REVIEW ARTICLE

Assessing Teachers' Competencies in Identifying Aspects of Nature of Science in Educational Critical Scenarios

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ABSTRACT

Many scholars and science curricula from around the world describe socioscientific issues (SSIs) as meaningful contexts for teaching about the nature of science (NOS). These calls are guided by the assumption that science teachers are able to identify relevant aspects of the NOS in a given SSI and to decide how to utilize these for NOS instruction. To this end, this study aimed to assess a group of science teachers' competencies in identifying aspects of the NOS in various educational critical scenarios (ECS) featuring different SSI. 15 science teachers' understandings of the NOS were assessed through interviews and their competence in identifying aspects of the NOS in given ECSs was addressed through an open-ended questionnaire. The results indicated that, although all of the participants had informed views regarding the majority of the aspects of the NOS, the majority of them failed to transfer this knowledge and could not exhibit similar competence in identifying some aspects of NOS in ECSs. This implies that having an informed understanding of the NOS does not guarantee effective translation of this understanding into the classrooms.

KEY WORDS: nature of science; socioscientific issues; in-service teacher education; science teacher; competencies

INTRODUCTION

The 21st century has experienced more social transformations than any other period in history due to the introduction of sophisticated communication technologies and recent developments in science. In this "science and technology era," scientific literacy has emerged as an important aim for science education. The term "scientific literacy" is widely seen as meaning the ability to appraise scientific information critically and to participate in (informed) decision-making processes in real-world social issues (DeBoer, 1991) and appreciate science as a part of contemporary culture (Hanuscin, 2013). Although there may be different conceptions of scientific literacy, it is generally agreed that understanding the nature of science (NOS) is an essential component of scientific literacy and public engagement with science (AAAS, 1994; Millar, 2006; and NRC, 1996). In this sense, developing understandings about the NOS have been a central goal of science education reform aiming to achieve scientific literacy (AAAS, 1994; Achieve, 2013; NRC, 1996; and Nuffield Foundation, 2009).

In general, the NOS is defined as the ontological and epistemological foundations of science, a way of knowing or essential characteristics of scientific knowledge and its development (Lederman, 1992). McComas (2004) considers the NOS as "the sum total of the rules of the game leading to knowledge production and evaluation of truth claims in the natural sciences" (p. 25). There is a general agreement in the science education community about enhancing learners' understanding of NOS. Furthermore, a significant academic consensus has been achieved on aspects of the NOS to be taught in school science (Lederman, 2007). These aspects include scientific knowledge is tentative, based on empirical evidence, subjective, the product of human imagination and creativity, socially, and culturally embedded. In addition, there is a general agreement that students should be informed about the distinction between observation and inference and the nature and relationship between theories and laws (Lederman, 2007).

Research has been conducted regarding the assessment and development of NOS understandings in the last few decades. This research base indicates that students generally do not have informed views on the NOS and that the development of functional and adequate NOS understandings in students is a difficult goal to achieve (Deng et al., 2011 and Lederman, 1992). Despite these difficulties, researchers have managed to describe several important contexts and approaches, which make the NOS accessible to students. These include, but not limited to, inquiry-based teaching (Akerson and Hanuscin, 2007 and Lederman et al., 2014), using the history of science (McComas and Kampourakis, 2015) and argumentation (McDonald, 2010). One of the most important contexts offered by science educators is utilizing socioscientific issues (SSIs) in science education (Khishfe, 2014).

SSI refers to social science-based problems that are open ended and ill structured (Kolsto, 2001 and Sadler and Zeidler, 2005) such as global warming and genetically modified food. These issues are controversial in nature and do not have discrete right or wrong answers. By definition, SSIs deal with content that is uncertain, evolving, and socially relevant. These issues are frequently reported in the media, described and debated in blogs and websites, and discussed through social media (Sadler et al., 2015). SSI provides students with opportunities for not only using scientific reasoning but also considering social, economic, and moral dimensions (Sadler, 2009). Therefore, SSI has the potential to engage students' interest (Eastwood et al., 2012). Researchers also agree that addressing SSI in the classroom provides a point for coping with several components of scientific literacy (see, for example, Sadler, 2004), enable learners to realize the connection of science and their lives, and to make informed decisions about SSI. Informed decision-making would provide citizens the opportunity to play a more active and effective role in society and increase citizens' awareness of their personal choices and decision play in delivering sustainable development (Ratcliffe and Grace, 2003).

SSI is considered an important means in communicating the NOS in school science. Zeidler et al. (2011) have emphasized that using SSI as a context in the classroom may be helpful to develop NOS understandings. Several other researchers have also advocated that SSI can be used to encourage students to discuss central processes of science (Bell and Lederman, 2003; Sadler et al., 2004; Walker and Zeidler, 2007; Zeidler et al., 2009; and Zeidler et al., 2002). This discussion has been supported by several empirical studies. Walker and Zeidler (2007), for example, designed a unit about genetically modified food to promote student discussion about NOS aspects. A qualitative approach was utilized to analyze students' understanding of NOS that was expressed in response to interview questions. They also analyzed classroom debate to examine features of argumentation as well as students' understanding of NOS. They reported that although students' NOS understanding was not apparent in the classroom discussion, written answers to interview questions related to NOS showed an improvement of students' NOS conceptions, especially on the tentative NOS, creativity in science, the subjective NOS, and the science and society relationship.

Another study assessing the relationship between NOS and SSI was designed by Eastwood et al. (2012). In this study, two high school classes were selected as SSI groups and another two were selected as content groups. Both groups received explicit-reflective NOS instruction at the beginning of the year. After the instruction, the SSI groups were taught by the SSI framework using 10 major SSI themes regarding anatomy and physiology, whereas content groups were taught using traditional, content and textbook-driven lecture, and laboratory approaches. It is important to note that as the semester progressed, the instructor adapted integrated approaches for both groups to make explicit connections between features of the NOS and content. The analyses revealed that both groups significantly improved their NOS understanding; however, the SSI groups used various effective examples when presenting their understanding of social\cultural aspects of NOS. Researchers concluded that the SSI-based learning environment could provide effective context for developing students' NOS understanding.

In light of such research findings and discussions, many science education reform documents have started to include SSI as a productive context for teaching and learning of NOS. The revised elementary science curriculum introduced in 2018 in Turkey, for example, has emphasized the importance of utilizing SSI in science classrooms stating one of the important aims of science education was, "Developing scientific thinking habits, reasoning, and decision-making skills of students through utilizing SSI" (MNE, 2018. p. 11).

No doubt, the emphasis put on SSIs by science curricula is important; however, it is surely the science teachers' role to facilitate effective curriculum planning and delivery, including the development and use of appropriate learning contexts and teaching strategies (Irez, 2016). In this sense, science teachers are one of the most important players in teaching the NOS as their understandings and approaches are the key determinants of what is learned in the classrooms. As Abd-El-Khalick and Lederman (2000) emphasized, teachers' need:

> …Knowledge of a wide range of related examples, activities, illustrations, demonstrations, and historical episodes. These components would enable the teacher to organize, represent, and present the topic for instruction in a manner that makes the target aspects of NOS accessible to pre-college students. Moreover, knowledge of alternative ways of representing aspects of NOS would enable the teacher to adapt those aspects to the diverse interests and abilities of learners. (pp. 692-693)

Although the recent literature on SSI for teaching NOS presents promising results, it seems that it is simply guided by the assumption that science teachers are able to identify relevant NOS aspects in a given SSI and to decide how to utilize these for NOS instruction. However, SSI contains complex and multifaceted dimensions such as economical, societal, ethical, and epistemological. NOS is only one of these dimensions. In this respect, teachers' competence to identify relevant NOS aspects in various SSI and to decide how to utilize these for NOS instruction becomes an important issue. To this end, this research aimed to address a group of science teachers' competencies in identifying relevant NOS aspects in various SSI scenarios and their views about how to utilize these for NOS instruction.

METHODOLOGY

The Context of the Study and the Participants

This study was conducted in the context of a professional development project aimed at developing science teachers' understanding about NOS. Participants of this study were 15 elementary science teachers (teaching grades 5 through 8) that had voluntarily attended this large-scale teacher professional development project. The demographic information about the participating teachers is provided in Table 1.

As seen in Table 1, nine of the participants were female and six of them were male. Four participants reported that they had Master of Science degrees. Participating teaching time in service varied from 1 to 17 years. At the time of the study, all of the participants were working in state schools in the city of Bolu and its surrounding districts. Bolu is a city located at the North-west region of Turkey.

The Scientific and Technological Research Council of Turkey funded this project. Three universities in Turkey and the Turkish Ministry of National Education collaborated in this project. The intervention process with the science teachers consisted of 10 monthly meetings with teachers, each lasting about 8 h, over two semesters. In this process, the teachers were introduced to various aspects of NOS relevant to school science through well-known activities in science education literature in a collaborative and reflective environment and ways of using explicit instruction (Abd-El-Khalick and Lederman, 2000 and Khishfe and Abd-El-Khalick, 2002). Enough teaching activities and materials were provided to participating teachers to implement in their classrooms for a year of teaching. During this process, an explicit-reflective NOS instruction was used as a pedagogical framework in the context of 57 content-specific NOS activities, which were developed by the project team in collaboration with the participating teachers.

The current study took place at the end of this professional development project. The aim was (1) to assess if the participating science teachers developed the desired understanding regarding the NOS and (2) if this understanding was enough to recognize and locate discussions related to NOS in SSI scenarios.

Data Collection

Data were collected through interviews and an open-ended questionnaire at the end of the professional development project. Both the interviews and open-ended questionnaire were conducted in Turkish, as Turkish was the native language of the participants. The analysis of the interviews and open-ended questionnaire was made in Turkish too, only the parts reported in this study were translated to English. The researchers of this study are Turkish nationals but conducted their postgraduate studies in the UK or the USA. Therefore, as bilinguals, all of the researchers contributed to the translation process.

The participants' understandings of NOS were assessed through face-to-face interviews. These interviews were semi-structured in nature and the questions of the Views on NOS Questionnaire, Form C (VNOS-C) developed by Lederman et al. (2002) were utilized as the questions of the interview guide. Although the original questionnaire was developed as a paper-and-pencil instrument, the questions have been shown to be appropriate for use in interviews (Irez, 2006). VNOS-C is a well-established instrument in terms of face and content validity and has been used in several studies with students, pre-service teachers, and in-service teachers (Lederman, 2007).

Table 1: The demographic information about the participating teachers (all names are pseudonyms)

Teachers	Gender	Teaching experience	Degree
Harun	Male	6	Bachelor
Yelda	Female	4	M.Sc.
Buse	Female	17	Bachelor
Zehra	Female	3	Bachelor
Lara	Female	6	Bachelor
Akın	Male	12	Bachelor
Oya	Female	2	Bachelor
Mete	Male	1	Bachelor
Fulya	Female	13	Bachelor
Gamze	Female	9	M.Sc.
Sevgi	Female	5	M.Sc.
Sarp	Male	10	Bachelor
Can	Male	16	Bachelor
Efe	Male	12	Bachelor
Duru	Female	5	M.Sc.

Teachers' competence to identify NOS issues in SSI was assessed through an open-ended questionnaire. The questionnaire featured five SSI scenarios entitled "Dinosaurs," "Global warming," "Cholesterol," "Ozone layer," and "Classification." These scenarios were used to assess teachers' competence in identifying relevant NOS aspects. We called these scenarios "Educational Critical Scenarios" (ECSs) since each scenario was constructed to provide a context enabling the teacher discuss critically some of the central processes of science during instruction. Some of the ECSs were taken from current literature and some developed by the researchers in the light of contemporary socioscientific discussions. Each scenario embraced one to three NOS aspects (the empirical NOS, the tentative NOS, subjectivity in science, creativity and imagination in science, or the science-society relationship). The relevant research base guided the researchers in preferring to utilize these aspects of NOS in ECSs. The research in this field indicates that using SSI as a context could help science teachers to bring several aspects of NOS into classroom discussion, especially those about the tentative NOS (Eastwood et al., 2012; Khishfe and Lederman, 2006; Sadler et al., 2004; Walker and Zeidler, 2007; and Zeidler et al., 2002), the empirical NOS (Eastwood et al., 2012; Khishfe and Lederman, 2006; Sadler et al., 2004; and Zeidler et al., 2002), science and society (Eastwood et al., 2012; Khishfe and Lederman, 2006; Sadler et al., 2004; Walker and Zeidler, 2007; and Zeidler et al., 2002), the subjective NOS (Khishfe and Lederman, 2006 and Walker and Zeidler, 2007), and creativity and imagination in science (Eastwood et al., 2012; Khishfe and Lederman, 2006; Walker and Zeidler, 2007; and Zeidler et al., 2002). Table 2 presents the embedded aspect(s) of NOS in each scenario.

To ensure that the scenarios embraced intended NOS aspect(s), they were presented to four experts who had experience and expertise in teaching and learning about the NOS. These experts had a Ph.D. in science education and had 7, 11, 12, or 16 years teaching experience. The experts were asked to identify aspect(s) of NOS embedded in the scenarios. The intercoder agreement between the experts was 100%, confirming intended NOS aspect(s) - scenario relationship.

One of the scenarios is presented as an example below. The "cholesterol" scenario was specifically constructed to teach both the tentative NOS and science-society relationship. The participating teachers were presented with this scenario and asked to write which aspect(s) of NOS would be taught using this scenario. Only the scenarios were different in the remaining three ECSs, the structure and the questions were the same.

Data Analysis

The participants' understandings of NOS and their competence in identifying NOS themes in ECSs were analyzed separately. The correlation between the two is addressed later. As the ECSs do not cover all NOS aspects that the VNOS-C assesses, the analysis of the VNOS-C interviews focused only on revealing the participants' views about the related aspects of the NOS (the empirical NOS, the tentative NOS, subjectivity in science, creativity and imagination in science, and the science-society relationship). Two members of the research team were involved in the analysis of the VNOS-C interviews. To develop a valid coding scheme, the researchers first examined all 15 interviews independently. The researchers read each interview transcript and coded each sentence implying a unit of information in the participant's answer. The second step of the analysis involved theme generation in which the participants' statements regarding NOS aspects were grouped together. In this step, for example, a participant's statements providing information about his/her understanding about the empirical NOS were group together. This step helped the researchers highlight the consistency, or lack thereof, between the participants' statements regarding an aspect of NOS. The researchers noted their initial ideas about each participant's understanding of the NOS aspects with evidence from interview transcripts. Once the independent analysis of VNOS-C data was completed, the researchers shared and compared their initial ideas about the participants' understandings of NOS aspects. The intercoder reliability between the researchers was 82%. Then, any disagreement was discussed until full agreement was achieved among the researchers.

Once the analysis of VNOS-C data was completed, the researchers analyzed the participants' success in identifying NOS aspects in ECSs. As the researchers analyzing the participants' written responses to the scenarios, they focused on whether the participant had successfully identified the NOS aspect(s) in each scenario. The analyzing procedure was similar to that of VNOS-C interviews. First, both researchers coded the written responses of the participants independently. The researchers read responses of the participants to the ECSs and located the statements in which the participants had pointed out a NOS connection. The researchers noted their initial ideas about each participant's performance regarding the identification of NOS connections in the ECSs. Once the independent analysis of ECSs data was completed, the researchers shared and compared their notes about the participants' performances in identifying NOS aspects in ECSs. The intercoder reliability between the researchers was 100%.

The last stage in data analysis involved comparing and contrasting the findings on the participants' understandings of NOS and their competence in identifying NOS aspect(s) in ECSs to explore the relationship between the two.

Table 2: The scenarios and embedded aspects of NOS

Scenarios	Embedded NOS aspects
Ozone Layer	The science-society relationship
	Empirical nature of scientific knowledge
	Creativity and imagination in science
Global warming	Subjectivity in science
Dinosaurs	Tentative nature of scientific knowledge
Cholesterol	The science-society relationship
	Tentative nature of scientific knowledge
Classification	Tentative nature of scientific knowledge
	Creativity and imagination in science

NOS: Nature of science

FINDINGS

Table 3 presents the findings about the participants' understandings about the related aspects of NOS. The aspects of NOS in consideration are placed in the left-hand column of the table. The names of the participants are placed on the top. The symbol "•" in each participant's cell corresponding to each aspect shows that the participant presented informed views about that aspect of NOS. The right-hand column reveals the participants' performance as a group, whereas the individual performances are presented at the bottom.

Table 3 reveals that the participating science teachers who had attended the professional development program on the teaching and learning NOS presented generally informed views about the NOS. As it is showed in the group performance's column, all the participants presented informed views about the tentative NOS, subjectivity in science and creativity, and imagination in science. All but one presented informed views on the empirical NOS. The participants' performance was the lowest about the science and society relationship, with only 10 of 15 participants presented informed views about this aspect. On the other hand, nine participants presented informed views about all aspects of science considered in this study.

The analysis of the interviews revealed that all participants presented an understanding that scientific knowledge can change over time. They thought that existing scientific knowledge can change in light of new evidence made possible through advances in technology. Representative comments from the participating teachers are below:

Table 3: The participants' understandings of NOS as revealed through VNOS-C interviews

Aspects of nature of science	Sarp	Efe	Buse	Gamze	Yelda	Mete	Oya	Can	Harun	Akın	Zehra	Duru	Sevgi	Lara	Fulya	Performance group
Empirical nature of scientific knowledge	•	•	•		•	•	•	•	•	•	•	•	•	•	•	14/15 (93%)
Tentative nature of scientific knowledge	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
Subjectivity in science	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
The science-society relationship	•	•	•	•		•		•	•				•	•	•	10/15 (66%)
Creativity and imagination in science	•	•	•		•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
Performance (individual)	5/5 (100%)	5/5 (100%)	5/5 (100%)	5/5 (100%)	5/5 (100%)	5/5 (100%)	4/5 (80%)	5/5 (100%)	5/5 (100%)	4/5 (80%)	4/5 (80%)	4/5 (80%)	5/5 (100%)	5/5 (100%)	5/5 (100%)	

NOS: Nature of science, VNOS-C: Views on Nature of Science Questionnaire, Form C

> We obtain new evidence thanks to developing new technologies. I mean that new evidence emerges continuously. As a conclusion, our current understanding and knowledge change. (Lara)
>
> Scientists reach new evidence every day and everywhere. Scientific knowledge changes in light of these. (Gamze)

All participants believed that the scientific process was influenced by personal subjectivity due to scientists' values, knowledge, and prior experience. They pointed out that these factors form a mindset that affects the problems scientists investigate and how they conduct their investigations, and how they make sense of, or interpret their observations, for example:

> …Scientists can come up with different interpretations and conclusions even if they evaluated the same data. Because everybody has their own perspective. (Lara)
>
> …Here, we see that scientists reached different conclusions from each other. The reason for this is probably they were educated in different disciplines; their background might be different … Such factors explain the differences between their interpretations. (Sevgi)
>
> Scientists' backgrounds and education affect the way they conduct investigations and interpret findings. (Gamze)

Similarly, all participants agreed that creativity and imagination played a significant role throughout scientific practices:

> I think scientists use their creativity in data collection, I mean in experimentation. Because your approach may not work, you may not get what you want. Here, you use your creativity and try a different method. You use your creativity and imagination throughout, but I believe that you need them especially in data collection and interpretation of your data. (Nihan)
>
> Scientists use their imagination and creativity at every phase of scientific investigation. However, they may use them intensely at some stages. For example, their imagination and creativity may not play a major role in data recording but play a substantive role in interpreting their observations. (Sevgi)

The majority of participants (14 of 15) believed that scientific knowledge had a basis in empirical evidence:

> The difference of science from religion and politics is that science has an empirical basis. Scientific claims should be supported by evidence. (Oya)
>
> Not all knowledge is scientific. To be scientific, a claim should be supported by evidence. (Zehra)

The analysis revealed that most of participants (10 of 15) agreed that scientific investigations were influenced by society and culture. Examples of participating teachers' comments are as follows:

> Scientific investigations are affected by many societal and cultural factors such as the needs of society, religion… even language may affect scientific investigations. (Sarp)
>
> For example, I remember a discussion about the studies on organ transplantation between animals and human. A part of the society was not supporting such studies

arguing that it is against religion… I mean, the culture and society inevitably affect scientific studies. (Lara)

On the other hand, five participants believed that scientific processes were independent from social and cultural influences, as seen in Zehra's comment below:

Science is universal and is not affected by society.

These results indicate that, clearly, the vast majority of the participating teachers developed adequate understandings about the majority of NOS aspects at the end of the professional development project. The next stage of the study aimed to find out if these adequate understandings about the NOS would help them recognize embedded NOS aspect(s) in the ECSs.

Table 4 presents the findings on the participants' success in identifying embedded NOS aspect(s) in the ECSs. In the left column is the names of the scenarios and the aspect(s) of science embedded in each scenario. The names of the participants are placed on the top. The right hand- side column presents the group's performance, whereas the individual performances are placed at the bottom. The symbol "•" in each participant's cell corresponding to each aspect indicates that the participant was successful in identifying corresponding aspect of NOS in that scenario.

By looking at the total number and percentages in the right column of the table, the reader can see the performance of the participants as a group vary between none to 93%. What is immediately evident in these results was the success of the participants in identifying the discussion on the tentative NOS aspect in three of the scenarios (the dinosaurs, cholesterol, and classification). Indeed, 14 of 15 of the participants were able to identify this aspect of the NOS in each of these scenarios. For example, regarding the Classification scenario, Can discuss that one of the main messages given by the scenario was how our understanding and classification of living things had evolved through time and in light of new scientific and technological developments. He concluded that the scenario provided opportunities to teach the tentative NOS in the classroom. Fulya's approach was similar, she wrote:

The text tells the story of how our understanding about classification of living things changed over time. We classified the living things as animals and plants for over 2000 years, but today, we are using a different classification. This creates an ideal context to talk about scientific change with students.

The participants were similarly successful in identifying the discussion on the tentative NOS in the Dinosaurs and Cholesterol scenarios, for example:

(Regarding the Cholesterol scenario) …One of the aspects of science that could be discussed through this scenario is tentativeness of scientific knowledge and the reasons behind scientific change. Here, it tells, just like in the case of Pluto debates, the criteria for the total cholesterol level have changed. (Duru)

(Regarding the Cholesterol scenario) …Scientific knowledge can change over time interpretation of recent scientific knowledge. (Mete)

(Regarding the Dinosaurs scenario) …There are accounts in this scenario, such as "… an article published in Nature in 2012 clearly indicated that the bone rings are not specific to cold-blooded animals. Such studies provided important evidence that dinosaurs could be warm-blooded." I think, such accounts would provide the teacher an opportunity to discuss that scientific knowledge is open to change. (Lara)

(Regarding the Dinosaurs scenario) …I would use the scenario to teach that scientific knowledge can change over time in light of new evidence. (Yelda)

On the other hand, the participants' success in identifying the other aspects of the NOS in the scenarios was noticeably lower. The results revealed that the participants' success was especially lower in identifying discussions about creativity and imagination in science. Only three participants were able to identify this aspect of the NOS in the Classification scenario and only one in the Ozone Layer scenario. Oya was one of the three participants who were able to identify the discussion on creativity and imagination in science in the Classification scenario:

The fact that different scientists suggested different ways of classifying living things would provide an opportunity to discuss the place and role of imagination and creativity in science.

Among the participants, only Duru was able to realize that the Ozone Layer scenario could be utilized to teach creativity and imagination in science:

As told by the story, in the 1970s, Mario Molina and Sherwood Rowland realized that sprays containing CFC gases could negatively affect the upper layers of atmosphere. This indicates the role of creativity and imagination in science.

Similarly, the participants' performances in identifying the debates regarding science and society relationship in the scenarios were poor. None of the participants noticed that the Cholesterol scenario embraces a discussion on science and society relationship; on the other hand, only six participants pointed out that the Ozone Layer scenario included such a discussion. Regarding the Ozone Layer scenario, one of the participants, Can, noted:

Here, the text clearly indicates that despite the evidence indicating that the ingredients in these products damage the ozone layer, the companies tried to mask this evidence due to economic reasons. This can be utilized to start a discussion about societal influences on science.

The participants' performances were relatively higher in identifying the discussions on the empirical NOS (in the Ozone Layer scenario, nine of 15). Duru, for example, mentioned that evidence put forward by Molino and Rowland in the Ozone Layer scenario gave messages about the empirical NOS:

Molino and Rowland provided important evidence that these gases damage the ozone layer, which is very important for the sustainability of life in the earth. The

Table 4: The participants' success in identifying embedded NOS aspects in the ECSs

Nature of science aspects in scenarios	Teachers															Performance (group)
	Sarp	Efe	Buse	Gamze	Yelda	Zehra	Mete	Oya	Can	Harun	Akın	Duru	Sevgi	Lara	Fulya	
Ozone layer																
The science-society relationship			•				•		•				•	•	•	6/15 (40%)
Empirical nature of scientific knowledge					•		•		•	•	•	•	•	•	•	9/15 (60%)
Creativity and imagination in science												•				1/15 (6%)
Global warming																
Subjectivity in science				•		•		•		•	•	•	•	•	•	9/15 (60%)
Dinosaurs																
Tentative nature of scientific knowledge	•	•	•	•	•	•	•	•	•	•	•		•	•	•	14/15 (93%)
Cholesterol																
The science-society relationship																0/15 (0%)
Tentative nature of scientific knowledge	•	•		•	•	•	•	•	•	•	•	•	•	•	•	14/15 (93%)
Classification																
Tentative nature of scientific knowledge	•	•	•	•	•	•	•	•	•	•		•	•	•	•	14/15 (93%)
Creativity and imagination in science								•			•				•	3/15 (20%)
Performance (individual)	3/9 (33%)	3/9 (33%)	3/9 (33%)	4/9 (44%)	4/9 (44%)	4/9 (44%)	5/9 (55%)	5/9 (55%)	5/9 (55%)	5/9 (55%)	5/9 (55%)	5/9 (66%)	6/9 (66%)	6/9 (66%)	7/9 (77%)	70/135 (52%)

> way they approach to the issue and their efforts to search for evidence clearly show that scientific claims require evidence.

In the same vein, nine participants were able to identify the discussion on subjectivity in science in the Global Warming scenario, for example:

> I can draw on the scenario to teach that scientist uses same data but makes different inferences. (Akin)
>
> I would use the scenario to state that scientific knowledge is influenced by subjectivity of scientist. (Zehra)

Fulya was one of the participants who successfully identified the debate on the subjective NOS in the Global warming scenario. She wrote that the scenario provided a context for discussing the possibility of different perspectives among scientists regarding a natural phenomenon:

> In this scenario, we come to understand that all scientists agree that average temperature is rising. However, you can see in the text that there are different perspectives among groups of scientists regarding the reasons behind this rise. I would use this to start a discussion with students about objectivity-subjectivity in science and scientists.

In summary, the findings regarding the participants' group success in identifying the embedded aspects of the NOS in the scenarios pointed out that while the participants were quite successful in identifying some of the embedded aspects of science in scenarios (namely the tentative NOS, the empirical NOS, and subjectivity in science), they did not present the same success on locating embedded discussions about the science-society relationship and creativity and imagination in science.

The participants' individual performances in identifying the embedded aspects of NOS in the scenarios varied greatly as well. The individual performances varied from 33% to 77%. As seen in Table 4, none of the participants were able to identify all embedded aspects of NOS in the scenarios. The most successful participant (Fulya) was able to locate seven of nine aspects of the NOS (77%), whereas the least successful three participants (Sarp, Efe, and Buse) were able to identify only three aspects of NOS in the scenarios. The overall rate of the participants' success in identifying the embedded aspects of NOS in the scenarios was 52%.

DISCUSSION AND CONCLUSIONS

This study aimed to address a group of science teachers' competencies in identifying relevant NOS aspects in various SSI scenarios and their views about how to utilize these for NOS instruction. The findings revealed that the participant teachers developed informed views about the majority of the aspects of NOS as a result of the professional development program. All the participants presented informed views about the tentative NOS, the subjective NOS, and creativity and imagination in science. Again, all except one showed that they understood the empirical base of science. The development of the understandings about the relationship between science and society, on the other hand, was relatively limited. The overall development of the participants' understandings confirms previous research that explicit-reflective approach supports learning about NOS (Akerson et al., 2000; Akerson et al., 2007; Khishfe and Abd-Khalick, 2002; and McDonald, 2010).

It seems that, however, the participants failed to transfer this knowledge and could not exhibit similar competence in identifying some aspects of NOS embedded in ECSs. For example, while 10 of 15 participants presented informed views about science and society relationship in the interviews, none of these 10 participants were able to detect the embedded discussion with regard to science and society relationship in the Cholesterol scenario. The reader may consider that the reason might have been the nature of the scenario; however, in the same vein, the majority of the participants were not able to identify the same aspect in the OZONE LAYER scenario. Similarly, while all of the participants presented informed views regarding the role played by creativity and imagination in science in the interviews, they failed to present the same success in identifying discussions involving creativeness and imagination in science in ECSs. Only three participants were able to detect this aspect of NOS in the classification scenario, whereas only one participant detected it in the Ozone Layer scenario. The participants were relatively more successful in identifying the other aspects of NOS in the remaining scenarios. As explained, all of the participants presented informed understandings regarding subjectivity in science. Parallel to that, the majority (nine participants) recognized the embedded discussion with regard to subjective NOS in the Global Warming scenario. In a similar fashion, 14 of 15 participants presented informed ideas about the empirical nature of scientific knowledge; nine of them were able to detect it in the Ozone Layer scenario. The participants' seemed more successful in determining discussions involving the tentative NOS. All of them presented informed views about the tentative NOS in the interviews and the majority was able to detect the related discussion in the Dinosaurs, the Cholesterol, and the Classification scenarios (14 of 15 in each).

Research acknowledges that despite the emphasis put by science educators on the teaching about NOS, limited success has been achieved in improving the NOS views for all learners (Abd-El-Khalick and Akerson, 2004). Especially, research in science classrooms shows that even when teachers have developed an understanding of the NOS congruent with informed views of the NOS; they generally do not translate their understanding into the classroom. Therefore, Schwartz and Lederman (2002) concluded that understanding the NOS is necessary but not sufficient to translate NOS understanding into the classroom.

Research has shown that many factors mediate the translation of science teachers' NOS views into instructional practice. These factors include the depth of teachers' content knowledge (Lederman et al., 2001), their pedagogical understandings and skills related to enacting student-centered and inquiry learning environments, as well as their attention to students' prior NOS conceptions, their abilities to locate, adapt, and/or design NOS-related instructional resources (Wahbeh and Abd-El-Khalick, 2014). Similarly, the results of this study point out that the participating teachers experienced problems in transferring and utilizing their knowledge about NOS when they were faced with scenarios involving embedded discussions regarding NOS. This indicates that having an informed understanding of the NOS does not guarantee effective translation of this understanding into the classrooms.

Science curricula from around the world call for science teachers to bring and utilize SSI as a means for NOS instruction. This requires not only informed science teachers with regard to NOS but also competent science teachers who are able recognize and communicate discussions regarding NOS in SSI. This points out a need for developing pedagogical content knowledge (PCK) of science teachers for NOS instruction as well as developing their understandings of NOS. We believe that identifying and utilizing issues regarding NOS in instructional sources should be considered as an important dimension of PCK for teaching NOS. In this vein, we agree with the calls by researchers that education on NOS should use both contextualized and decontextualized approaches (Clough, 2006) and present opportunities for learners to transfer their knowledge to real-world issues. To this end, courses aiming to develop teachers' understandings of NOS should utilize contexts such as SSI, the history of science, and authentic inquiry experiences besides explicit-reflective approach (Allchin et al., 2014).

It should be noted that the findings of this study also point out that while these science teachers presented relatively high performances in identifying some aspects of NOS in the scenarios (the tentative NOS, the empirical NOS, and subjectivity in science); they were less successful (or, not at all successful) with regard to other aspects (creativity and imagination in science and the science-society relationship). This finding points out that it might be difficult for science teachers to bring some aspects of NOS into the classroom as compared to others. There could be many reasons for that. In their study, for example, Wahbeh and Abd-El-Khalick (2014) found that teachers were successful in addressing those NOS aspects which they (a) had understood and internalized well as a result of the intervention and (b) learned about in the context of activities, narratives, discussions, historical case studies, and/or science contents that were well matched with contexts within which participants taught about NOS in their planned units. Along with these, some other reasons should be considered. For example, some aspects of NOS, such as the tentative NOS, might be more perceptible and noteworthy for teachers in any educational material. Some aspects, such as creativity and imagination in science, on the other hand, might be difficult for them to recognize and expose. Alternatively, maybe teachers find some aspects of NOS more relevant and important and therefore deliberately look for these aspects in any material. This area warrants further research. Whatever the reason, this study indicates that in promoting learning about the NOS in school science, teachers do need effective contexts such as SSI and clear guidance and support with regard to the ways in which these contexts could be utilized in an effective manner.

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