigarette smoking and cancer. The scenarios are real-world issues with a connection to science and technology topics upon which a citizen might be expected to vote or make personal decisions (Bell & Lederman, 2003). These scenarios include some level of controversy, so they are suitable to construct arguments considering several perspectives. All scenarios were designed to engage participants in a complex decision-making process that is one of the main goals of current science education reforms (Bell & Lederman, 2003). After the passage, scenario was followed by three to five questions designed to elicit decisions and reasoning patterns. For the purpose of this study, participants' answers to SSIs were examined in terms of the justifications made to support their decisions regarding the cases.

Data Analysis

In the analyses of the two questionnaires, the unit of analysis is identified as a sentence in which the participant constructed a claim. Participants' NOS views were analyzed through transcription of VNOS-C questionnaire and coding of the interview responses. Responses were coded in three categories: informed (I), adequate (A) and inadequate (IN). Informed views are those indicating a fully developed understanding of the NOS aspects

including extended examples and deeper explanations. Adequate views indicate a developing view with explanations and examples given in class., and inadequate views indicate a misconception held by the student. Two researchers independently analyzed the responses and the differences resolved through discussion and consensus.

Participants' writings of their positions on socio-scientific cases were analyzed in terms of their justifications for their decisions. Justifications were identified as parts of the sentences which support the main claim and usually start with "because…" or lead to another sentence beginning with "Therefore, …". The grounds on which justifications were made were determined by open-coding for the responses provided by two participants. We looked for patterns in participants' responses, categorized the patterns, checked them against the data and literature, and modified accordingly through several rounds until the data was summarized efficiently. The resulting codes and categories were compared with the findings provided by Bell and Lederman (2003). The determined codes were discussed by two researchers for agreement. After determining the codes, two researchers independently analyzed the remaining three participants' responses. The inter-rater reliability was calculated over %90 for three participants. Each participant was given two letters to keep their identities secure through the analysis procedure and in the presentation of results part.

Results and Discussion

The research questions of the study were examined for each participant and presented to include the change in participants' NOS views assessed by VNOS-C over the course intervention, and change in participants' justifications in their arguments determined by their responses to SSIs and relation between participants' views of NOS and their justifications in their arguments on SSI over the science teaching method course.

The Change in Pre-Service Science Teachers' Views of Nature of Science

The participants of this study were 5 pre-service science teachers. Their views of nature of science were assessed by their responses to VNOS-C questionnaire and follow up interviews before and after the explicit teaching of NOS through a semester. By means of responses to VNOS-C questionnaire and follow-up semi structured interviews on NOS views participants' in-depth profiles of NOS understandings were created. Later, the change in each participant's NOS understanding regarding each aspect was described. Three types of categorization were used to define NOS understanding; inadequate (IN), adequate (A), and informed (I).

The participants were anonymously named as AE (male), MS, ED, BA, and JE (females). Figure 1 summarizes the change in their views of NOS with respect to the following aspects described in consensus view of NOS (Abd-El-Khalick, Bell & Lederman, 1998): Subjectivity in science, tentative nature of scientific knowledge, empirical-based nature of scientific knowledge, the role of inference in the process of scientific inquiry, the role of creativity of scientists in the construction of scientific knowledge, the social and cultural influences during scientific inquiry, and the difference between scientific theories and laws.

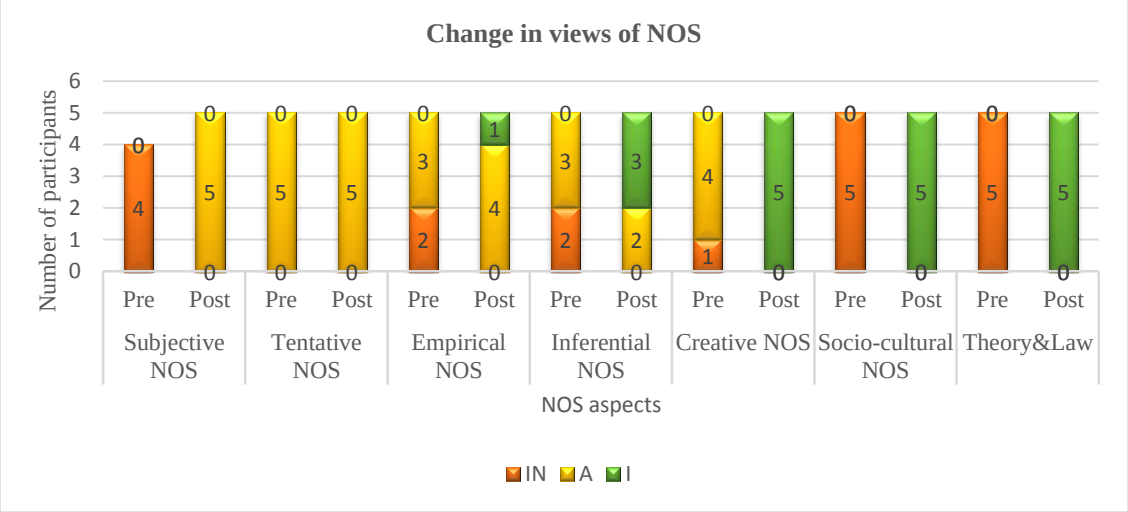

Figure 1. The change in participants' views of NOS

Figure 1 demonstrates the change in participants' views of NOS in seven aspects from mostly inadequate to adequate and informed. Specifically, the participants changed their views from inadequate to adequate or informed in the subjective nature of science (pre ninadequate=4, 1 no-response; post nadequate=5), socio-cultural nature of science (pre ninadequate=5; post ninformed=5), and views about theory and law (pre ninadequate=5; post ninformed=5). In regard to empirical-based nature of science (pre ninadequate=2, nadequate=3), inferential nature of science (pre ninadequate=2, nadequate=3), and creative nature of science (pre ninadequate=1, nadequate=4), participants' views in the pre- application of the questionnaire were mostly adequate but in the post- application, their views were either stayed as adequate or changed to informed (post empirical-based NOS nadequate=4, ninformed=1; inferential NOS nadequate=2, ninformed=3; creative NOS ninformed=5). The participants did not change their views on tentative nature of science between pre- and post-application of the questionnaire (nadequate=5). When we analyzed each participant individually, the results were as follows.

Participant 1- AE: AE had had inadequate views assessed by pre-test in some NOS aspects such as tentativeness, scientific methods, creativity and imagination and socio-cultural embeddedness of science. After the course, his views improved to adequate and informed views in these aspects. Participant 2- MS: MS had adequate view only on the role of observation and inference play in science when the pre-VNOS was administered. Over the course of intervention, she had developed her views on all aspects of NOS to either adequate or informed. Participant 3-ED: Analysis of pre-VNOS questionnaire revealed that ED had mainly inadequate views on NOS except having adequate views of observation and inference. However, ED made a shift toward having adequate views on all other aspects of NOS. The only view changed from adequate to informed is the one on observation and inference. Participant 4-BA: The participant's responses on pre-VNOS questionnaire revealed inadequate views on tentativeness, role of creativity and imagination at scientists' work, socio cultural embeddedness of science and function of theories and laws. However, over the course, participant showed enhancement related with these views by making a shift either adequate or informed view. Participant's views only remained the same for empirical-based nature of science over the course. Participant 5-JE: JE held adequate views on subjectivity, empirical basis and multiple scientific methods in science, but for the rest of the considered NOS aspects, she showed inadequate views prior to NOS instruction. However, she was holding either adequate or informed views over the course on all considered NOS aspects. Some quotations taken from the participants' responses to NOS questionnaire were presented in Table 1.

Table 1. Examples of the change in participants' views of NOS

Part.	**NOS**	**Before the intervention**	**After the intervention**
AE	Empirical NOS	*Adequate;* "Science is different from other disciplines by its aspects of to measure and having valid result that affect life of all living organisms"	*Adequate;* "Scientific knowledge is testable and based on observable data…"
	Inferential NOS	*Adequate;* "They examine some remaining that is belonging to animals. Also they make research on DNA."	*Informed;* "They gather some data like fossils and they infer that these fossils are not belong to any organism that known by scientists. Therefore, they refer to a different animal now known as dinosaurs."
MS	Subjective NOS	*Inadequate;* "The ancient times, there occurred lot of events which damage the world, so the scientists disagree about the cause of extinction of dinosaurs"	*Adequate;* "Scientist look at same events and an object but they can infer different conclusions.it is related to their prior knowledge, preconceptions and socio cultural environment which they live. All of these aspects can affect their work"
	Empirical NOS	*Inadequate;* "science people try to prove the reasons of some events. If they are not proved some experiments how we accept the truth of that event"	*Adequate;* "for example, in science we support our ideas with experiments or observations, however in religious or philosophy we cannot support our ideas such as existence of God"

Table 1. Examples of the change in participants' views of NOS (Cont.'d)

Part.	NOS	Before the intervention	After the intervention
MS	Inferential NOS	*Inadequate;* "They proved the existence of dinosaurs with finding and examining fossils"	*Informed;* "they make inferences according to their observations…. Actually they are not too much certain because they make dinosaurs models according to bigness and shape of fossils"
	Theory & Law	*Inadequate;* "Theory is the truthiness of a hypothesis, but it is not exact …Law is the rule of unchangeable things. Laws cannot be change"	*Informed;* "Theory is the explanations of natural phenomena. It can change because scientific knowledge is not absolute and subject to change… Law explains the relationship between some phenomena. It can change… there is difference. Scientific law explains relationships while scientific theories give explanations to phenomena. Newton's law of gravity shows us. There is a gravitational force but it does not have a theory because Newton could not explain the reason of gravitational force"
ED	Inferential NOS	*Inadequate;* "Bone findings that scientists found, proved the dinosaurs really existed"	*Adequate;* "They found fossils of dinosaurs"
	Creative NOS	*Adequate;* "Yes... Let's think about the mobile phone. If scientists do not use their creativity or they don't imagine the mobile phones would not like today's model, I think all technological development includes imagination and creativity of scientific people"	*Informed;* "The structure or appearance of dinosaurs are the reflection of the creativity /imagination of scientists. Therefore, it is not certain knowledge… In every part of the investigation, scientists use their imagination and creative. In the black box experiment we saw this. We thought about what we observe and we try to find an answer what we cannot observe"
BA	Empirical NOS	*Adequate;* "To develop science evidences are needed and experiments are required to provide evidences. For example, it is not enough to say boiling point of water is 100^0C.To make that knowledge a scientific one experimental evidences are needed"	*Informed;* "Empirical based nature of science makes it different from other subjects. It depends on observations and experimental results but other disciplines do not need observations …From the fossils –bones (evidence) scientists know that dinosaurs existed"
JE	Empirical NOS	*Adequate;* "It (Science) can be explained by observations and experiments"	*Adequate;* "Scientific knowledge is supported by evidence"
	Inferential NOS	*Adequate;* "observe fossils again, their bone structure and bone shape therefore they can obtain some ideas about now dinosaurs looked"	*Informed;* "They investigate some dinosaur fossils. They have done some observations inference and experiments on the bones of dinosaurs. Therefore, they conclude that dinosaurs were really existed"
	Creative NOS	*Inadequate;* "because for being a scientist they should be objective. they should ass's results truly and objectively. With imaginations they cannot result true answer"	*Informed;* "Scientists use their creativity in every step of science process skills. Because their interpretations and ideas can be different other scientist… For example, a scientist who looks a fly can think that I can make a machine that fly. He/she uses their creativity while looking fly also she /he uses creativity while designing a model"

The Change in Pre-Service Science Teachers' Justifications of Socio-scientific Issues

The participants' responses to socio-scientific scenarios were examined for their justifications of decision-making assessed by their responses to DMQ questionnaire before and after the explicit teaching of NOS through a semester. By means of responses to DMQ questionnaire, the justifications were categorized based on their sources. For example, if a participant brings the ethical considerations to the forefront to justify his/her decision, the source of this justification was coded as ethics. However, these codes or categories were not always clear-cut, rather, in some responses the justifications are quite intertwined. For example, in a response to Case 2 about global warming, one of the participants argued that

> Yes, there must be laws because it is a fact that greenhouses gases increase the level of CO2 in the atmosphere. This much CO2 will absolutely lead to instability in the ecosystem. It may also have a negative impact on economy, but human life and health comes first.

In this response, the social right to live healthy, economy perspective, environmental concerns are all included in a few sentences. In such a case, we chose to identify all categories and codes individually even when they are in one sentence instead of deciding just to one category. In the analysis of the participants' justifications in this study, we first open-coded the responses and then compared our categories with the ones in the study by Bell and Lederman (2003). The resulting codes and categories were given in Table 2.

Table 2. The sources of justifications resulted in the participants' responses

The Source of Justification	Consideration	Example
Ethics	Humanity	"If the embryo is going to die, this would be depriving the baby's right for healthy living"
Ethics	Social responsibility	"They don't think if other people is going to be disturbed or not"
Religion		"The God decides who is going to live"
Pedagogical		"Because small children cannot be conscious about the harm, they emulate the behavior"
Legality		"If the legal allowed time for abortion is exceed, this might be bad for them"
Science	Conservation of nature	"Global warming is a disaster for the Earth, so all precautions are acceptable"
Science	Empirical	"Because most of the patients were getting better by the treatment"
Science	Empirical	"If the treatment has found to be successful by lots of experiments"
Social	Rights	"If they don't want to have a baby, the decision is theirs"
Social	Economy	"I am sure that most people will not support because it is beyond their effort (money)"
Personal		"As well as I know by my friends, it is hard to give up if you get used to it early in your childhood"

When we analyzed each participant individually, the results and some quotations taken from the participants' responses to pre- and post-DMQ questionnaire were as follows.

Participant 1- AE: Regarding the source of justifications, he relied on ethical, religious, and pedagogical reasoning to make decisions on SSI before the intervention. For example, regarding case-1 about fetal tissue implantation, he emphasized the religious views as follows:

> God gives the right to live or to die… A decision to kill the baby will be a murder.

After the NOS instruction, there was not much difference especially on ethical and religious grounds for him. He added legality perspective regarding the 3rd case related to smoking. He justified his decision by writing

> Smoker does not only harm himself/herself, but also the others around. To protect citizens' right to healthy living is responsibility of government and the state, so there must be a law that bans smoking in public.

Participant 2- MS: MS had ethic, legality, science, and pedagogical considerations in her responses in the pre-questionnaire. The following justification of her, which is grounded on pedagogical considerations did not appear in her post-DMQ.

> Children are influenced what or who they observe around.

In the post-questionnaire, she had more considerations related to science in the scenarios about global warming and smoking. She usually thought about legality in addition to conservation of nature in her post-DMQ. For example, regarding case-2 about global warming, she wrote that

> If we damage the stability of the nature, this will have an impact on our life… These resources are dangerous for Earth… There should be limitations to save the other living beings and the environment because it increases the global warming.

Participant 3-ED: Analysis of pre-DMQ questionnaire revealed that ED used justifications that she drew from science and ethics mostly. She rarely mentioned the social considerations. For example, as a social consideration, she wrote that

> If they would like to donate the tissue, I think nobody has right to prevent them to do so

In contrast, in her post-DMQ responses, she pointed out the social and pedagogical concerns as well to decide. For example, she emphasized that

> It is sad that smoking age is decreased

Participant 4-BA: BA had already been using various sources of justifications to make connections in her decisions. For example, she justified her decision referring to science, ethics, legality, pedagogical and social grounds. Her justifications on social grounds was more related to economy before the intervention. For example, she wrote that

> I think smoking is a big stroke to the family budget and to the economy of the country.

In the post-DMQ, she increased the number of justifications, and she started to make decision based on human rights in social grounds. In her responses, at several points, she wrote that

> In closed spaces, people who do not smoke are feeling uncomfortable because of the people who smoke. I think this is injustice for those who don't smoke.
>
> … Their right to have quality time has been taken from them

Participant 5-JE: The participant had grounded her justifications to a variety of sources related to SSI. In the pre-DMQ, she based her justifications on social rights and economy, pedagogy, legality, science, and ethics from the perspective of social responsibilities. In the post-DMQ, she did not emphasized justifications based on legality. The number and the variety of her justifications decreased with respect to the pre-DMQ.

The change in participants' justifications in pre- and post-DMQ questionnaire were presented in Table 3. When the table examined, the individual differences come into prominence rather than the general patterns. In other words, the changes observed in the participants' justifications were not alike, and did not show any pattern. While the number of justifications increased in the responses of some of the participants (ED, BA), there was a decrease in others' (AE, MS, JE). The sources of justifications were not differentiated among the participants. There were certain categories repeated in cases and in pre- and post-DMQ. When examined for each participant, 1 of the participants (AE) used at least one more different source to ground his justifications. For the other 3 (MS, BA, JE), the variety of grounds on which the justifications were constructed were less than the ones in the pre-DMQ. For the participant ED, although the sources varied, the number of sources were the same between pre- and post-DMQ.

The summary of the change in their NOS views were assessed by pre-post application of VNOS (Lederman, et.al, 2002) questionnaire and the change in their justifications were detected through pre-post responses to the DMQ (Bell & Lederman, 2003) were presented in Table3.

Table3. The change in participants' justifications

		The Source of Justification			
Participant		**Before the intervention**	**#**	**After the intervention**	**#**
AE	Case 1	Ethic (Humanity) Religion	2 1	Ethic (Humanity) Religion	2 3
	Case 2	Ethic (Social Responsibility)	1	Ethic (Social Responsibility)	1
	Case 3	Pedagogy Ethic (Social Responsibility)	1 1	Pedagogy Legality	1 1
	AE Total	4 types	6	5 types	8
MS	Case 1	Ethic (Humanity) Legality	2 1	Ethic (Humanity) Legality	1 1
	Case 2	Science (Conservation of Nature)	2	Science (Conservation of Nature) Legality	2 1
	Case 3	Ethic (Social Responsibility) Science Pedagogy	1 1 1	Ethic (Social Responsibility) Science	1 1
	MS Total	6 types	8	5 types	7
ED	Case 1	Science (Empirical) Social (Rights) Ethic (Humanity)	1 1 1	Science (Empirical) Social (Rights)	1 1
	Case 2	Science (Empirical) Ethic (Social Responsibility)	1 3	Science (Empirical) Legality Science (Conservation of Nature)	1 1 1
	Case 3	Science (Empirical) Science	1 1	Science (Empirical) Pedagogy Legality	1 1 3
	ED Total	5 types	9	5 types	10
BA	Case 1	Science Ethic Legality	1 1 2	Science (Empirical) Ethic	1 1
	Case 2	Science (Empirical) Ethic (Social Responsibility) Science (Conservation of Nature)	2 1 1	Science (Empirical) Ethic (Social Responsibility) Science (Conservation of Nature) Legality	1 1 1 2
	Case 3	Social (Economy) Pedagogy Science (Empirical)	1 1 1	Social (Rights) Pedagogy Science (Empirical) Ethic (Social Responsibility)	2 1 1 2
	BA Total	8 types	11	7 types	13
JE	Case 1	Social (Rights) Science	1 2	Social (Rights) Science (Empirical)	1 2
	Case 2	Science Legality Social (Economy) Science (Empirical)	1 1 1 2	Social (Rights) Social (Economy) Science (Empirical)	1 1 2
	Case 3	Pedagogy Legality Social (Rights) Ethic (Social Responsibility)	2 1 1 1	Pedagogy Social (Rights) Ethic (Social Responsibility)	1 1 2
	JE Total	7 types	13	5 types	11
		Total	47		49

Conclusion

The purpose of the study was to explore how pre-service teachers' views of NOS was related with their justifications of SSI and if their justifications change following an explicit NOS instruction. To accomplish this task, participants were exposed to explicit reflective nature of science instruction through a fall semester of science method course. The change in their NOS views were assessed by pre-post application of VNOS (Lederman, et.al, 2002) questionnaire and the change in their justifications were detected through pre-post responses to the DMQ (Bell & Lederman, 2003). The examination found that participants improved their NOS views for all NOS tenets except tentative NOS aspect. Pre-service teachers lacked NOS understanding prior to

explicit reflective NOS instruction was not a surprise because previous studies reported that both pre- and in service teachers needed to scrutinize and improve their NOS views for more informed understanding of how science works through NOS instruction (Bell, Matkins, & Gansneder, 2011; Tasar, 2006). Pre-service teachers learning experiences with science and textbooks' illustrations of science as a factual knowledge lacking human creativity and imagination were claimed to be main causes that pre-service teachers constructed more positivist views of science (Abd-El-Khalick, Waters & Le, 2008; Niaz & Maza, 2011). However, as applied in current research, explicit reflective NOS instruction provided learning environment for pre-service teachers to revise and refine their NOS views (Abd-El-Khalick, & Akerson, 2004). Through the explicit reflective NOS instruction, pre-service teachers could be able to think about their initial NOS concepts, revise their concepts, and reflect on their relative status of these concepts without pressure of understanding of science concepts (Abd-El-Khalick & Akerson, 2004). The analysis of data revealed that pre-service teachers achieved either adequate or informed views in almost all NOS aspects. The variation in the development of NOS views as adequate or informed might stem from several reasons. First, the duration of the intervention might not be enough for them to internalize NOS concepts and develop informed views. The other possible explanation raised by Mesci and Schwartz (2016) is that to get a deeper understanding of NOS concepts individuals need to have meta-cognitive value among the instructional, motivational, and socio-cultural factors that explain the variability in internalization of NOS aspects. In current case, the pre-service teachers might not recognize their flaws related to NOS concepts and might not pay attention NOS as an important aspect of their teaching enough.

Interestingly, in this study, all of the pre-service science teachers showed adequate understanding of tentative NOS even at the outset of the study and they did not improve their views to informed tentative NOS views. Participants' adequate tentative NOS views might be related to their experiences with informal learning opportunities. That is, these kinds of learning settings might convey more appropriate messages related to tentative NOS. As Hogan (2000) proposed they built more appropriate view of NOS based on their own personal experiences with science. Regarding no change in their creative NOS views over the explicit reflective NOS instruction, the claim proposed by Mesci and Schwartz (2016) applied the situation here. That is, since pre-service science teachers did not find any flaws or lack in their tentative NOS conceptions, they did not pay enough attention to revise their NOS concepts.

Regarding pre-service science teachers' justifications revealed in responses to DMQ, they used variety of sources of justifications in both pre and post responses. The analysis did not show any difference between pre and post responses regarding their sources and variety of justifications. Only slight changes were detected related to sources of justifications. Participants grounded their decisions primarily on personal values, morals/ethics, and social considerations. This result was opposed with the claim that one's understanding of NOS had an impact on their decision making process (Cook & Buck, 2013; Kolsto, 2001b; Sadler, Chambers, & Zeidler, 2004). Consistent with that claim, Bell and Lederman (2003) also reported no relationship between university professors' NOS views and their justifications in their positions for socio-scientific issues. Keeping in mind that there might be no connection between NOS views and decision making for socio scientific issues, there have been some claims that explicit instruction on socio scientific argumentation skills and guidance in addressing NOS conceptualization during decision making process helped learners better support their positions in their responses (McDonald & McRobbie, 2012; Zohar & Nemet, 2002). However, in current study, no specific argumentation or SSI instruction had been provided with pre-service teachers. Thus, further studies should address how NOS views impact decision making process in which learners provided with explicit SSI instruction.

Interestingly, in the responses to the second case related to global warming, three of the participants increased the number of justifications they provided in their post answers to the DMQ. Several researchers stated that the decision making on SSI issues required in depth conceptualization of the science content (Erduran & Jimenez-Aleixandre, 2012). Additionally, the participants' personal experience as well as familiarity regarding SSI had impact on the variety and source of justifications one provided in responses to SSI issues (Albe, 2008; Topçu, Yılmaz-Tüzün, & Sadler, 2011). In current case, global warming as a SSI issue could be familiar to the pre-service teachers through some elective courses they took in their teacher education program, or through media and some informal learning settings, and these personal experiences could result in higher number of justifications in responses to the DMQ.

In conclusion, current research reported no association between the change in NOS views and their justifications of SSI. However, keeping in mind nature of qualitative research, the findings of the study could not be generalized and to some extent be limited to the context of the explicit reflective NOS instructed science method course. Further research is necessary to better understand the complex relationship between NOS understanding

and justifications of SSI. Perhaps better judgments could be made regarding the relationship between NOS views and justifications of SSI if longitudinal research embodied contextualized explicit reflective NOS instruction and guidance of SSI decision-making have been conducted.

References

Abd-El-Khalick, F. (2014). The evolving l and scape related to assessment of nature of science. In Abell, & N. G. Lederman (Eds.), Handbook of research on science education (volume II, pp. 621–650). New York, NY: Routledge.

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. Science Education, 88(5), 785-810.

Abd-El-Khalick, F. & Lederman, N.G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. International Journal of Science Education, 22, 665 – 701.

Abd- El- Khalick, F., Waters, M., & Le, A. P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. Journal of Research in Science Teaching, 45(7), 835-855.

Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: Students' argumentation in group discussions on a socio-scientific issue. Research in Science Education, 38(1), 67-90.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. Science Education, 95(3), 518–542.

Allchin, D. (2012). Toward clarity on whole science and KNOWS. Science Education, 96(4), 693–700.

Bell, R. L., & Lederman, N. G. (2003). Understanding of the nature of science and decision making on science and technology based issues. Science Education, 87(3), 352-377.

Bell, R. L., Matkins, J. J., & Gansneder, B. M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. Journal of Research in Science Teaching, 48(4), 414-436.

Billig, M. (1987). Arguing and thinking: A rhetorical approach to social psychology. Cambridge, UK: Cambridge University Press.

Boran, G. H., & Bag, H. (2016). The influence of argumentation on understanding nature of science. International Journal of Environmental & Science Education, 11(6), 1423-1431.

Cinar, D., & Bayraktar, S. (2014). Evaluation of the effects of argumentation based science teaching on 5th grade students' conceptual understanding of the subjects related to "Matter and Change". International Journal of Education in Mathematics, Science and Technology, 2(1), 49-77.

Cook, K. L., & Buck, G. A. (2013). Pre-service teachers' understanding of the nature of science through socio-scientific inquiry. Electronic Journal of Science Education, 17(1), 1-24.

Dawson, V., & Carson, K. (2016). Using climate change scenarios to assess high school students' argumentation skills. Research in Science & Technological Education, Online first.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84, 287-312.

Erduran, S. (2014). Revisiting the Nature of Science in science education: Towards a holistic account of science in science teaching and learning. Proceedings of the Frontiers in Mathematics and Science Education Research Conference, 14–25.

Erduran, S., & Dagher, Z. (2014). Reconceptualizing the nature of science in science education. Dordrecht, The Netherlands: Springer.

Erduran, S., & Jiménez-Aleixandre, M. P. (2012). Argumentation in science education research: Perspectives from Europe. In D. Jorde, & J. Dillon (Eds.), Science education research and practice in Europe: Retrospective and Prospective (pp. 253-289). Rotterdam, The Netherlands: Sense Publishers.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. Science Education, 88, 915-933.

Hodson, D. (2003). Time for action: Science education for an alternative future. International Journal of Science Education, 25(6), 645–670.

Hogan, K. (2000). Exploring a process view of students' knowledge about the nature of science. Science Education, 84(1), 51-70.

Kampourakis, K. (2016). The "general aspects" conceptualization as a pragmatic and effective means to introducing students to nature of science. Journal of Research in Science Teaching, 53(5), 667-682.

Karisan, D., & Topcu, M. S. (2016). Contents exploring the preservice science teachers' written argumentation skills: The global climate change issue. International Journal of Environmental & Science Education, 11(6), 1347-1363.

Kelly, G. J., Regev, J., & Prothero, W. (2007). Analysis of lines of reasoning in written argumentation. In Argumentation in science education (pp. 137-158). The Netherlands: Springer.

Khishfe, R. (2012). Nature of science and decision-making. International Journal of Science Education, 34(1), 67-100.

Khishfe, R. (2014). Explicit nature of science and argumentation instruction in the context of socioscientific issues: An effect on student learning and transfer. International Journal of Science Education, 36(6), 974-1016. doi:10.1080/09500693.2013.832004

Kolsto, S. D. (2001a). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. Science Education, 85, 291-310.

Kolstø, S.D. (2001b). To trust or not to trust, ... —pupils' ways of judging information encountered in a socio-scientific issue. International Journal of Science Education, 23,877 – 901.

Kolsto, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socio-scientific issue. International Journal of Science Education, 28(14), 1689-1716.

Kolsto, S. D., & Ratcliffe, M. (2008). Social aspects of argumentation. In S. Erduran, & M. P. Jiménez-Aleixandre (Eds.), Argumentation in science education: Perspectives from classroom-based research (pp. 116-136). Dordrecht: Springer.

Lederman, N. G., Abd- El- Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. Journal of Research in Science Teaching, 39(6), 497-521.

Lederman, N. G., & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In Abell, & N. G. Lederman (Ed.), Handbook of research on science education (volume II; pp. 600–620). New York, NY: Routledge.

Lin, S. S., & Mintzes, J. J. (2010). Learning argumentation skills through instruction in socioscientific issues: The effect of ability level. International Journal of Science and Mathematics Education, received from http://www.springerlink.com/index/9654h6u2501x8642.pdf.

Mesci, G., & Schwartz, R. S. (2016). Changing Preservice Science Teachers' Views of Nature of Science: Why Some Conceptions May Be More Easily Altered than Others. Research in Science Education, 1-23.

McComas, W. F. (Ed.). (2006). The nature of science in science education: Rationales and strategies (Vol. 5). Springer Science & Business Media.

McDonald, C. V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. Journal of Research in Science Teaching, 47(9), 1137-1164.

McDonald, C. V., & McRobbie, C. J. (2012). Utilising argumentation to teach nature of science. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), Second International Handbook of Science Education (Vol. 2, pp. 969-986). Dordrecht: Springer.

Merriam, S. B. (2009). Qualitative research: A guide to design and implementation: Revised and expanded from qualitative research and case study applications in education. San Franscisco: Jossey-Bass.

Mun, K., Shin, N., Lee, H., Kim, S.-W., Choi, K., Choi, S.-Y., & Krajcik, J. S. (2015). Korean secondary students' perception of scientific literacy as global citizens: Using global scientific literacy questionnaire. International Journal of Science Education, 37(11), 1739-1766.

Namdar, B., & Shen, J. (2016). Intersection of argumentation and the use of multiple representations in the context of socioscientific issues. International Journal of Science Education, 38(7), 1100–1132.

Niaz, M., & Maza, A. (2011). Nature of science in general chemistry textbooks. In Nature of Science in General Chemistry Textbooks (pp. 1-37). The Netherlands: Springer.

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. Science Education, 88(2), 263–291.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. Journal of Research in Science Teaching, 41(5), 513-536.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? Research in Science Education, 37(4), 371-391.

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. International Journal of Science Education, 26(4), 387-409.

Saglam, Y., Kanadli, S., Karatepe, V., Gizlenci, E. A., & Goksu, P. (2015). Dialogic discourse in the classroom. International Journal of Education in Mathematics, Science and Technology, 3(4), 322-335.

Sampson, V., & Clark, D. B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. Science Education, 92(3), 447-472.

Sampson, V.D., & Clark, D.B. (2006). The development and validation of the nature of science as argument questionnaire (NSAAQ). Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching (NARST), San Francisco, CA.

Simonneaux, L. (2001). Role-play or debate to promote students' argumentation and justification on an issue in animal transgenesis. International Journal of Science Education, 23(9), 903-927.

Simonneaux, L. (2008). Argumentation in socio-scientific contexts. In S. Erduran, & M. P. Jiménez-Aleixandre (Eds.), Argumentation in science education: Perspectives from classroom-based research (pp. 179-199). Dordrecht: Springer.

Tasar, M. F. (2006). Probing preservice teachers' understandings of scientific knowledge by using a vignette in conjunction with a paper and pencil test. Eurasia Journal of Mathematics, Science and Technology Education, 2(1), 53-70.

Topçu, M. S., Yılmaz-Tüzün, Ö., & Sadler, T. D. (2011). Turkish pre-service science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning. Journal of Science Teacher Education, 22, 313-332.

Toulmin, S. E. (1958). The uses of argument. Cambridge: Cambridge University Press.

Yerrick, R. K. (2000). Lower track science students' argumentation and open inquiry instruction. Journal of Research in Science Teaching, 37, 807–838.

Yin, R. K. (2008). Case study research: Design and Methods (4th edition). Newbury Park, CA: Sage.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. Journal of Elementary Science Education, 21(2), 49-58.

Zeidler, D. L., & Sadler, T. D. (2008). Social and ethical issues in science education: A prelude to action. Science & Education, 17(8), 799-803.

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. Science Education, 86(3), 343 – 367.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. Journal of research in science teaching, 39(1), 35-62.

Author Information

Dr. Kader Bilican
Kırıkkale University
Turkey
Contact email: *kaderbilican@gmail.com*