Elementary Education Online, 2019; 18(1): pp. 343-366
İlköğretim Online, 2019; 18(1): s. 343-366. [Online]: http://ilkogretim-online.org.tr
doi: 10.17051/ilkonline.2019.527626

Zooming in on scientific practices and evidence-based explanations during teaching NOS: A study in pre-service teacher education program

Bilimin doğasının öğretimi sırasında bilimsel pratiklere ve kanıta dayalı öğretime yakından bakış: Öğretmen yetiştirme programında bir çalışma

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Abstract. Investigating pre-service science teachers' tendency for emphasizing nature of science in their lesson plans is crucial. Students should construct scientific explanations based on data-based evidence gathered from the activities they actively engage in a discourse environment. Focusing on evidence-based explanations and evaluation experiences in teacher education and professional development is also crucial as it is practiced and experienced in the real world. In this study, we investigate how pre-service science teachers incorporated nature of science aspects and used evidence-based explanation in their lesson plans. The findings of this study suggest that enabling pre-service teachers to design lesson plans for the use of competing theories may guide them to enable their students to engage in arguments from evidence and evaluate the trustworthiness of these evidences in a discourse environment. The results also indicate the necessity of explicit teaching of nature of science through instructional scaffolds that promote evaluation of evidence-based explanations.

Keywords: Nature of science, scientific practices, evidence, explanations

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Öz. Fen öğretmen adaylarının ders planlarında bilimin doğasını vurgulama eğilimlerinin araştırılması çok önemlidir. Öğrenciler, bir konuşma ortamında aktif bir şekilde katıldıkları etkinliklerden elde ettikleri veriye dayanan kanıt temelli bilimsel açıklamalar oluşturmalıdır. Öğretmen eğitimi ve mesleki gelişimde kanıt temelli açıklamalar ve değerlendirme deneyimleri, gerçek hayatta uygulandığı ve deneyimlendiği için bunlara odaklanmak da büyük önem taşımaktadır. Bu çalışmada, öğretmen adaylarının bilimin doğasının boyutlarını ders planlarına nasıl kattıkları ve kanıt temelli açıklamaları bu planlarda nasıl kullandıkları araştırılmaktadır. Bu çalışmanın bulguları, öğretmen adaylarının yarışan teorilerin kullanıldığı ders planları tasarlamaya yönlendirilmesinin, öğrencilerine kanıta dayalı argüman oluşturma ve bu kanıtların güvenirliğini değerlendirme yönünde rehberlik etmesine olanak tanıyacağını göstermektedir. Sonuçlar ayrıca, kanıt temelli açıklamaların değerlendirme becerilerini geliştiren öğretim araçlarının kullanımı yoluyla bilimin doğasının açık bir şekilde öğretilmesi gerekliliğini de ortaya koymaktadır.

Anahtar Sözcükler: Bilimin doğası, bilimsel pratikler, kanıt, açıklamalar

Received: 16.05.2018 Accepted: 08.12.2018 Published: 31.01.2019

** This paper was presented at the annual conference of Natioanal Association for Research in Science Teaching (NARST) 2017.*

INTRODUCTION

Science education aims at deepening students' understanding of the nature of science (NOS) (Abd-El-Khalick, Bell, & Lederman, 1998). One of the learning areas of the National Science Curriculum in Turkey is teaching NOS, which discusses NOS understanding, the creation and purpose of NOS, and the processes of constructing scientific knowledge (Ministry of National Education [MONE], 2013). In order to apply NOS in classroom settings, science educators should consider two fundamental questions: (a) what is NOS? and (b) what aspects of NOS should be taught and learned in science classrooms? These questions are critical for framing and determining which aspects are worthy to include in science lessons (Erduran & Dagher, 2014; Dagher & Erduran, 2016).

Turkey's National Science Curriculum underwent some major changes in the last decade in order to meet the needs of science education reform both nationally and globally (MONE 2004; MONE 2013). The curriculum design in 2004 aimed at raising scientifically literate citizens and adopting a constructivist philosophy of learning and instruction (MONE 2004). The 2004 curriculum design in Turkey underscored conceptual understanding, NOS, critical thinking processes and particularly reflective thinking. While keeping these features in the curriculum design, MONE made some changes in the elementary science curriculum in Turkey by decreasing the number of objectives and reorganizing the sub-dimensions of learning areas (MONE, 2013). The 2013 National Science Curriculum in Turkey also added socio-scientific issues, awareness of sustainable development as new learning areas, and pointed out the NOS aspects in the vision of the curriculum.

In the last decades, teaching NOS in science education gained importance not only in Turkey, but also in other developed and developing countries. For instance, a recent report on science education reform developed by the US National Academy of Sciences emphasized the importance of NOS with the following statement: "…there is a strong consensus about characteristics of the scientific enterprise that should be understood by an educated citizen" (NRC, 2012, p. 78). Recent science education reform reorganizes science learning around understanding both NOS and disciplinary specific content knowledge, as well as classroom participation in authentic activities in which scientists and engineers engage (e.g., constructing explanations and designing solutions; NRC, 2012). In this sense, learners are expected to define and analyze the development of scientific and engineering ideas through questioning, exploring for evidence, and evaluating alternative explanations in order to understand and explain the world (Lombardi, Sibley, & Carroll, 2013). Science teachers' perspective of scientific understanding and their way of teaching is crucial in achieving this goal (Saribas & Ceyhan, 2015). Therefore, there is a need to include evidence-based explanations and scientific evaluation experiences into teacher education and professional development (Lombardi, Brandt, Bickel, & Burg, 2016).

There is a considerable amount of literature focusing on teaching NOS in teacher education programs. NRC (2012) emphasized not only teaching NOS, but also engaging students with scientific and engineering practices. Since then, science education research has increasingly focused on scientific practices (SPs) (Beggrow, Ha, Nehm, Pearl, & Boone, 2014; Erduran & Dagher, 2014; Yoon, Suh, & Park, 2014; Berland, Schwarz, Krist, Kenyon, & Reiser, 2015; Evagorou, Erduran, & Mantyla, 2015). However, engaging in SPs is worthy of emphasis if it facilitates a deeper and broader understanding of both (a) *what* we know about science and (b) *how* we know about science, including epistemic and procedural knowledge that guide SPs (Osborne, 2014). Yet, Osborne (2014) also stressed that there is little evidence that science education has been able to achieve these goals. Osborne (2014) argued that teacher educators need to have a clear plan of the structure they want to construct and go beyond unclear, ill-specified goals in order to develop students' capabilities of making explanations, analyzing and interpreting data, developing models, and engaging in argument from evidence.

In alignment with Osborne (2014), this paper argues that pre-service teachers should have a clear picture of science and its endeavor. We believe it is important for pre-service teachers to know that science is subject to change based on new evidence and be competent to design instruction that enables their students to make explanations based on evidence derived from the data they gathered from their activities (e.g., during observation, classification, and experimentation; and engaging in argumentative discourse to evaluate evidence and explanation connections. Therefore, it is necessary to probe pre-service teachers' tendency for which aspects of NOS they focus on and whether they use effective methods and tools to lead their students to make evidence-based explanations.

There is not enough research focusing on NOS and SPs and particularly focusing on examining pre-service teachers' competency to design lesson plans (LPs) to enable their students to understand what science is and how it works. There is lack of research investigating pre-service teachers' understanding of NOS and incorporating it into their teaching without teaching them any theoretical framework. This kind of research is necessary to point out the gaps in pre-service teachers' understanding of NOS. In light of this research gap, our purpose in conducting the present study was to investigate pre-service science teachers' preference of different NOS aspects to emphasize in their instruction and their understanding and designing instruction that promotes evaluation of evidence and explanations. This study has the potential to contribute to NOS and pre-service science teacher education literature in both theoretical and practical ways. It brings new insights theoretically by emphasizing the need for further research regarding NOS, SPs, and evaluating evidence-based explanation. It also contributes to the NOS research by using various data sources, other than questionnaires, such as student-written LPs and reflections. Furthermore, this study provides some insight for designing teacher education programs that increase NOS understanding.

THEORETICAL FRAMEWORK

Our theoretical perspective is based on the proposition that teaching NOS from the perspective of the Family Resemblance Approach (FRA; Erduran & Dagher, 2016) facilitates the teaching and learning of evaluations about evidence-based explanations. This perspective is based on philosophical foundations (Irzık & Nola, 2011) and recent research on the teaching and learning of NOS (Erduran & Dagher, 2014; MONE, 2004; NRC 2012). FRA provides a holistic approach to NOS teaching and learning, and therefore, we decided to use FRA framework as the basis of our study. In subsequent parts we discuss the usage of this framework and assess participants' NOS understanding based on this framework. We also situate our study by highlighting the literature supporting our theoretical framework, as well as recent descriptive work examining instructional scaffolds used to promote critical evaluation of the connections between evidence and alternative explanations.

Nature of science

Nature of Science (NOS) has been on the agenda of research in science education for a few decades (Abd-El-Khalick, et al., 1998; Eflin, Glennan, & Reisch, 1999; Lederman, 1999; Lederman, 2007; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas, Almazroa, & Clough, 1998). Although researchers proposed several approaches and frameworks for teaching and learning NOS in science classrooms throughout the years, we used a Family Resemblance Approach (FRA) to NOS framework to emphasize the "holistic, inclusive, diverse and comprehensive and metalevel conceptualization" of science (Dagher & Erduran, 2016, p. 153). We believe focusing on cognitive-epistemic and social-institutional systems that take place in this framework, will be beneficial for a holistic approach to teaching science (Erduran & Dagher, 2014).

In FRA, Irzik and Nola (2011) classified the categories for the structural description of NOS as activities, aims and values, methodologies and methodological rules, and products. They concluded that scientific disciplines share some or most of the characteristics under each category, they are all similar in terms of some characteristics, but different in terms of others. Erduran and Dagher (2014) represented FRA aspects with a visual illustration to emphasize FRA's implication in science education and to represent various features of science (Figure 1). This figure, named the FRA Wheel, aims to represent science as a holistic, dynamic, and comprehensive system. The FRA wheel specifically represents the cognitive-epistemic system of science with aims and values, SPs, methods and methodological rules, and scientific knowledge. The cognitive-epistemic system of science takes place within the social-institutional system. Therefore, Erduran and Dagher (2014) emphasized the social system of science with including social values, scientific ethos, professional activities, social certification, and dissemination. The institutional system of science is indicated in FRA wheel by social organizations and interactions, political power structures and financial systems.

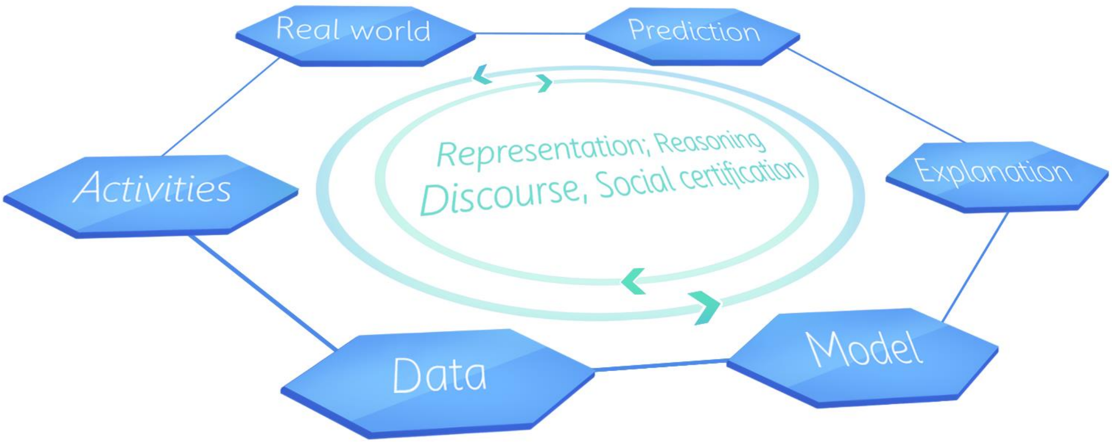

FIGURE 1. *Updated version of BRH*

Although FRA framework conceptualizes the holistic approach to science, researchers needed a tool to assess the use of NOS in science classrooms. To develop such a tool, Kaya and Erduran (2016) came up with the framework called, "Reconceptualized FRA-to-NOS (RFN)." This framework used Erduran and Dagher's (2014) FRA wheel to generate keywords researchers could use in "pedagogical, instructional, curricular and assessment issues in science education" (Kaya & Erduran, 2016, p. 1115). For instance, aims and values in RFN categories are explained as "the key cognitive and epistemic objectives of science, such as accuracy and objectivity", and "aim, value, goal, accuracy, objectivity" are selected as keywords to detect RFN categories in curricula (Kaya & Erduran 2016, p. 1123). Scientific ethos are explained as "the norms that scientists employ in their work as well as in interaction with colleagues", and are traced in curricula with "scientific norms, ethics, bias, being sceptical, caution against bias" (Kaya & Erduran 2016, p. 1123). In this study, we use RFN categories to analyze pre-service teachers' LPs as it explains all the NOS aspects identified in FRA wheel, describes all the components, and provides keywords for systematic data analysis. Table 1 lists these categories of RFN, with descriptions.

TABLE 1. *The categories and descriptions of RFN*

RFN Category	***Description***
Aims and values	The key cognitive and epistemic objectives of science, such as accuracy and objectivity
Methods	The manipulative as well as nonmanipulative techniques that underpin scientific investigations
Scientific practices	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification

Scientific knowledge	Theories, laws and explanations that underpin the outcomes of the scientific inquiry
Social certification and dissemination	The social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals
Scientific ethos	The norms that scientists employ in their work as well as in interaction with colleagues including scientific norms, ethics, bias, being skeptical, caution against bias
Social values	Values such as freedom, respect for the environment, and social utility
Professional activities	How scientists engage in professional settings such as attending conferences and doing publication reviews
Social organizations and interactions	How science is arranged in institutional settings such as universities and research institutes
Financial systems	The underlying financial dimensions of science including the funding mechanisms
Political power structures	The dynamics of power that exist between scientists and within science cultures

Scientific practices and evidence-based explanations

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas listed eight scientific and engineering practices (NRC, 2012, p.49):

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Erduran and Dagher (2006) represented these practices in a Benzene Ring Heuristic (BRH). This heuristic reflects these practices through epistemic and cognitive aspects of science that are represented as each carbon atom around the ring. Futhermore, the ring represents socio-cognitive practices as an electron cloud referring to representation, reasoning, discourse, and social certification. Saribas & Ceyhan (2015) introduced the BRH to pre-service science teachers in order to investigate their perceptions of scientific processes and improve their understanding of science and scientific practices (SPs). Thirty-six pre-service science teachers participated in the study and participants designed concept maps and group LPs after a series of workshops about SPs, the relationships between each component in BRH and the holistic approach of SPs. The findings revealed the need to focus on a holistic approach to science, as well as domain-specificity, ethics, and the utility of SPs (Saribas & Ceyhan, 2015).

Duschl and Grandy (2011) stressed the necessity of developing and evaluating scientific evidence, explanations, and knowledge. According to Erduran and Dagher (2014), in BRH all aspects of SPs can embed argumentation as a discourse process that enables the connection between claims and evidence. In this study, we suggest deeper analysis on pre-service teachers' understandings of the connection between evidence and explanation and its significance for their knowledge about NOS through their LPs.

Dagher and Erduran (2016) suggested using the FRA in analyzing the content of curriculum standards by illustrating the FRA categories with recent reform documents in USA.

They specifically showed the alignment of SPs in making valid and plausible scientific explanations based on reliable and credible lines of evidence. In this study, we investigate how learners connect SPs through evaluation of evidence-based explanations.

Teaching NOS to pre-service science teachers

Since early 1990s scientific inquiry (AAAS, 1989; Adamson, Banks, Burtch, Cox, & Judson, Turley, …& Lawson, 2003) and in recent years SPs (NRC, 2015) have been in the agenda of science education. For increasing knowledge of the SPs, pre-service teachers should deepen understanding about the nature of science, including the idea that scientific explanations are based on logical and conceptual connections with evidence validated through evaluative processes (NGSS Lead States, 2013, p. 98). Providing explicit and purposeful instruction to pre-service teachers about NOS, and specifically about constructing lessons about evidence-based scientific explanations, is one necessary ingredient needed to increase the likelihood that pre-service teachers will effectively engage future students in authentic SPs (Abd-El-Khalick, 2013). In this study, we examine pre-service teachers' understanding and incorporation of NOS, as well as evaluating evidence-explanation connections, into their instructional designs.

Prior research suggests that increasing pre-service teachers' understanding of NOS might facilitate infusion of NOS into their teaching; yet, infusion of NOS into teaching is quite rare. Specifically, Lederman, et al., (2002) says that there are four intrinsic factors affecting pre-service science teachers' teaching of NOS: knowledge of NOS, knowledge of subject matter, pedagogical knowledge, and intentions toward teaching NOS. Furthermore, Höttecke and Silva (2011) indicated additional four factors that are the obstacles of implementing history and philosophy of science as follows: culture of teaching; teachers' skills, epistemological and didactical attitudes and beliefs; institutional framework of science teaching; and textbooks as fundamental didactical support. With these many factors influencing pre-service teachers understanding of NOS and how to teach NOS, it is no surprise that effective teaching of NOS is relatively uncommon.

There are some studies focusing on the pre-service teachers' efforts to teach NOS. For example, Lederman, Schwartz, Abd-El-Khalick and Bell (2001) investigated pre-service teachers' conceptions of NOS and the translation of those conceptions into classroom practice. They found that regardless of NOS views or science background, pre-service teachers did not teach in accordance with their NOS views if they had not internalized the importance of teaching NOS. There are also empirical studies examining LPs incorporating NOS. For example, Kim, Ko, Lederman, and Lederman (2005) examined how K-12 teachers incorporated NOS aspects into their lessons. Their findings indicated the necessity of explicit teaching of NOS and reflective and student-centered approach rather than didactic approach. Similarly, Akerson and Volrich (2006) argued that pre-service teachers are required to design LPs for the purpose of improving their students' NOS conceptions and these LPs need to be analyzed by the instructor in terms of the emphasis made on NOS aspects. However, a deep understanding of the ways pre-service teachers emphasize NOS and evidence-based explanations in designing LPs without orienting them towards a theoretical framework is needed. It seems also necessary to detect pre-service teachers' preliminary understanding of NOS after reading basic literature that different NOS frameworks depend on. Such descriptive understanding is essential to help think about how research may support pre-service teachers in developing lessons concerning the construction and evaluation of evidence-based explanations may increase the effectiveness of their science instruction.

Designing and teaching evidence-based instruction

Instructional scaffolds may facilitate construction of evidence-based explanations. For example, model-evidence link (MEL) diagrams—originally developed by a team of researchers at Rutgers University under the NSF-supported Promoting Reasoning and Conceptual Change in Science project (Chinn & Buckland, 2012)—is an activity where individuals weigh the connections between evidence and alternative models about a phenomenon by drawing different types of arrows that relate to the judgment about the strength of connections (i.e., a line of evidence (a) strongly supports, (b) supports, (c) has nothing to do with, or (d) contradicts a model). After completing the diagram, individuals complete an explanation task where they write explanations justifying the strength of the evidence-to-model connections that they drew. Recent empirical studies reveal that the MEL activity can facilitate critical evaluations of alternatives, promote plausibility reappraisal of scientific alternatives, and increase understanding of fundamental scientific concepts (Lombardi, Sinatra, & Nussbaum, 2013; Lombardi, Bickel, Bailey, & Burrell, 2018). Construction of such explanations allows individuals to understand "that alternative interpretations of scientific evidence can occur," and ultimately "that predictions or explanations can be revised on the basis of seeing new evidence or of developing a new model that accounts for the existing evidence better than previous models did" (National Research Council, 2012, p. 251). This process promotes a deeper understanding of NOS, because it places evaluation at the nexus of scientific activity (Lombardi, Bickel, Bailey, & Burrell, 2018).

In summary, FRA is the framework to facilitate understanding science in a holistic way and RFN is a tool enabling the assessment of the use of NOS in science classrooms. Thus, it seems beneficial to utilize RFN during analysing pre-service teachers' incorporation of NOS in their teaching. As SPs are significant to help individuals understand what and how they know about science and evidence during making valid and plausible scientific explanations, it is also necessary to include SPs and evidence-based discourse in the anaysis of pre-service teachers' instruction.

In this study, we investigate pre-service science teachers' incorporations of NOS aspects into LPs, and how they apply evidence-based explanations in their LPs. We conducted this investigation by applying FRA, RFN, NOS, and evidence-based discourse in a holistic way during analysing pre-service teachers' teaching science. Specifically, the research questions directing the investigation are as follows:

1. Which NOS aspects do the pre-service science teachers emphasize in their LPs?
2. Which SPs do the pre-service science teachers emphasize in their LPs?
3. How do the pre-service science teachers use evidence in their LPs?

METHOD

The Study Context

The study was situated within a course, named "Critical Issues in Science Education", which is part of the Bachelor of Science in Primary Science Teacher Education degree program at a public university in Turkey. This is one of the major research university located in western Turkey that offers undergraduate and graduate programs in engineering, applied and social sciences, and many considered the university to be highly selective because of its high number of applicants and low acceptance rate.

The course in which we conducted the present study was designed for 14-weeks over three hours per week in the third-year of the program. The aims of the course were examining critical issues in science education in terms of the decision-making processes on scientific explanations; analyzing socio-scientific and controversial issues considering the nature of science and SPs; developing instructional materials, methods and strategies; and preparing lesson plans (LPs) specifically to teach critical science topics.

Participants

Participants of the study comprised 40 pre-service science teachers in junior years, who enrolled in the Critical Issues in Science Education Course on 2014-2015 spring semester. The participants were predominantly female (88%) and all were in their early-to-mid 20s (M = 22.6, SD = 1.26). All of the participants took courses from the major science disciplines in physics, chemistry and biology. Besides, participants completed some general education and teaching courses like principles and methods of instruction, educational psychology and laboratory application in science education. The instructor of the course, who is one of the researchers of this study, informed the participants that their written tasks will be analyzed for a research study and ensured them that she will not publish or use the data for any other purpose. The protocols used for this study were approved by the university's Institutional Review Board (IRB).

Procedure

The following highlights the flow of the course and the procedures of the present study (Table 2). The course was consisted of two parts including a 9-weeks of lecture to teach NOS and evidence-based explanations in science and a 5-weeks of practice in which pre-service teachers reflect these ideas into their teaching. The study was based on a desctiptive analysis on pre-service science teachers' LPs instead of a comparison of pre- and post-designs of instruction because the aim of this study was to detect pre-service teachers' inclusion of these ideas into their teaching after introducing them to NOS views rather than comparing their initial and final instructional designs. As pre-service teachers had no information about NOS and evidence-based instruction before the course, they would most probably never reflect these ideas into their teaching or this incorporation would be very limited. However, we aimed to explore how deeply they include NOS views and evidence in their instructions after having a basic information about these topics.

Introducing NOS aspects

In the first three weeks of the course, participants and the instructor discussed how science works by giving examples from history of science including the topics of evolution and heliocentrism, the role of NOS in science education by emphasizing the importance of the integration of scientific and engineering practices, disciplinary core ideas in four disciplinary areas and crosscutting concepts that unify the study of science and engineering; and the terms used in teaching NOS such as the fact, hypothesis, law, and theory. The following three weeks focused on reading and analyzing different perspectives and dimensions of NOS. The participants read the articles of different perspectives including McComas (1996), Lederman and Abd-El-Khalick (1998), Allchin (2011), Duschl and Grandy (2013) and two reports as follows: A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC, 2012) and Next Generation Science Standards (NGSS Lead States, 2013).

Sample activity for making evidence-based explanations

In the following weeks, participants discussed how to teach making evidence-based explanations in science classrooms and they were introduced with an instructional scaffold, called Model-Evidence Link (MEL) Diagram. Recent empirical studies reveal that the MEL activity can facilitate critical evaluations of ideas, promote plausibility reappraisal of scientific alternatives, increase understanding of fundamental scientific concepts and promote deeper knowledge of NOS (Lombardi, Sinatra, & Nussbaum, 2013; Lombardi, Bickel, Bailey, & Burrell, 2018). In groups of four to six, participants engaged in three different MEL activities covering the topics of climate change (CC), evolution (E) and genetically modified organisms (GMOs).

Designing and presenting lessons in groups

We asked the participants, again in groups of four to six, to design and present LPs on a science topic they choose that emphasize NOS aspects and explain how they intended to lead their students to make evidence-based explanations. We also wanted the participants to determine which dimension of NOS to be taught and how to teach them.

Designing individual lesson plans

We asked the participants to design individual LPs on one of the topics of CC, E and GMOs in which they discussed the NOS aspects they would focus. CC, E and GMOs are the socio-scientific issues that are science-related, policy relevant and socially controversial topics. Although there is scientific consensus about the validity of E and CC mechanisms, and also that GMOs are safe for consumption, there is much and continuing socio-political debates about these topics. For example, in Turkey ideological and/or religious stances have made the topics of CC, E, and GMOs salient and controversial. Therefore, integrating NOS aspects in the teaching practices of these topics in teacher education programs may lead teacher educators to find ways to overcome biased thinking.

Writing reflections

Participants wrote group reflections on the underlined NOS aspects and the way they aimed at emphasizing evidence-based explanations in both their group and individual LPs.

TABLE 2. *The flow of the course*

Week	*Instruction*
1	NOS & history of science
2	NOS in science education
3	NOS in science education
4	Different perspectives of NOS
5	Different perspectives of NOS
6	Different perspectives of NOS
7	MEL activity on GMOs
8	MEL activity on CC
9	MEL activity on E
10	Presentation of group LPs
11	Presentation of group LPs
12	Presentation of group LPs
13	Submission of reports of group LPs and reflections
14	Individual LPs

Data sources

Examining pre-service teachers' incorporation of NOS aspect in their instruction needs an analysis of LPs and their written reflections. NRC (2015) specifically recommended training emphasizing science teachers' metacognitive analysis, where teachers engaged in reflection and analysis about their own learning as they participated in science investigations. They considered ideas that could be learned through the investigation, tricky or surprising concepts, and implications for students' learning. In the present study, we specifically used reflections, and group and individual lesson plans (LPs) of the participants as data sources for our examination of pre-service teachers' plans to teach about NOS.

Group Lesson Plans

As a part of the course, participants were asked to divide into groups of four to six, and then to design and present a LP on a science topic that is included in the Turkish Science and Technology Curriculum. In the LP, participants were asked to emphasize and embed the NOS aspects; and lead students to make evidence-based explanations. In total, seven groups designed and presented their LPs.

Individual Lesson Plans

Each participant was asked to choose one of the topics from genetically modified organisms (GMOs), climate change (CC) or evolution (E) and design an individual LP. Although no restriction was made for the determination of the group LP topics, individual LPs were designed on one of the environmental topics stated.

Reflections

After designing group and individual LPs, participants were supposed to clarify how they are planning to lead their students to make evidence-based explanations, indicate the NOS aspects that take place in their instruction, and explain the reason of your choice of the aspect(s) of nature of science.

Data Analysis

This present investigation is descriptive in nature. We specifically aimed to explore pre-service science teachers' incorporations of NOS aspects and evidence-based explanations into their LPs. We conducted a content analysis using qualitative data in this study. In our conceptual content analysis, we assigned different categories to participants' explanations by determining the concepts that characterize the range of explanations (Mayring, 2000). We determined the codes by selectively reducing the data to categories of concepts based on the research questions. The two authors read, reread and coded the data independently and then compared the coding results. Then, they decided on the selection of codes for the three aspects (NOS, SPs and evidence) and determined percentages for each code. We analyzed 26 categories in total. We agreed on approximately 22 categories for each participant. When individual assessments were compared, 22/26, i.e. 85% agreement was reached. After discussion of their discrepancies, 100% agreement was reached. The authors specifically examined the occurrence of the concepts for NOS aspects that the participants mentioned in their lesson plans.

RESULTS and DISCUSSION

Use of NOS in LPs

The participants determined the NOS aspects in their individual and group LPs. We categorized their answers according to RFN categories. Analyses of the LPs showed that participants mostly focused on the aspects of scientific knowledge (100% in group and 92.5% in individual LPs), SPs (87.5% in group and 100% in individual LPs), methodology (65% in group and 45% in individual LPs), aims and values (47.5% in group and 20% in individual LPs), and social values (37.5% in group and 60% in individual LPs). 20% or less of the participants mentioned other aspects of NOS listed in RFN. It is important to note that none of the participants listed scientific ethos, professional activities, social organizations and interactions, political power structures, and financial systems in their group LPs, while some of them emphasized these aspects in their individual LPs (7.5%, 10%, 17.5%, 5%, and 2.5% respectively). Table 3 shows sample answers for each aspect that the participants mentioned in their LPs they constructed both individually and in groups.

TABLE 3. *The categories of RFN*

Categories of RFN	***Group LPs***	***Individual LPs***
Aims and values	"Science require accurate record keeping." "We investigated accuracy of our knowledge from other resources."	"A student who thinks GMOs are harmful should be encouraged to search various researches to have adequate information. I believe that in order to convince the students that science is objective they should be encouraged to search evidence from different sources."
Scientific practices	"We benefitted from scientific practices in the Benzene Ring to explain the reason why ships float, or why paperclip sinks."	"Science includes some scientific practices. This is because students collect and analyze data like scientists do. They make observation and conduct an experiment or make a model while doing the activity. And predict the results."
Methodology	"We continue with the leaf example in which we emphasize some properties of science which are the strong relationship between science and technology, that there is no universal scientific method, and that science is an attempt to explain natural phenomena."	"There are many methods in science besides experimentation." "Experiment is not the only route for explanation. When we don't use an experiment and activity, we can still reach the knowledge." "There is no universal scientific method."
Scientific knowledge	"We focused onto the learners' attention on the model building and doing actions, such as measuring, observing, arguing from evidence and explaining that are parts of the growth of scientific knowledge."	"Scientific knowledge change when new evidence is found. The topic can be investigated by more than one scientist. Therefore, more than one information takes place. With the help of gathering information, laws and theories are asserted."
Social certification and dissemination	"Science requires peer-review and replicability."	"Social certification (also discussion) is important in scientific process. Students' ideas change with scientists' ideas and new explanations."
Scientific ethos	None of the groups mentioned	"Students will be able to discuss about the ethical issues in genetically modified organisms." "Students first see the greenhouse effect. I give them some data sheets and

		they see that the relationship with temperature of the Earth and ppm of these gases. The data is confirmed by scientists and there is no bias in it."
Social values	"The examples of animals about to be extinct can help the students to gain an awareness and this awareness enables them to protect their environment."	"In evolution, it is also possible to emphasize that science is not the final truth, can be falsifiable and every scientist can be effected from their social environment and find different results."
Professional activities	None of the groups mentioned	"The teacher gives each group essays and scientific journals about climate change and gives a worksheet to students to write the findings, similarities and differences within the materials."
Social organizations and interactions	None of the groups mentioned	"During my lesson plan, I use scientific facts to give evidence-based explanations. For example, I always refer to scientific foundations and studies and my students can benefit from research, survey and percentages based on current studies that contribute to the development of GMO."
Financial systems	None of the groups mentioned	"In poor countries, while the cost of vaccine is expensive, genetically modified organisms can be beneficial because genetically modified banana can be used for remediation. However, on the other side, GMOs lead to negative effect for food chain and can cause allergic diseases."
Political power structures	None of the groups mentioned	"In the materials students will see that climate change become a debate between scientists and the governments."

We discuss the following categories listed in Table 3 and how participants discussed these categories in their group and individual LPs as follows:

- Aims and values: The participants mostly used accurate record keeping, accuracy of knowledge, and objectivity of science with respect to cognitive and epistemic objectives of science.
- Scientific practices (SPs): The participants listed nearly all of these practices by referring to BRH in their LPs.
- Methodology: The participants frequently stressed other activities than experimentation by emphasizing that experiment is not only route to scientific

explanation. We also found the statement that there is not a universal scientific method in LPs.

- Scientific knowledge: The participants mostly mentioned the growth of scientific knowledge, change of scientific knowledge based on new evidence, and laws and theories regarding this category.
- Social certification and dissemination: Regarding this category the participants argued the requirements of peer review and replicability, social certification and change in students' ideas when introduced with scientific information.
- Scientific ethos: In group LPs none of the groups mentioned about scientific ethos in their reflections. In individual LPs, we mostly saw ethical issues and bias in their explanations.
- Social values: The statements such as protecting environment, social utility, and the effect of society on scientists were the typical indicators of this category.
- Professional activities: In group LPs again none of the groups mentioned about professional activities in their reflections. However, in their group LPs they mostly emphasized essays, journals, worksheets to be used in the classroom.
- Social organizations and interactions: Again none of the group listed any of the components that can be included in this category in their group LPs. In their individual LPs they mentioned scientific foundations.
- Financial systems: None of the groups discussed this category in their group LPs either. In individual LPs, some of them emphasized the economic status of a country during discussing issues such as vaccines and GMOs.
- Political power structures: Again none of the groups mentioned it in their group LPs. The participants who mentioned it in their individual LPs mostly discussed the debate and/or contradiction between scientists and governments.

The findings showed that the participants appreciated the significance of SPs, methodology, scientific knowledge, and social values regarding NOS. On one hand, the participants seem to have understood the cognitive-epistemic system of science. Nearly half of the participants in group LPs also seem to have appreciated the importance of aims and values in science. On the other hand, the participants did not consider teaching the aspects of NOS included in the social-institutional system. In the middle school science curriculum analysis they made, Kaya and Erduran (2016) concluded that both MONE 2006 and MONE 2013 include statements that identify science as a cognitive-epistemic system, however, they underemphasize science as a social-institutional system. The participants of this study were educated with similar curriculums and they were not well-informed about social certification and dissemination, professional activities of scientists, such as conferences, articles, publications, etc. and social-institutional context of science. Although the participants discussed all these aspects in this course, this study provides evidence of their insufficient appreciation of the significance of these aspects. Further research may reveal the ways to integrate social-institutional system of science in teacher preparation programs.

We acknowledge that students, especially in primary and middle grades, may first need to understand cognitive-epistemic systems, rather than social organizations, political power structures, and financial systems. However, students should also be informed how scientists work and their activities including writing articles, presentation in conferences and seminars and peer review during the publication process.

The participants focused on what they already knew, including the content knowledge of the topic to teach and the pedagogical approaches they use during teaching these topics. However, the participants did not focus on the social and philosophical aspects of science. This suggests that instructors should clearly make pre-service teachers aware of the importance of science's social and philosophical aspects, and give pre-service teachers the opportunities to reflect on these aspects considering their current and future teaching. The results also suggest the need of additional research to examine more effective ways to infuse NOS into pre-service teacher education programs.

Scientific Practices

Although participants were not asked to identify and reflect SPs to their instruction they emphasized them in their LPs. It is evident from this result that they consider SPs as one of the aspects of NOS. This finding might have arisen from their backgrounds. The participants of this study took a course called Laboratory Applications in Science Education in previous semester in which they designed and presented laboratory instructions. During presenting and reporting their designs they implemented and discussed SPs. The course mentioned was mostly designed on the discussions of pre-service teachers' laboratory instructional designs on various science topics based on different pedagogical approach. A complete semester of discussion on SPs might have led them to include these practices within the aspects of NOS. One can infer from this result that encouraging pre-service teachers embed and discuss SPs in their instruction facilitate their understanding of the significance of these practices in terms of NOS teaching.

The participants mostly emphasized on the need of including activities in science teaching (75% in group and 82.5% in individual LPs), while model and representation / discourse / argumentation were the aspects that they emphasized least (60% in group and 50% in individual LPs and 60% in group and 60% in individual LPs respectively). Table 4 illustrates the categories of SPs that participants listed in their LPs and the sample answers they gave both in their group and individual LPs.

TABLE 4. *The categories of SPs*

Categories of SPs	*Group LPs*	*Individual LPs*
Real world	"The teacher explains components such species, genetic and environmental biodiversity that manifest biodiversity itself with the examples of real life."	"I used real world examples since science means real world, and students need to know the relationship between the subject and the real world."
Activities	"Students are expected to observe the resemblance and construct a model according to the traits they observed."	"Teacher wants students to make an activity through observation and role playing. In this activity, students will demonstrate how climate change can affect the species."
Prediction	"Before distribution of the worksheets she asked her students to collect some materials from the environment in break and write their predictions about the water."	"The teacher wants students to predict possible outcomes of climate change."
Explanation	"The teacher explains the properties of solids, liquids and gases in terms of particles but she does not mention anything about the particle arrangement of each states."	"Students made explanations since students should be able to explain what they have learned. It also deepen the understanding of students."
Model	"We made a model as using	"Students model the structure of DNA with playdough, ribbons and

	toothpicks and play dough.”	steels. I choose this aspect because I want to enhance the students' thinking about DNA by hands on activity.”
Data	“We continue with the leaf example by collecting and analyzing data through observations.”	“By using actual data, students can relate the level of carbon dioxide and temperature.”
Representation / discourse / argumentation	“Communicating information was done during activity and after activity. It was provided via various questions and explanations. Discussion/discourse helped us to draw a general conclusion.”	“The teacher wants students to discuss the roles of GMO in our daily life and their effects.”

In the following list we discuss the participants' inclusion of each component of SPs in their LPs:

- Real World: The participants mostly included real world in their LPs as daily life examples and everyday materials to reveal real world applications of scientific subjects. One group stated that real world connection may increase student engagement and get the students excited about what they are learning in science classrooms.
- Activities: The majority of the participants expressed the need of activities in science classrooms and one group mentioned the role of activities on making connection with real world. This finding is crucial because it is important for pre-service teachers to understand the SPs and the connections between SPs in their instruction (Saribas & Ceyhan, 2015).
- Prediction: Nearly half of the participants used prediction in their LPs. One of the participant stated that asking what students think will happen in an upcoming activity helps keep the students mentally involved.
- Explanation: Majority of the participants used explanation in their individual and group LPs. Some of them mentioned teacher explanation, whereas some of them focused on the use of student explanations in their LPs.
- Model: Half of the participants included models in their LPs and expressed the use of models to enhance students' conceptual understanding.
- Data: Participants either used actual data in their LPs that has been shared by scientific organizations as public data or plan to let the students collect their own data.
- Representation/Discourse/Argumentation: More than half of the participants included classroom discourse and argumentation in their LPs. The participants included some guiding open-ended questions to probe insightful answers.

At least half of the participants emphasized discussion, discourse, representation or argumentation as the aspects of SPs while few of them (20% in group LPs, 10% in individual LPs) argued social certification and dissemination in their instructional designs. Even if they addressed scientific discourse as a scientific practice, they rarely emphasized of validation procedure during which scientists evaluate and certificate works of each other after a peer-review process in a collaborative environment.

Using evidence in LPs

Participants explained the methods and the tools they would use to lead their students to make evidence-based explanations by mentioning the terms listed in Table 5. Most of the participants mentioned visual tools (77.5% in group and 52.5% in individual LPs), empirical evidence (45% in group and 45% in individual LPs), and graphs and data (35% in group and 37.5% in individual LPs). Others were mentioned by 25% or less of the participants. 15% of the participants in group LPs and 25% of them in individual LPs emphasized the necessity of using reliable and scientific articles and other sources. Only one (2.5%) of the participants mentioned the need to focusing on confirming results and again one of them emphasized the need of using contradicting results to lead their students to make evidence-based explanations in their individual LPs, while none of them listed them in their group LPs.

TABLE 5. *The kinds of evidence pre-service teachers utilized*

Evidence	Group LPs	Individual LPs
Visual materials	"We used a video and a simulation in order to contribute to the students' understanding of bonding concept."	"Students watch a video about the effects of climate change on living things. Then the teacher wants students to choose one effect of climate change from the video and to construct a theory about how systems or living things can be affected from climate change."
Models	"The teacher considers students as scientists by making their own hypothesis and their own models about the topic."	"The students model various animals and their living environments to illustrate the variation and discuss their properties."
Reliable and scientific articles/sources	"We used popular science resources. While using resources, we controlled whether resources are trustworthy or not. For this purpose, we investigated the accuracy of our knowledge by searching other resources."	"They chose a topic and to make further explanations they need to do research by giving trustworthy scientific resources."
Graphs and data	"Students used some graphs and data from New York Times magazine and from some scientific journals."	"The teacher gives some scientific data sheets taken from IPCC, there are some rates of carbon dioxide in ppm and average temperature of Earth."
Empirical evidence	"We try to show some evidences from real life so that students can make an evidence-based relationship by using these evidences."	"At the beginning of the lecture the teacher wants students to observe change in the ice, then answer the questions the teacher pose depending on these observations."
Historical cases	"In the beginning of lesson, we	"The teacher shows pictures of some

	explained about the history of skeletal system because we wanted to emphasize the history of science."	animals which are ancestors of today's living animals and wants students to discuss their properties and living environments."
Confirming results	None of the groups mentioned	"Students first see the greenhouse effect. I give them some data sheets and they see that the relationship with temperature of the Earth and ppm of these gases. The data is confirmed by other scientists and there is no bias in it."
Contradicting results	None of the groups mentioned	"The teacher wants students to explain there is no one way to approach to a topic in science by depending on the scientists' different points of view on climate change."

In order to elaborate the participants' understanding and using evidence in their LPs we list and discuss each of the categories they mentioned in their LPs as follows:

- Visual materials: Majority of the participants mentioned videos, simulations, and pictures in their group and individual LPs and they mostly used them for the purpose of knowledge construction. Some of them also emphasized developing hypotheses or theories. However, they discussed neither how they would lead their students to make evidence-based explanations nor what constitutes evidence in these materials.
- Models: Some of the participants provided models as evidence in their group and individual LPs. However, they utilized models again for knowledge construction and developing hypotheses and theories. Despite the benefit of using the models in their LPs, they didn't seem to be aware of how to use these models to let their students make evidence-based explanations and explain them what constitutes evidence.
- Reliable and scientific articles/sources: Some participants emphasized trustworthiness of the sources that they would use in their group and individual LPs. However, none of them discussed how to let their students evaluate the trustworthiness of these sources and the claims asserted in these sources or specified what kinds of sources are considered to be trustworthy/reliable.
- Graphs and data: Some participants mentioned using graphs and data in the magazines, journals, and web pages such as scientific data sheets taken from IPCC showing rates of carbon dioxide in ppm and average temperature of Earth.
- Empirical evidence: Nearly half of the participants, both in their group and individual LPs used empirical evidence, such as observations and experiments and answering questions based on these practices.
- Historical cases: The participants mentioned history of science or teaching various science topics by using historical cases in their group LPs more frequently than in their individual LPs.

- Confirming and contradicting results: The participants rarely focused on the confirming and contradicting results of different studies in their LPs. This result may be cause of their underestimation of replicability of results and scientific debates or uncertainty in findings of different studies. Another possible reason may be that they might have found this issue is an overloading task for the students in early grades.

Participants listed various kinds of evidence in their LPs. However, they listed these kinds of evidence in an unorganized and unsystematic way, with limited discussion of what constitutes reliable and trustworthy evidence. Although it is promising that participants sometimes mentioned the trustworthiness and reliability of evidence, there was virtually no meaningful mention of evaluating how this evidence connects to scientifically valid explanations. We therefore suggest that teacher preparation programs should integrate the discussions of what constitutes reliable and trustworthy evidence (i.e., criteria for evaluating if evidence is scientific), as well as ways to evaluate how well evidence supports explanations to ascertain validity. For example, Allchin (2013) stresses the importance of deeply understanding how scientific practices, such as the norms of handling data and using such data to construct meaningful graphs, contribute to trustworthiness and reliability. He also suggested the use of historical cases to highlight sources of credible evidence. In the present study, pre-service science teachers' generally accepted the data and data representations (e.g., graphs) as reliable, with little mention of how they evaluated the reliability of the data and the connection of these lines of evidence to explanations. This suggests that pre-service teachers should be encouraged to discuss how to challenge their students to evaluate all these sources of evidence in teacher education courses. Discussing these components based on FRA framework may be a good starting point for achieving this aim.

A major finding of this study is that none of the participants used an activity in which students provide or discuss evidence for two competing theories like they did in MEL activities nor did students discuss discourse environment that enable their students critically evaluate evidence in a collaborative way. Despite a recent emphasis on students' active engagement in their own learning in a discourse environment, the Turkish educational system has traditionally emphasized teaching methods in which teacher gives the relevant information as authority and the students passively receive this information. In other words, this more traditional approach has underemphasized students' meaning making and being an active agent in critically evaluating connections between lines of evidence and alternative explanations. Therefore, recent emphasis on learners' active engagement in the learning process may be still problematic because pre-service teachers do not seem to be familiar with this kind of critical evaluation in a discourse environment. Therefore, teacher educators need to be explicit in getting students to think scientifically by reflecting on how they are making evaluations about alternative explanations of a phenomenon.

Another important result is that 25% of participants applied historical cases to provide their students evidence in their group LPs while only one (2.5%) of them listed the need to use this kind of evidence in her individual LP. This big difference might have arisen from the topics on which participants designed their LPs. The participants might have thought that the topics of skeletal system and phases of moon are more appropriate than the topics of GMOs, CC, and E for presenting their students historical cases. However, Allchin (2013) argues that science teachers can benefit history in order to teach science and NOS.

Our aim is here to provide evidence for the participants' use of each aspect of NOS, SPs and evidence in both their individual and group LPs. This is a descriptive study whose scope is only presenting the participants' understanding and incorporating of these aspects in their LPs. Besides, these LPs are different tasks in nature. Individual LPs include individual participants' point of view, while group LPs require these individuals to make decisions in using these aspects collaboratively in a group. Thus, we did not need to compare or connect these two tasks.

LIMITATIONS and IMPLICATIONS

We introduced the participants to various approaches to learning about and teaching of NOS, and at the end of the course we examined their incorporation of NOS and evaluating the connections between evidence and explanations into their instructional design. The analyses of LPs indicated that the participants have a general understanding of NOS emphasizing mostly on aims and values, SPs, methodology, scientific knowledge, and social values. They also seem to understand that SPs are an indispensable part of teaching science and NOS. Although they were not asked to mention SPs in their LPs they all mentioned various components of these practices. From this result, we concluded that pre-service science teachers should be provided experiences that they can apply all the aspects of NOS listed in RFN into their instruction and discuss them in the classroom.

This study adds value to the field because it indicates pre-service science teachers' ability to teach what science is and how it works after a solid course. All of the participants were able to include important aspects of NOS in their LPs. We suggest that these LPs constitute a performance assessment of pre-service science teachers' capabilities of applying important NOS aspects into their teaching. Therefore, it seems to be an appropriate measure of pre-service teachers' success in learning by gauging how they integrate NOS into their teaching. However, here additional research questions arose from the findings of this study: How do the pre-service teachers actually implement their LPs in a real classroom? Also, what will their future LPs look like? Will they also contain the same aspects of NOS when they are in a classroom, by themselves dealing with students and school culture? If the conditions are not supportive what will they do? This will be the true test of effectiveness of the implementation. Further research, therefore addressing these questions may clear up this issue.

Although participants emphasized cognitive-epistemic aspects of NOS, they underemphasized social-institutional context of science as well as professional activities of scientists. Instructors should emphasize that pre-service teachers should include these aspects in their LPs. Kaya and Erduran (2016) suggested including "engage in activities such as writing, presenting and communicating results of investigations to other teams" in the curriculum for the professional activities category (p. 1123). In the same sense, pre-service teachers need to be encouraged to design instructions that enable their students to engage in activities such as writing, presenting and communicating results of investigations to other teams.

The lesson on just one topic may be extremely overloaded if it contains all the social-institutional categories. However, pre-service teachers need to consider these aspects during instructional design and emphasize the related category in their teaching. For example, social organizations and interactions can be emphasized during teaching physics by referring to university professors or CERN researchers. The decisions of governments on the manufacturing and selling foods including GMOs or the case that Energy Department climate office banned to use of phrase climate change to point out political power structures can be discussed during teaching-related topics. Likewise, governments' financial support to space researches may be discussed to emphasize financial systems during teaching units about astronomy. We also suggest that pre-service teachers need to be introduced to all the categories of NOS listed in RFN and discuss when and how to apply them in their teaching. It may depict a more coherent and organized way of teaching NOS.

Another important finding of this study is that pre-service teachers regard discussion, discourse, representation or argumentation as the aspects of SPs while they underemphasized the role of social certification and dissemination in science. In order to overcome this drawback teacher education programs need to involve peer-review activities in which they evaluate and certificate works of each other in a collaborative environment. Pre-service teachers should also be encouraged to include peer-review techniques in their teaching. They also need to discuss the issues of scientific norms, ethics, being skeptical to any kind of information and caution against bias in teacher education courses.

Although the participants of this study discussed these issues included in scientific ethos during MEL activities it does not seem to be sufficient to let them appreciate these issues as the important aspect of science. In the same way, only some of the participants emphasized the necessity of using reliable and scientific articles and other sources during the discussion about how to enable their students make evidence-based explanations. Besides, none of them discussed how to let their students evaluate the trustworthiness of these sources. In order to overcome this limitation, activities, such as the MEL, can be modified to include discussions on the trustworthiness of the provided evidence and the potential bias that these evidences may include besides model-evidence relations. For the purpose of encouraging them to implement these issues in their teaching they can be asked to design and implement an activity based on the discussion of competing theories in a discourse environment during which their students evaluate not only model-evidence relations but also trustworthiness of the claims presented as evidence and potential bias that these evidences may involve.

Using historical cases may be another option for teaching NOS. Cases of historical errors seem to be beneficial to differentiate honest mistakes from bias. History also facilitates reasoning about evidence and alternative explanations as well as understanding human and cultural dimensions of science and teaching inquiry skills (Allchin, 2013). MEL activities including evidence from historical cases may be fruitful in this respect.

The foremost NOS aspect, we think, the revision of scientific knowledge by evaluating evidence should be included in teacher education courses. Evaluation is included in SPs such as questioning, observing, collecting data, experimenting, imagining, developing and using models and constructing explanations about all aspects of phenomena (NGSS Lead States, 2013). So, teacher education programs should also include how to use and teach these practices.

Even though participants emphasized the aspect of evidence-based explanation in both their group and individual LPs, they used mostly empirical evidence. Despite the use of MEL diagrams in this study, none of the participants used any kind of competing theories for teaching their students about evidence-based explanation. This result reveals that pre-service teachers should not only be engaged in this kind of discussion, but instructors should also inform pre-service teachers about this technique explicitly on examples during their instruction. For example, Erduran (2007) suggested using argumentation by presenting two alternative theories with evidence that would support each theory for teaching chemical laws. Instructional materials, such as MEL diagrams provide the tools to weigh the merits of scientific explanations compared to a plausible, but non-scientific alternative by critically evaluating how well lines of evidence support each alternative. Activating such critical thinking through evaluation is essential skill for engaging in many of the scientific and engineering practices—asking critical questions, using model-based reasoning, planning and analyzing scientifically valid investigations, constructing plausible explanations, engaging in collaborative argumentation—which in sum represent a critical dimension used to build the Next Generation Science Standards (NGSS Lead States, 2013). Pre-service science teachers can be introduced to such instructional activities in the pre-service classes and use these strategies in their own class.

This study has some limitations including the design and the methods of this research. First, this study considered only participants' written explanations in their written LPs because discussing and justifying their views about NOS aspects, SPs, and evidence to explanation connections is a beneficial activity to facilitate pre-service teachers to make sense of these issues. Detailed observations of pre-service teachers during lesson plan design presentations and lesson plan implementation may provide additional help to researchers understand how deeply pre-service teachers understand how to incorporate NOS into their teaching.

A second limitation is the lack of FRA conceptualizations among the list that the participants were supposed to read, which implies that they were not familiar with this approach during designing their LPs. They were free to choose any NOS aspects that they prefer to emphasize as well. However, one group of participants mentioned BRH during emphasizing on SPs. In the Laboratory Applications in Science Education course they took during the previous semester they discussed SPs based on BRH. This result provides evidence that presenting heuristics during discussions of these conceptualizations may help pre-service teachers to recognize and emphasize them in their teaching. This result leads to the conclusion that the further investigations of implications including the discussions of FRA framework in teacher education programs may bring new light to teaching NOS.

Another limitation of this study is the context-relatedness of NOS. We introduced pre-service science teachers to different approaches in teaching NOS. However, in this study, students discussed the connection between lines of evidence and two alternative models within the context of specific topics, CC, E and GMOs, without an explicit emphasis on the aspects of NOS. We believe the discussion of relevant NOS aspects in a context by using an instructional scaffold like MEL diagrams may be crucial in investigating pre-service teachers' understanding of NOS. However, some questions may arise regarding the findings of this study such as what are pre-service teachers' trustworthiness evaluations in the given information in MEL diagrams regarding the socio-scientific issue under study? How do they relate the aspects of NOS listed in FRA framework to the ideas in these issues? Does the information given in the text as evidence in MEL diagrams meet the criteria of NOS aspects listed as RFN categories? Which aspects of NOS in FRA framework were emphasized in the given texts of MEL diagrams? How do teachers and pre-service teachers reflect these ideas in their teaching? Further investigation addressing these questions may bring new light to research on NOS and evaluations of evidence.

CONCLUSION

Science teacher education programs should focus on SPs, modeling, and argument from evidence for explaining NOS (Duschl & Grandy, 2013). In order to achieve this aim, teacher educators need to understand pre-service teachers' incorporations of NOS and evidence into their teaching. Based on the findings of this study, we suggest examining pre-service science teachers' understanding about NOS aspects listed in RFN list and SPs and their use in various science topics before teaching them. Understanding their stances about these issues may help teacher educators to design teacher education programs including NOS aspects and evidence.

The results of this study show that pre-service teachers underemphasize social-institutional systems in science, scientists' activities, social certification and dissemination, and constructing arguments based on evidence in a discourse environment. Discussing various aspects of NOS and different approaches to lead the students make evidence-based explanations, based on the information of how these practices, ideas, and concepts develop as the grade level increases may help pre-service teachers develop creative ideas and innovative approaches to appreciate the significance of these topics and integrate them into their teaching. Instruction may also help pre-service teachers understand the revolutionary changes in scientific theories by referring to social, political and historical cases. The use of instructional scaffolds that promote critical thinking and evaluation of alternatives, in the context of socio-scientific issues (e.g., MEL diagrams, Lombardi, Sinatra, & Nussbaum, 2013; critical questions and argument Vee diagrams, Nussbaum & Edwards, 2011) seems to be promising for enabling pre-service teachers make evidence-based explanations and understand NOS. However, explicit teaching to pre-service teachers by introducing various examples of competing theories for classroom use seems to be needed. Teacher preparation programs need to include designs that encourages pre-service teachers design their own teaching tools and materials for the use of competing theories to enable their students to engage in argument from evidence and evaluate the trustworthiness of these evidences by integrating the discussions of what constitutes evidence and which criteria to depend on in order to evaluate the trustworthiness of the sources of evidence.

This study neither features a pre/post design, nor a comparison group of pre-service teachers that did not take part in the program. Therefore, conclusions as the effectiveness of the treatment implicated in this study cannot be made because the participants' prior appreciation of NOS and SPs (or that of a control group, respectively) is not available for comparison. Although the study does give some qualitative insights in what kinds of NOS aspects and SPs pre-service teachers put most emphasis on, further research with a pre/post, comparative design may bring additional insights to this issue. It will also help teacher educators to observe pre-service teachers during implementing their LPs in a real classroom. Further investigations focusing on these points may clarify this issue.

We also recommend placing emphasis on NOS explicitly by using FRA framework during using MEL diagrams. Discussions should be carried not only on the connection of model and evidence, but also various aspects of FRA. Discussions about which aspects of NOS in FRA framework are included in the evidence provided in the texts may be helpful for pre-service teachers to reflect these ideas in their teaching. Other implications, such as historical cases besides MEL diagrams may facilitate evidence-based discussions of socio-scientific issues. Pre-service teachers may then asked to design LPs enabling their students critically evaluate evidence by emphasizing the aspects of NOS in FRA framework. This kind of design may help pre-service science teachers construct their understanding of NOS by critically evaluating different perspectives.

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