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INFLUENCE OF A SOCIALLY-MEDIATED CONTEXTUAL PROFESSIONAL DEVELOPMENT PROGRAM ON PROSPECTIVE SCIENCE TEACHERS' UNDERSTANDINGS OF NATURE OF SCIENCE, AND INTEGRATING IT INTO THEIR INSTRUCTIONAL PLANNING

Case Study

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INFLUENCE OF A SOCIALLY-MEDIATED CONTEXTUAL PROFESSIONAL DEVELOPMENT PROGRAM ON PROSPECTIVE SCIENCE TEACHERS' UNDERSTANDINGS OF NATURE OF SCIENCE, AND INTEGRATING IT INTO THEIR INSTRUCTIONAL PLANNING[1]

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Abstract

This study, which was conducted in 2016-2017 academic year, scrutinized the impact of a purposefully designed professional development program titled 'NOS-PD' on the understandings of the Nature of Science (NOS) via instructional practices. Specifically, the purpose of this qualitative multiple-case study was to delineate the impact of a NOS program with a socially-mediated contextual support on the prospective science teachers' understandings of NOS and integrating it into their instructional planning. In the study process, 13 prospective science teachers took part in an intensive 9-week program conducted at 3 stages (5 weeks + 3 weeks + 1 week) based on a 6-week explicit-reflective NOS instruction plus three weeks of participants' developing lesson plans with the help of socially-mediated contextual support. Data sources included an open-ended NOS questionnaire and lesson plans. Results indicated that as a result of the NOS instruction, the vast majority of the participants improved their understandings of NOS in an appropriate way. The analysis of the lesson plans revealed three characteristics of participants' instructional planning for teaching NOS after the NOS-PD program, a) NOS was not sufficiently interpreted except for three NOS components, b) some improvements in terms of the instructional and evaluation strategies were observed, but the knowledge of objectives did not show substantial change, and c) few participants exhibited a robust reported PCK by performing NOS integration at a high level.

Keywords: Nature of science translation, professional development program, highly-contextualized nature of science instruction, prospective science teachers

1. Introduction

What is at the core of science education reform efforts is to establish adequate nature of science (NOS) understandings. This is because the NOS is a fundamental component of scientific literacy serving as the vision of reform efforts (Abd-El-Khalick & Lederman, 2000a; Herman & Clough, 2016; Lederman, Antink & Bartos, 2014). In contrast, it has frequently been reported that students possess naive NOS understandings (e.g., Akerson & Donnelly, 2010; Khishfe, 2008; Khishfe & Abd-El-Khalick, 2002). Teachers have an essential role to play in students' gaining desired NOS understandings (Deniz & Adibelli, 2015; Hanuscin, Lee & Akerson, 2011; NGSS Lead States, 2013). Research findings show that teachers, regardless of their experience in practice, do not have views that are in line with the paradigm of contemporary science (Abd-El-Khalick & Lederman, 2000a; Akerson, Abd-

[1] This study was partly presented in ICEMST 2017: International Conference on Education in Mathematics, Science and Technology on May 18-21, 2017 in Kusadasi/Turkey as oral presentation entitled "Both lasting and translated NOS understandings. Is it really possible?: A collaborative intervention by means of instructional planning within highly-contextualized explicit-reflective NOS instruction".

El-Khalick & Lederman, 2000; Abd-El-Khalick, 2005; Akerson & Hanuscin, 2007; Bell, Matkins & Gansneder, 2011; Mulvey & Bell, 2017). In addition, criteria that are accepted internationally in the field of science education require that students have informed NOS understandings (AAAS, 1993; NGSS Lead States, 2013). Teachers with inadequate NOS understandings are unlikely to be able to guide their students to acquire informed ones (Bell et al. 2011). Having informed NOS understandings paves the way for a more purposeful and integrated way of learning scientific concepts (Mulvey & Bell, 2017). Teachers should establish explicit connections between instructional activities and NOS components in order for students to develop desired NOS understandings (Abd-El-Khalick, Bell & Lederman, 1998). In summary, teachers need to be able to translate their informed NOS understandings into teaching at the K-12 level (Abd-El-Khalick, 2005; Akerson, Buzzelli & Donnelly, 2010; Akerson & Volrich, 2006; Bell, Mulvey & Maeng, 2016; Hanuscin et al. 2011; Wahbeh & Abd-El-Khalick, 2014).

Pedagogical Content Knowledge (PCK) has a dynamic structure, and teaching experience is one of the most essential sources of PCK development (Abell, 2008; Davidowitz & Potgieter, 2016). One of the basic assumptions is that teachers who have more teaching experience have more robust PCK. In such a case, experienced teachers are expected to teach NOS more effectively. However, experience may not always enhance PCK (Friedrichsen et al. 2009). This result has raised the question whether prospective teachers who lack the opportunity of teaching experience could develop robust PCK. Since prospective science teachers lack teaching opportunities at first-hand, it is quite difficult to make any substantial claims related to their NOS teaching practices (Bilican, Tekkaya & Çakıroğlu, 2012). Prospective teachers who can develop especially PCK readiness for instructional practices due to lack of teaching experience (Davis, 2003) lack robust PCK in relation to instructional practice (Loughran et al. 2004; Van Driel et al. 1998). While prior research has been successful in identifying ways to support NOS teaching by means of developing teachers' NOS understandings, they have been less successful in developing PCK for NOS instruction (e.g., Akerson & Abd-El-Khalick, 2003; Faikhamta, 2013; Schwartz & Lederman, 2002). A similar situation corresponds to prospective science teachers (Akerson & Volrich, 2006; Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci & Köseoğlu, 2016). Not much is known from research about the process of development in PCK for NOS and specifically about how this development may be facilitated for prospective science teachers. Teacher education programs are a valuable resource with respect to answering this question. This is because prospective teachers who have not had the chance to gain teaching experience can be supported to develop PCK by having them attend pedagogical courses, prepare instructional plans and observe classroom lessons of mentor teachers at the internship schools (Grossman, 1990; Hanuscin, Cisterna & Lipsitz, 2018). Despite institutional constraints, prospective teachers can effectively teach about NOS embedded in a specific science content when they receive the appropriate training (Clough & Olson, 2012). During the design phase of this study, an extensive literature review was conducted based on the assumption that the recommended strategies for effective NOS instruction would also be required for enhancing PCK for NOS. This review highlighted the highly-contextualized explicit-reflective NOS instruction proposed by Clough (2006) among others. Highly-contextualized instruction may support subject matter and help connect students to science knowledge. A potential alternative to the either-or approach is NOS instruction along a context continuum, a combination of highly and non-contextualized NOS instruction including various degrees of contextualization between the aforementioned extremes (Bell et al. 2016). Given that highly-contextualized NOS experiences can be easily affected by inadequate NOS understandings, first explicit-reflective NOS instruction based on a context continuum was implemented in this study by the researcher in order for prospective science teachers to develop their NOS understandings and PCK for NOS within a teacher education program. That instruction was followed by pedagogical instruction framed by PCK for NOS. The latter predominantly focused on the objectives of science education, instructional strategies and evaluation components in order to teach NOS effectively. As studied by many researchers (e.g., Akerson & Abd-El-Khalick, 2003; Akerson & Volrich, 2006; Bilican et al. 2012; Demirdöğen, 2012), it was ensured that participants received intense pedagogical support through socially-mediated contextual professional support as soon as the highly-contextualized NOS instruction began.

The present study mainly focuses on how highly-contextualized explicit-reflective NOS instruction coupled with socially-mediated contextual professional support influence prospective science teachers' NOS understandings and their NOS translation into instructional planning. Three questions guided the investigation:

1. How does highly-contextualized explicit-reflective NOS instruction influence the development of prospective science teachers' understanding of NOS?
2. To what extent do prospective science teachers integrate the components of reported PCK for NOS into lesson planning following highly-contextualized explicit-reflective NOS instruction?
3. How can the participant prospective science teachers' progress be reported about PCK for NOS as a result of socially-mediated contextual professional support following highly-contextualized explicit-reflective NOS instruction?

2. Theoretical Background and Literature Review

2.1. Nature of Science (NOS)

One of the key priorities of being scientifically literate is to understand the NOS. The NOS is an umbrella concept that hosts the history, philosophy, sociology and psychology of science (Laugksch, 2000; McComas, Almazroa & Clough, 1998). Inquiries in these areas are usually guided by epistemological beliefs about scientific knowledge. As a result, cyclical definitions of the NOS are quite common. Such definitions appear to be constructed at large based on Lederman's (1992) NOS definition, and the NOS appears to be referred to as a dynamic structure based on science and its underlying epistemological foundations as a way of knowing, as well as values and beliefs that are strictly bound to the process of development of scientific knowledge. Because of this dynamic interaction, the NOS can be assumed to have become more frequently influenced by scientific developments. In spite of the existence of views that are contrary, it is seen that especially science educators have reached a general consensus about what the NOS is and they think that the NOS can be taught at the K-12 level. As is the case with learning subject matter or developing science process skills, NOS teaching should be intentionally planned (Abd-El-Khalick & Akerson, 2009). One of the first conceptualizations of the NOS, which is thought to be taught through curricula, is the set of components referred to as the "Lederman Seven" (see Lederman, 1999). These NOS components are constructed on the understanding that scientific knowledge is tentative (subject to change), empirically based, subjective and socially embedded as well as involving explanations produced by human imagination and creativity, revealing the difference between observations and inferences, and finally referring to the relationships between laws and theories. These components are the product of a robust interaction with regard to the NOS. This interaction has an important role to play in the integration of insights relevant to the paradigm of contemporary science that form around the NOS components in the context of student learning. With the help of effective NOS instruction, students can learn that new knowledge is acquired based on the exploration of new evidence that undermines the validity of previous knowledge or the evaluation of existing data within more comprehensive and reliable theoretical frameworks and that none of the types of knowledge can be conclusively proven even if countless evidence is reached that supports them. They do not defend the argument that scientific knowledge is precise regardless of its being a type of knowledge that is reliable and long-term. On the other hand, they know that our observations about nature are always interpreted by taking into account certain theoretical frameworks, regarding our perceptions and instruments through which observations are conducted. They also know that scientific knowledge is constructed at the end of a process formed by the common influence of a variety of assumptions. Similarly, they realize that scientific results are based on the evidence acquired in this process. Students who understand the role of evidence stemming from the natural world in generating scientific arguments become successful in distinguishing science from other research disciplines, from what is non-scientific and from what is pseudo-scientific. NOS instruction can also keep students from regarding science as a solely logical and sequential activity that is detached from life. Once typical misconceptions about the image of science are eliminated, students understand that science is practiced in a process that depends heavily on imagination and creativity. Another important subject to teach to students is that science never begins with impartial observations. Science and scientific knowledge are unlikely to be considered independently from scientists because scientific knowledge is influenced by scientists' prejudices, experiences, accumulation of knowledge, the values of the society in which they live, their beliefs, the nature of the education they receive and their expectations. Such characteristics about the NOS can be said to have certain similarities to the framework pointed out by AAAS (1990). The fact that the studies in the field of NOS have recently shown significant improvements in terms of content, scope and method draws attention. However, it is claimed that research in this field has a deep-rooted history (Abd-El-Khalick et al. 1998). Indeed, Lederman (1992) has collected the research on the NOS until that date under four headings to illustrate a hierarchical progress. The last of these headings, which is the one that is closest to the present day, is the examination of the relationship between the understandings of the NOS that teachers have and the translation of these understandings into classroom practices (Abd-El-Khalick & Lederman, 2000a). In order for students to understand the aforementioned NOS components, teachers need to improve their PCK about how to teach the NOS. Otherwise, due to regular classroom lecture of science content (explicit instruction), which are the common tendency today, it is likely that NOS components are perceived by students as a list that should be memorized, and therefore students will continue to have naive NOS understandings. This highlights the importance of the urgent need for the conceptualization of PCK for NOS.

2.2. The Reciprocal Interplay Between Nature of Science (NOS) and Pedagogical Content Knowledge (PCK)

Teacher preparation has an invaluable clear impact on the successful implementation of the reform efforts in the science classroom. Today, teachers need much more subject matter knowledge than they already know, which has led to the emergence of PCK, which is, in some way, a mix of such content and pedagogical knowledge (Abell, 2008; Alonzo & Kim, 2016). PCK, which forms the essence of this conceptualization, is a special type of knowledge that distinguishes an effective teacher from a subject matter expert (Shulman, 1986). PCK brings together several knowledge components that work systematically to help teachers represent specific subject matter in a way that make it accessible and comprehensible to students (Magnusson et al. 1999). Such teaching knowledge base, more often called as the lost paradigm, has become a kind of facilitator for understanding the complex relationship between pedagogy and subject matter through an integrated process rooted in classroom practices (Van Driel, Verloop & de Vos, 1998). Consequently, content knowledge about the NOS can be examined under instructional subject matter that is a sub-dimension of general PCK (Hanuscin et al. 2011; Lederman, 1999). Once placed within the context of national standards for science education, it is indicated that teachers should choose some suitable instructional content and transform it to fit the goals set out in the curricula (e.g., NRC, 1996). The fact that there are a variety of ways to teach the NOS is one of the characteristics that distinguishes PCK for teaching the NOS from general PCK. The value attached to this concept stems from the fact that it empowers teachers to have the opportunity to translate their NOS understandings to their classroom practices through this kind of pedagogical knowledge (Akerson & Volrich, 2006; Hanuscin et al. 2011; Wahbeh & Abd-El-Khalick, 2014). A teacher who has sufficient PCK to teach the NOS can translate his or her informed NOS understandings into a way that students can learn in-depth in a meaningful way, and he or she can conduct the lessons in that way (Akerson & Hanuscin, 2007; Hanuscin et al. 2011). In order to teach the NOS content, one needs to have informed NOS understandings, but this does not guarantee effective NOS instruction (Akerson & Abd-El-Khalick, 2003; Akerson & Volrich, 2006). Moreover, it is common for teachers to be unable to translate their understandings of the NOS to classroom practice and to need pedagogical support in this regard (Akerson & Abd-El-Khalick, 2003; Abd-El-Khalick, 2005; Park & Chen, 2012; Wahbeh & Abd-El-Khalick, 2014; Bilican, 2014). Studies reveal that even experienced teachers who have informed NOS understandings and motivated to teach their students these understandings need support for classroom practices during their lessons (Akerson & Abd-El-Khalick, 2003; Hanuscin et al. 2011; Wahbeh & Abd-El-Khalick, 2014). In this respect, even in the best case, NOS translation into classroom practices is limited, and this mechanism is mediated through a variety of variables (Abd-El-Khalick et al. 1998; Abd-El-Khalick & Lederman, 2000b; Bell et al. 2000; Southerland et al. 2006). Teachers, especially prospective teachers, may have difficulty in embracing the relevance of PCK for NOS and their science teaching (Demirdöğen et al. 2016). Moreover, prospective teachers' content knowledge may be less structured and can contain inaccuracies (Käpylä, Heikkinen & Asunta, 2009). Because of its crucial role in this process, PCK is regarded as a key criterion for teacher effectiveness by many scholars (Van Driel et al. 1998; Mazibe, Coetzee & Gaigher, 2018).

Most science teacher education programs are not successful at improving prospective teachers' PCK as a whole through integrating courses on subject matter, pedagogy and field experiences (Van Driel et al. 2002). Joining this lively debate, Mellado et al. (2008) have advocated that teacher education that teachers receive along teacher education programs is not effective in helping them develop PCK for NOS. Accordingly, it can be said that science education programs alone may not improve all PCK components due to various restrictive conditions (Magnusson et al. 1999). Abd-El-Khalick (2005) found that the prospective science teachers who participated in a science philosophy-based science curriculum not only had more intention to design explicit NOS instruction but also began to include it in their lesson plans at the PCK level. One of these variables is teachers' informed understandings about NOS components. Teachers should know basic subject matter knowledge as well as examples, demonstrations, and historical links associated with it. They should be able to talk seamlessly about the components, to teach content in the context of examples from the history of science, and to develop new science-based activities in this direction. In brief, teachers should have PCK that is unique to the NOS. More importantly, teachers must be able to integrate those components into PCK coherently to effectively plan and enact instruction in a specific science context (Loughran, Berry & Mulhall, 2006; Van Driel et al. 2002).

PCK may offer science teachers a purposive way to represent a plenty of scientific practices within their teaching (Van Dijk, 2014). For this reason, PCK is an academic framework that can be adapted to a highly-contextualized setting because it is connected to a specific grade, students and teaching events (Berry, Loughran & Van Driel, 2008; Loughran et al. 2001). Such a highly-contextualized setting mandates that the professional development of prospective teachers who are likely to teach science should be planned through a consistent PCK theoretical framework that is embraced in the field on the basis of various professional development programs. Hence, professional development programs should be aware of idiosyncratic style of PCK in order to promote student teachers' professional development in a meaningful way (Rozenszajn & Yarden, 2014). Understanding teachers' practices for the process of student learning necessitates an understanding not only of the instructional methods they use but also of what content they use the methods through (Park & Oliver, 2008). NOS instruction should be planned by taking into account instructional objectives, instructional strategies, and measurement and evaluation techniques, just like any other contents, and the NOS components should explicitly be emphasized during science teaching (Schwartz & Lederman, 2002). It is worthy of note that an explicit-reflective approach is often used to improve NOS understandings of teachers and prospective teachers throughout these programs, and that there is plenty of evidence for the appropriateness of this approach (e.g., Abd-El-Khalick & Lederman, 2000a; Bell et al. 2011; Abd-El-Khalick & Akerson, 2004a; Abd-El-Khalick & Akerson, 2009; Akerson & Hanuscin, 2007; Khishfe, 2013; Khishfe & Abd-Khalick, 2002; Matkins & Bell, 2017). This approach should not be mistaken with didactic instruction, as this approach offers an effective context for students to construct their NOS understandings under teacher guidance (Deniz & Adibelli, 2015). Recent research seems to corroborate that explicit-reflective NOS instruction has more effective results when taught in a context or contexts. With regard to NOS instruction, it is widely seen that researchers prefer either towards decontextualized NOS instruction without any instructional content (e.g., Akerson et al. 2000; Bell et al. 2011; Khishfe & Lederman, 2006) or towards contextualized NOS instruction with instructional content (e.g., Abd-El-Khalick & Lederman, 2000b; Matkins & Bell, 2007). Activities used during decontextualized NOS instruction are intended to address concepts that may seem complex at first glance, instead of internalization of NOS components. By this means, students have the opportunity to trigger their prior knowledge of NOS components (Abd-El-Khalick, 2001). It is known that decontextualized NOS instruction creates a limited effect (Abd-El-Khalick & Akerson, 2004a; Akerson & Hanuscin, 2007; Akerson et al. 2000). To date, contextualized NOS instruction has been conducted in contexts such as inquiry (Khishfe & Abd-El-Khalick, 2002; Akerson & Hanuscin, 2007), conceptual change (Abd-El-Khalick & Akerson, 2004a; Mulvey & Bell, 2017), history of science/current reading texts (Abd-El-Khalick ve Lederman, 2000b; Abd-El-Khalick, 2005; Duruk, 2017; Rudge & Howe, 2009; Kim & Irving, 2010), and instructional content/socio-scientific issues (Matkins & Bell, 2007; Bell et al. 2016). However, it is recommended that decontextualized and contextualized activities be combined for the NOS instruction to be effective (Mulvey & Bell, 2017). Clough (2006) took this argument one step further and recommended that a "context continuum" be used to contextualize NOS instruction (see Bell et al. 2016). The concept of contextualizing at varying levels relating to decontextualized as well as contextualized instruction has taken pivotal role in this approach. A context continuum is organized in a way that ranges from decontextualized contextualization to highly-contextualized contextualization. In the steps other than the first step, subject matter knowledge is arranged in an interconnected way. It is thought that teachers' PCK can be a valuable source for them to be able to teach the NOS in contexts that is also rich in content (Wahbeh & Abd-El-Khalick, 2014). Indeed, it has been pointed out that teachers with strong PCK are able teach in a more balanced way, between instruction for students' subject matter knowledge and skills that are desired to be taught (Bayram-Jacops et al. 2019). As noted earlier, the NOS content can also be seen as a type of content knowledge addressed under PCK components. As a matter of course, teachers' ability to develop NOS understandings is strongly linked to their PCK. Put differently, teachers must improve their PCK for NOS so that they can teach such NOS content. It can be argued that NOS instruction deprived of a context can only make a small contribution to the improvement of prospective teachers' NOS understandings and their development of PCK for NOS (Abd-El-Khalick, 2001; Clough, 2006). The importance of the final step of the continuum in particular is also due to its promising significant opportunities for teachers' development in PCK for NOS. Therefore, the context continuum played a part within the conceptual framework of this study in a way to guide the implementation process.

Recent research has highlighted the significance of the distinction between declarative/dynamic (Alonzo & Kim, 2016) and reported/enacted (Mazibe et al. 2018) PCK. Specifically, these two conceptual frameworks are based on the idea that declarative and reported PCK does not guarantee dynamic and enacted PCK in any case, respectively. Developing teachers' PCK for NOS is considered as a challenge for science teacher educators. Teachers who exhibit robust dynamic PCK appear to focus heavily on their declarative or reported PCK when judging different spontaneously occurring examples of student thinking and related pedagogical maneuvers (Alonzo & Kim, 2018). Therefore, we developed a specialized highly-contextualized explicit-reflective NOS course to improve both prospective science teachers' NOS understandings and their PCK for NOS planning (Demirdöğen et al. 2016).

3. Method

3.1. Research Design

This study was conducted as a qualitative multiple-case study taking into account the specified cases. Case studies are valuable in offering in-depth information about cases related to participants' real-life experiences (Hancock, 2002; Creswell, 2003; Stake, 2010). In this study, which was also based on the assumptions of interpretive paradigm with its qualitative aspect (Merriam, 2009), PCK for the NOS was considered as the analysis unit of a limited system (Marshall & Rossman, 2011). During this research, prospective science teachers who participated in the specifically contextualized explicit-reflective NOS instruction constituted the case through activities conducted in the course titled "Nature and History of Science".

3.2. Participants and Instructional Context

Instructional practices were carried out in the 3-credit hour mandatory course of "Nature and History of Science". The participants were a group of 13 student science teachers (12 females, 1 male) enrolled in Science Education Department of the Faculty of Education at a public university in the south east of Turkey. The participants were seeking bachelor's degree in Science Education. Prior to NOS instruction, they completed such courses as Foundations of Education, Educational Psychology, and Teaching Methods in Literacy and Social Studies. In other words, all participants had similar background such that they completed the same number of credit hours of mandatory field courses of science as well as the educational courses. They were in their sixth semester in the program and their main responsibility was to teach science to their students from grades 5 to 8 after graduation. They were introduced all the process they were likely to encounter voluntarily and supposed to do during the study. All the participants were assured about the confidentiality of the research, and their autonomy of withdrawal at any time during the implementations.

The instructional context was based on pedagogical instruction framed by PCK for NOS. Within the scope of the previously mentioned program, the researcher taught explicit-reflective NOS instruction in the context of certain instructional content that more contextualized over time, by focusing specifically on NOS components. This instruction was shaped under the assumptions of the conceptual change in general. The instruction was based on the idea presented by Clough (2006) on the monitoring and modification of the levels of differentiation of contexts during the course of the study. According to this framework, the activities used during any explicit-reflective NOS instruction should be addressed in a way that goes from basic to complex, in other words, from generic activities to highly-contextualized activities. The researcher noted that this process comprised of four consecutive stages. Within this scope, a modular teaching process was designed. This instructional process was carried out as three modules. The first two modules were carried out as in-class activities, and the other was carried out as an extracurricular activity. The first module lasted five weeks and a total of 15 class hours. It consisted of non-contextualized (one week), minimally-contextualized (two weeks) and moderately-contextualized (two weeks) NOS instruction. The first of these stages was the stage that included just generic activities related to NOS components that had no context of instructional content. The instruction at this stage was based on analogies and directly targeted the instructional objectives of the NOS. A review of the findings of recent research has shown that, in most cases, the NOS instruction taught solely through generic activities is insufficient. In the current study, the following generic activities were used to teach the components of the NOS: “Young and Old,” “Mysterious Box,” “New Society,” and “Tangram.” These activities included seven NOS components introduced by Lederman (1992). The next stage was the stage in which the least contextualized NOS instruction was taught. What distinguishes this stage from the first one is that it establishes links or relationships between the activities carried out and a specific instructional content. A primary goal is the NOS instruction in this stage. Instructional content is also taken into account, although only slightly. In the current study, the activity called “Milk” was used. Following the completion of this activity, a general framework was established for a discussion on the distinction between science and pseudoscience by discussing whether the processes and methods used for this activity were scientific. Through these discussions, the prospective teachers’ views on the criteria for being scientific were captured, and they were asked to reflect on that. The stage at which the context of instructional content makes its effect felt more strongly is the moderately-contextualized NOS instruction stage. The instructional objectives about the NOS components remain a priority at this stage as in the previous stages. However, at this stage, the instructional content is contextualized under inquiry-based activities. Some of the case studies taken from the history of science — “Boyle and Torricelli” (Matthews, 1994) and “Discussion on the extinction of dinosaurs” (Alvarez & Azaro, 1990) — and various reading texts were selected in the current study. These reading texts, which were addressed under inquiry-based instruction throughout the instruction, were employed by integrating with the instructional content of “Gas Laws and Molecular Kinetic Theory” and “Natural Selection,” respectively.

Upon completion of the first module, which lasted five weeks, the implementation process of the second module began. The second module was planned in the form of highly-contextualized NOS course, and the implementation took three weeks and a total of 9 hours. The first week of these three weeks was devoted to highly-contextualized NOS instruction, and the remaining two weeks were devoted to PCK for NOS activities. Possible improvements that can be provided by the second module can be achieved through effective integration of activities at this stage with the activities at the previous stage. For the first time at this stage, it is the main goal to achieve the instructional objectives related to the instructional content. Examples of the history of science or contemporary science in general were given at this stage. It was the main goal for participants to reflect through these examples and to establish explicit links to the NOS components. Through this way, participants had the ability to reexamine their NOS understandings as well as building confidence in how to teach the NOS components (Mulvey & Bell, 2017). Various activities were used at this stage in the current study. These activities were addressed in the instructional content about friction force, historical development of the atomic theory, electricity, ways of heat transfer and genetics. This instructional content included hands-on activities, exemplary reading texts selected from the history of science, presentations and simulations. Moreover, the participants were offered the chance to superficially review ready-made lesson plans based on two units, friction force and ways of heat transfer, prepared according to the 5E learning model. This instructional content targeted the instructional objectives about empirical, tentative, inferential and finally socio-cultural NOS. In the practice section of the second module, the prospective teachers in the classroom were assigned into thirteen groups, each consisting of five participants. Then, following the modular instruction, a participant who had adequate NOS understandings and had motivation to teach NOS was randomly selected and named as the practitioner of his or her group. Each group leader was asked to design a draft lesson plan. There was no constraint with respect to subjects or NOS components that could be chosen during the preparation of the lesson plans. Thus, they were given the opportunity to choose freely, and they were encouraged to do so. For the next two weeks, the group leaders were asked to present their lesson plans in the classroom. During the discussions that took place throughout these presentations, the participants in other groups provided feedback on each of the lesson plans and the group leaders noted them. After the completion of the group presentations, the participants handed their lesson plans to the researcher. Pedagogical instruction framed by PCK for NOS was supported by feedback obtained as a result of the presentation of the lesson plans. This is because the stage mentioned above is a stage that allows participants to reflect on how to teach NOS and gives them a new insight into it, as well as improving their NOS understandings. The participants joined the discussions on the components of knowledge of science teaching orientation, knowledge of instructional strategies and knowledge of evaluation. This stage can be seen as the starting stage for the pedagogical instruction framed by PCK for NOS. This is because at this stage, as mentioned in the data analysis, three components of pedagogical content knowledge were highlighted. The discussions at this stage were guided by the open-ended questions asked by the researcher to get insight about the level of PCK for these components. After the general class discussion, the participants discussed the ideas within their groups and then shared them by presenting them to the other groups.

Once the first two modules were completed, a third module was implemented for a period of one week. This module was designed to offer socially-mediated contextual professional support where 13 participants would be able to conduct more in-depth pedagogical inquiries, share experiences of the practitioners, and reflect more critically on PCK for NOS through close contact with the researcher. The third module was carried out in the form of two workshops scheduled to be completed in a week. Accordingly, the researcher and the participants came together first. The participants attended a 2-day workshop regarding the implementation of PCK for NOS. The researcher interacted with them on a continuous basis. Throughout these workshops lesson debriefings, researcher- or teacher-initiated questions, clarifications, reflections and self-critiques were implemented, and the researcher delivered model lessons (Akerson & Abd-El-Khalick, 2003). Moreover, the participants were given the opportunity to discuss the criteria for the parts to be included in the lesson plans and to reflect on the NOS components they were considering to be included in the lesson plans. In other words, they were expected to integrate NOS understandings into all parts of the lesson plan, including objectives, instructional strategies and evaluation. In the objectives section of the lesson plans, they were asked to write instructional objectives that included both the instructional content they discussed and the relevant NOS components. In the activities section, they were asked to cover the strategies to use in order to integrate the two. In the evaluation section, they were asked to write about how to assess whether the targeted instructional objectives were fulfilled. The researcher informed the participants that following the focus group interviews that were planned to involve the participants two times during the workshop week, the participants were informed that they could revise and re-submit their lesson plans. With that, many of the participants were satisfied with this situation, and stated that they were excited to be able to finalize the parts that they had wanted to change in their previous version of the lesson plans. Thus, the participants had the opportunity to explore the structure of PCK components including knowledge of science teaching orientation, knowledge of instructional strategies and knowledge of evaluation within the NOS-PD.

3.3. Data Collection

Data sources included an open-ended questionnaire and the participant-generated artifacts as lesson plans. First, the participants were asked to fill out the Views of Nature of Science Questionnaire (Lederman et al. 2002). They completed it as a pre-test and a post-test at the beginning and end of the course, respectively. The data collected through the questionnaire were used to track the changes in NOS understandings of the participants who participated in NOS-PD, as well as to determine the participants who improved their NOS understandings as a result of this program. The primary method of data collection was to analyze the participants' lesson plans. These lesson plans represented the second and main data collection instrument of the study. The lesson plans gave the opportunity to identify the explicit connections the participants established about the NOS (Abd-El-Khalick et al. 1998).

3.4. Data Analysis

The data obtained were analyzed in two phases. In the first phase, the data collected through the Views of Nature of Science Questionnaire were analyzed. This analysis included the determination of NOS categories of participants who were chosen to be practitioners during the study. The participants' NOS understandings were analyzed and categorized as either informed, transitional, or naive (Khishfe & Lederman, 2006). Following, the participants' NOS profiles were created. In the second phase, the lesson plans prepared by the participants were analyzed. Consequently, NOS objectives, explicit-reflective NOS instructional strategies and evaluation were investigated during the analysis of lesson plans. These analyses were based on the lesson plan categories put forward by Bilican (2014), because the analyses focused on examining the participants' PCK for NOS as reported by themselves (see Table 1). These categories were collected under the following terms: objectives, evaluation and integration with respect to the course designed for the NOS instruction. What was expected of the participants in the objectives category was that the components of the NOS would be explicitly addressed in the lesson plan they prepared. Indirect connections established for the components were coded under this category as "needs development." The lack of any associations or connections was coded as the "poor" category. In the evaluation category, which had its own section in the lesson plan, if any evaluation was explicitly associated with NOS components or connections were established with it, this was coded as "exemplary". The part of the analysis that is considered to be the most important is the integration category that is frequently associated with PCK, with which the components of the NOS are integrated. For the participants to be coded in the "exemplary" category, they must ask specific questions about the NOS tailored to each unit in the lesson plan, make explicit connections between the instructional content of the unit and the NOS components, and finally maintain consistency between the instructional practices for the components and the objectives determined in the lesson plan. The "needs improvement" category, which described the participants' intentions of integration rather than explicit NOS instruction, points that this instruction, where the participants chose direct instruction, may not provide adequate pedagogical characteristics and that there were discrepancies between instructional practices and instructional objectives. Support was obtained from an expert working in the field of NOS during the data analysis process. The framework used for the analysis of the data from the lesson plans was explained to the coder. He was asked to assess the units in the lesson plans and code them in accordance with the relevant categories. After that, the researcher and the coder came together and discussed the units of the all analysis. Discussions continued until consensus was reached on the categories that were undecided. In order to resolve the discrepancies in opinions during the analysis, the coders came together once again. The discussion continued until a compromise was reached. The aim was therefore to avoid possible biases on the part of the researcher who is a NOS-PD practitioner.

Table 1. *Lesson plans analysis' categories*

	Instructional planning for NOS components	Categorization
Objectives	Inclusion of NOS explicitly	Exemplary
	Implicit NOS reference in objectives	Needs development
	No explicit NOS reference in objectives	Poor
Evaluation	Reference to NOS explicitly in evaluation part	Exemplary
	No NOS evaluation specifically	Poor
NOS integration	No explicit-reflective reference	Poor
	Intent for NOS integration: •Explicit but direct NOS instruction •Lack of coherence between NOS objective and NOS specific instructional prompts	Needs development
	Explicit–reflective NOS instruction: •Specific NOS questions •Clear connection between NOS and science content •Coherence between NOS objectives and NOS specific instructional prompts	Exemplary

4. Results and Discussion

The main purpose of the study was to explore the impact of NOS-PD on prospective science teachers' NOS understandings and instructional planning. Following is a presentation of results given in three separate sections in relation to the research questions previously given. All participant names are pseudonyms. Insights into science teacher education program were discussed and further recommendations for future research provided.

4.1. Impact of the Highly-Contextualized Explicit-Reflective NOS Course on Participants' NOS Understandings

This section includes highly-contextualized explicit-reflective NOS understandings of 13 participants before and after the NOS course who were willing to prepare lesson plans and were motivated to teach NOS to students. Table 2 shows the categorical changes in NOS understandings of these participants. The section also provides illustrative excerpts from participants' informed NOS understandings in relation to NOS aspects.

A review of Table 2 points to substantial changes in the participants' understandings of seven NOS components. Before the highly-contextualized explicit-reflective NOS course, the vast majority of the participants were found to have naïve NOS understandings. These results stand in line with the studies in the specific context of explicit-reflective NOS instruction (e.g., Abd-El-Khalick, 2005; Abd-El-Khalick & Akerson, 2009; Akerson & Volrich, 2006; Khishfe & Abd-El-Khalick, 2002).

Table 2. *NOS understandings before and after highly-contextualized explicit-reflective NOS course*

NOS components	Before NOS Course			After NOS Course		
	Naïve	Transitional	Informed	Naïve	Transitional	Informed
Empirical	8 (61.54%)	5 (38.46%)	0	2 (15.39%)	1 (7.69%)	10 (76.92%)
Tentative	13 (100%)	0	0	1 (7.69%)	1 (7.69%)	11 (84.62%)
Inferential	10 (76.92%)	3 (23.08%)	0	3 (23.08%)	4 (30.77%)	6 (46.15%)
Theory/law	13 (100%)	0	0	3 (23.08%)	1 (7.69%)	9 (69.23%)
Theory/laden	10 (76.92%)	2 (15.39%)	1 (7.69%)	2 (15.39%)	6 (46.15%)	5 (38.46%)
Socio-cultural	7 (53.85%)	5 (38.46%)	1 (7.69%)	0	4 (30.77%)	9 (69.23%)
Creativity	1 (7.69%)	12 (92.31%)	0	0	9 (69.23%)	4 (30.77%)
Total	68.13%	27.67%	2.20%	12.09%	28.57%	59.34%

The participants were identified to have mostly naïve (68.13%), then transitional (27.67%) and least frequently informed understandings (2.20%) in terms of all components. After the NOS course, the participants' inadequate understandings (naïve and transitional) decreased by about 56%, while their informed views increased by 57%. In other words, nearly all of the transitions were from inadequate to informed NOS understandings. In brief, the participants were overall found to have inadequate NOS understandings in all components before the course. This inadequacy is concentrated particularly in the empirical, tentative, inferential, theory/law, and theory-laden components. Following the NOS course, the components where informed understandings were improved the most were the empirical, tentative, theory/law and socio-cultural NOS. There was not as much increase as expected in informed understandings in the inferential and theory-laden NOS components which were intense in terms of inadequate understandings before the NOS course. When examined in terms of socio-cultural and creative NOS components, where inadequate understandings were relatively low prior to the course, there was not as much increase as expected in creative NOS. Limited and naïve NOS understandings can be discussed through various points of view. Participants with naïve empirical NOS understandings may not be aware enough that evidence plays a significant role in the construction of scientific knowledge. It was seen that the participants had reached informed understandings after the NOS course, except for three participants. Before the NOS course, more than half of the participants were found to have inadequate understandings in the inferential NOS component. In this component, what is expected of the participants is that they should know that observations address senses, while inferences are interpretations about observations. Inferences should be logical and consistent with the observations they are based on. In contrast, the participants who had naïve NOS understandings had the opinion that "seeing is believing." These participants could believe that observations instead of inferences were subjective. More than half of them achieved informed understandings in this component after the implementation. Before the NOS course, all participants were found to have inadequate views in the tentative NOS component. The participants pointed out that scientific knowledge had been proven and therefore would not change, and that laws would not change while theories would change since laws had been proven. After the NOS course, all but two participants had informed understandings in this component. It can be useful to give the participants' illustrative excerpts directly to better understand the change in the components. The participant codenamed Arzu prepared lessons plans for the empirical and inferential components. The participant's transitional understandings in the empirical NOS and her naïve understandings in the inferential NOS prior to the implementation were found to translate into informed ones:

"*In scientific fields such as physics and biology, one focuses on factual data rather than subjective opinions. In fields such as religion and philosophy, factual quality is not a matter of discussion. Factual data are mediated by observations and experiments*" (empirical NOS, post-test).

"*Scientists used a variety of observation data to decide the structure of the atom. Scientists who interpret the data obtained through observations, through their own perspectives make inferences depending on these observations. The shape of the atom is also a product of such inferences. As the boundaries of our imagination expand, so do our inferences*" (inferential NOS, post-test).

When her opinions were examined, it was observed that Arzu turned to factual data as a scientific measure and referred primarily to observations and experiments as the way through which such data were obtained. And, when discussing the structure of the atom, the participant was aware of the significance of observational data. She claimed that these observations were theory-laden, that inferences had been reached through observations, and that this process had continued in a loop of imagination-based creativity. Another participant, Begüm, had an informed understanding after the implementation in the empirical, tentative, and inferential components that she included in her lesson plan:

"Our imagination is, of course, effective when assuming the physical characteristics of dinosaurs, but our claims that we generate under the influence of our imagination have to be based on evidence. By studying fossils, we can learn about the true shape of dinosaurs" (empirical NOS, post-test).

"*If science is the matter of discussion, I think that no certainty can be the topic of conversation. Just like theories, laws are open to change. This is because scientific information can change by being reinterpreted through new evidence. Theories are helpful for us when generating new explanations*" (tentative NOS, post-test).

"*Even if we use an electron microscope, we can't be sure of what an atom actually looks like because our perceptions of the atomic phenomenon make sense through our inferences.*

Scientists are not capable of seeing atoms, contrary to what is known. Because they are human beings like us" (inferential NOS, post-test).

Begüm emphasized that fossils can be good evidence, noting that imagination-based creativity is carried out in an empirical manner. She pointed out that we cannot talk about the accuracy of knowledge even if it is based on evidence. She effectively explained the link between inferences through the structure of atoms and the tentativeness of the knowledge. The participant codenamed Defne had informed understandings after the implementation only in the first two of the empirical, tentative, inferential, and creative components that she included in her lesson plan:

"*We cannot get knowledge through experimentation all the time. Experiments are a form of observation after all. Scientific knowledge continues to be produced through observations in areas where experiments are not able to be conducted*" (empirical NOS, post-test).

"*Scientific knowledge may change as a consequence of new evidence and technological advances. For example, atomic theory or classical physics has changed over the course of time in this way. Certain scientific knowledge may also change with the reinterpretation of the evidence that is available. Later on, we may realize that the evidence at hand means much more, so we might also interpret it through other theories. This is because our mental competence while assessing the evidence is also important*" (tentative NOS-post-test).

Defne tended to reject the reductive interpretation and argued that evidence may not be collected through experimentation all the time. She implied that any experiment is another type of observation, and that its purpose is to gather evidence of certain facts only, rather than showing the truth. She argued that interpreting evidence in this process may also be constrained by the human factor. Duygu had an informed understanding after the implementation only in the first two of the empirical, tentative, and creative components — similar to Defne — that she included in her lesson plan:

"*Empirical NOS differentiates science from other research disciplines. Science makes observations on natural phenomena that function by displaying a specific pattern in the objective sense, and it bases its results on evidence*" (empirical NOS, post-test).

"*As the number of pieces of evidence that supports a scientific theory increases, that theory improves its explanatory power. In other words, the purpose of a theory is to explain facts of the natural world with its advanced explanatory and predictive characteristics, and it has tentativeness in the presence of new evidence and interpretations. Laws voice patterns of those facts descriptively. For this reason, these two are as different as apples and pears*" (tentative NOS, post-test).

Duygu, like Arzu, clearly expressed the empirical NOS component by claiming that the results are reached based on evidence. She emphasized that a theory would become a more reliable theory with more and more evidence. She is aware of the explanatory power and prediction of a theory. Providing an effective analogy, she explained that theories would not translate into scientific laws. Finally, while her understandings of all components were naïve, Yeşim, who had informed understandings in all of them following the course, did not refer to the tentative and inferential NOS components in her lesson plan. The participant's understandings in these components are as follows:

"*What can be given as good examples of the change of scientific knowledge are Thomas Kuhn's reinterpretation of the theses championed by the positivist scientific community and the claim that the accuracy and value of scientific knowledge have a meaning only in the paradigm to which it belongs. Paradigms change; everything changes!*" (tentative NOS, post-test).

"*Scientists should identify organisms in one way or another. This is because in order to figure out what a species is, we must be able to talk about it first. We cannot observe everything in an absolute certain way. Inferences are one of the scientists' greatest helpers, along with theories in this manner*" (inferential NOS, post-test).

In line with the first research question, the findings of the present study support research findings claiming that explicit-reflective NOS instruction (Abd-El-Khalick & Akerson, 2004; Akerson et al. 2000; Alan & Erdogan, 2018; Bell et al. 2011; Schwartz et al. 2004) as well as specifically explicit-reflective NOS instruction along a NOS context continuum are effective (Bell et al. 2016; Herman, Clough & Olson, 2013; Mulvey & Bell, 2017; Mulvey et al. 2016). More specifically, in studies on explicit-reflective NOS instruction, improvements have been reported in the following NOS components: empirical (Aglarcı, Sarıcayir & Sahin, 2016; Akerson et al. 2007; Khishfe & Abd-El-Khalick, 2002), tentative (Abd-El-Khalick & Lederman, 2000; Akerson et al. 2007; Khishfe & Abd-El-Khalick, 2002), inferential (Akerson et al. 2007; Williams & Rudge, 2016), socio-cultural (Aglarcı et al. 2016; Akerson et al. 2007; Williams & Rudge, 2016), and theory-laden (Aglarcı et. 2016; Abd-El-Khalick & Akerson, 2004; Akerson et al. 2007). After the highly-contextualized explicit-reflective NOS course, these improvements were found to be accomplished in all NOS components, both quantitatively and statistically (Bell et al. 2016). Improvements were observed in a few other studies in terms of empirical, theory/law and scientific method (Mulvey & Bell, 2017), tentative, theory/law and creative (Mulvey et al. 2016) NOS components. In comparison, as noted above, in the current study, there were substantial improvements in the empirical, tentative, theory/law and socio-cultural NOS components, whereas there was not sufficient improvement in the inferential, theory-laden and creative NOS. These findings were found to show similarities with (Bell et al. 2016) and differences from (Mulvey et al. 2016) the findings from some studies carried out in accordance with the context continuum approach. As the level of contextualization changes, the content-generic or content-embedded properties of instruction is represented at different rates. As a result, the reason why positive findings were achieved in different directions in the studies may be the level of contextualization of NOS instruction (Mulvey & Bell, 2017).

4.2. Impact of the Highly-Contextualized Explicit-Reflective NOS Course on Participants' NOS Instructional Planning

Various findings were attained as a consequence of detailed analysis of the draft lesson plans. First, it was observed that the participants created lesson plans by taking into consideration the following course content: heat transfer, periodic system, friction force, the structure of atom, digestion of nutrients, electricity, solar system and beyond, cell structure, physical and chemical digestion, propagation of light and sound, and finally physical and chemical change. This gave us the ability to simultaneously analyze the pedagogical content knowledge about plenty of course content through the lesson plans. A review of the relevant literature shows that studies on PCK concentrate on the subjects of the amount of substance and chemical equilibrium (Rollnick et al. 2008; Akin & Uzuntiryaki-Kondakci, 2018), photosynthesis and plant growth (Käpylä et al. 2009; Park & Chen, 2012), cell division (Sen, Oztekin & Demirdöğen, 2018), ozone layer depletion (Kaya, 2009), genetics (Mthethwa-Kunene et al. 2015), heritable variation (Friedrichsen et al. 2009), and electrochemical cells and nuclear reactions (Aydin et al. 2014). In most of these studies, PCK practices of experienced teachers have been examined. Another important finding of the study is that the participants prepared their lesson plans specifically for NOS components in which they developed transitional or informed understandings. This was not a surprising finding because most prospective teachers need some comfort in NOS understandings to teach NOS (Demirdöğen et al. 2016). This view is supported by the fact that only 3 of the NOS components that were referred to by the participants 30 times in total had inadequate NOS understandings (10%). For example, these understandings were tried to be translated by Defne in the unit of the structure of atom in the inferential NOS component, by Beyza in the unit of digestion in the inferential NOS component, and finally by Mine in the unit of physical and chemical digestion again in the inferential NOS component, although they had inadequate understandings. For NOS translation, the components of the inferential NOS (11/13), creative NOS (7/13) and empirical NOS (7/13) were found to stand out in the order given. However, the theory/law, social-cultural NOS and theory-laden NOS (excluding Ceyda) components were found not to be reflected in the participants' lesson plans. This situation is confirmed by the fact that none of the participants turned their attention into translate the theory/law component.

A review of Table 3 shows that a total of 10 participants could not write clear NOS objectives and therefore were in the poor category with regard to objectives. Only the participant codenamed Duygu was found to have specific NOS objectives in the teaching of the empirical NOS, tentative NOS and creative NOS components. In terms of the tentative NOS component, she described the objective of the lesson as "*discusses the transformation of views put forward in relation to the structure of cells from the past to the present in the light of technological developments.*" In line with this objective, she used a documentary film titled "Einstein and Eddington," an example of the history of science as an instructional strategy. When her lesson plan was reviewed, the participant was found to indicate that she intended to ensure that students first watched the film individually and then established groups and held discussions. Close to all participants classified as poor in terms of instructional objectives were found to be independently addressing instructional objectives for the course content and instructional objectives for NOS instruction in the course plans. In addition, the participants put to use various NOS teaching strategies during planning. When reviewed for the use of NOS teaching strategies, the participants were found to be planning to take advantage of generic activities, experiments, cases, specific NOS questions, poster presentations, drama and HOS-based reading texts. Beyza, one of the participants who was different from others in this regard, raised inferential NOS-specific questions in a case that she planned to use when teaching the digestive system. And after asking which animals would eat the food she brought to the classroom, she asked students the following question after discussions: "*You all talked about different animals eating the food that I hold in my hand. Well, why did you suggest different animal names even though you observed the same food?*" Dilara asked the students to prepare a poster describing the difference between astronomy and astronomers based on the framework of the inferential NOS within the scope of the teaching of the solar system and beyond unit. Following that she planned that the students portrayed lives of astronomers through a drama.

Table 3. *The overall view of participants' draft lesson plans*

Participant	Grades	Science content	NOS components	NOS instruction strategies	NOS objective	Explicit-reflective NOS instruction
Arzu	6	Heat transfer	Empirical	Lecture	Poor	Poor
			Inferential	Lecture	Poor	Poor
Aslı	6	Heat transfer	Creative	Generic Activity	Poor	Needs development
			Inferential	Generic Activity	Poor	Needs development
Ceyda	8	Periodic system	Theory-laden	Lecture	Poor	Poor

			Creative	Generic activity	Poor	Needs development
Begüm	5	Friction force	Empirical	Experiment	Poor	Needs development
			Tentative	Experiment	Poor	Needs development
			Inferential	Generic activity	Poor	Needs development
Defne	8	The structure of atom	Tentative	Lecture	Needs development	Poor
			Empirical	Lecture	Needs development	Poor
			Inferential	Lecture	Needs development	Poor
			Creative	Lecture	Needs development	Poor
Beyza	5	Digestion	Inferential	NOS question Case	Poor	Needs development
Ali	6	Electricity	Empirical	Lecture	Poor	Poor
			Inferential	Lecture	Poor	Poor
			Creative	Lecture	Poor	Poor
Dilek	6	Solar system and beyond	Empirical	Lecture	Poor	Poor
			Inferential	Nos question	Poor	Needs development
Duygu	6	The structure of cell	Empirical	HOS-based reading text	Exemplary	Exemplary
			Tentative	HOS-based reading text	Exemplary	Exemplary
			Creative	Lecture	Exemplary	Needs development
Mine	7	Physical and chemical digestion	Inferential	Case	Poor	Needs development
			Creative	Lecture	Poor	Poor
Sıla	5	Propagatio n of light and sound	Empirical	Lecture	Needs development	Poor
			Inferential	Lecture	Needs development	Poor
			Creative	Lecture	Needs development	Poor
Yeşim	6	Physical and chemical change	Tentative	Lecture	Poor	Poor
			Inferential	Lecture	Poor	Poor
Dilara	5	Solar system and beyond	Inferential	Poster Presentation Drama	Poor	Needs development

In data analysis of this study, robust PCK for NOS both refers to exemplary explicit-reflective NOS instruction and exemplary NOS integration. Most studies that address PCK practices in the context of NOS indicate that prospective teachers do not have robust PCK for NOS (Abd-El-Khalick, 2005; Abd-El-Khalick et al. 1998; Akerson & Volrich, 2006; Demirdöğen et al. 2016; Van Driel et al. 1998). The findings from this study are similar to those found in the literature. An example of explicit-reflection requires that NOS instructional objectives and relevant instructional strategies be discussed together in compliance with the scoring key used in the study. This categorical scoring is valuable for the determination of the explicit-reflective category of the participants. This is because in compliance with data analysis, a lesson plan in the poor category in terms of instructional objectives should be placed in the "needs development" category at best in terms of explicit-reflection, even if it is in the exemplary category in terms of instructional strategies (see Bilican, 2014). For this reason, as of the initial lesson plans, it was observed that almost none of the participants, except Duygu, were in the exemplary category in terms of explicit-reflection. Participants in this category were found to have failed, especially in empirical NOS, inferential NOS and creative NOS translation. In the draft lesson plans, only one participant was found to design exemplary explicit-reflective NOS instruction (Duygu) in the empirical and tentative NOS components, and only two participants were found to be able to achieve exemplary NOS integration (Aslı and Yeşim, see Table 5). What was effective in this is that both participants included specific NOS questions required for NOS integration, explicit connections between NOS components and course content, and ensured consistency between NOS objectives and NOS teaching strategies. Nevertheless, these two participants were found to be unable to plan for an exemplary explicit-reflective NOS teaching. This is directly associated with how lesson plan analysis categories were addressed. This is because for explicit-reflective NOS instruction, exemplary NOS objectives and NOS teaching strategies need to be present together (see Table 3).

4.3. Impact of the Socially-Mediated Contextual Professional Support on Participants' NOS Instructional Planning

Socially-mediated contextual professional support was predominantly discussed within the scope of the third module in this study. A variety of findings were attained as a consequence of the analysis of the final lesson plans prepared by the participants with the completion of the third module. A review of Table 4 shows that 9 participants could not write clear NOS objectives and therefore were in the poor category with regard to objectives. Unlike the previous lesson plans, in addition to Duygu, Defne was in the tentative NOS component, and Sıla in the empirical, inferential and creative NOS components in the exemplary category in terms of instructional objectives. These two participants were found to incorporate these exemplary instructional objectives throughout generic activities and history of science reading texts. Unlike the previous lesson plans where the direct instruction strategy based on lecture was intense, the participants were found to more frequently include instructional strategies such as generic activities, NOS specific questions, history of science reading texts, experiments, story completions, dramas, concept maps. The findings suggest that the participants substantially enhanced themselves in the NOS teaching strategies category but failed in the instructional objectives category after the socially-mediated contextual professional support. In terms of explicit-reflective NOS instruction, the participants were generally seen transitioning from the poor category to the needs development category. Defne and Duygu in tentative NOS component, Sıla in the inferential NOS component, and Duygu in the empirical NOS component were in the exemplary category. On the basis of this, the participants were found to have limited progress in terms of explicit-reflective NOS instruction. In terms of NOS integration, Aslı, Duygu and Yeşim were in the exemplary category. Compared to the previous NOS integration, Duygu showed progress by shifting from the poor category to the exemplary category. After the socially-mediated contextual professional support, most of the participants (9/13) were found to be in the needs development category in terms of NOS integration (Table 6).

Table 4. *The overall view of participants' final lesson plans*

Participant	Grade	Science content	NOS components	NOS instruction strategies	NOS objective	Explicit-reflective NOS instruction
Arzu	6	Heat transfer	Empirical	Generic activity	Poor	Needs development
			Inferential	Generic activity	Poor	Needs development
Aslı	6	Heat transfer	Creative	Generic activity	Poor	Needs development
			Inferential	Generic activity NOS question	Poor	Needs development
Ceyda	8	Periodic system	Theory-laden	Lecture	Needs development	Poor
			Creative	Lecture	Needs development	Poor
Begüm	5	Friction force	Empirical	Experiment	Needs development	Needs development
			Tentative	HOS-based reading text	Needs development	Needs development
			Inferential	HOS-based reading text	Needs development	Needs development
Defne	8	The structure of atom	Tentative	HOS-based reading text	Exemplary	Exemplary
			Empirical	Lecture	Needs development	Poor
			Inferential	Generic activity	Needs development	Needs development
			Creative	Generic activity	Needs development	Needs development
Beyza	5	Digestion	Inferential	NOS question Story Completion Generic activity Drama	Poor	Needs development
Ali	6	Electricity	Empirical	Lecture	Poor	Poor
			Inferential	Lecture	Poor	Poor
			Creative	Lecture	Poor	Poor

Dilek	6	Solar system and beyond	Empirical	NOS question Generic activity	Poor	Needs development
			Inferential	NOS question Generic activity	Needs development	Needs development
Duygu	6	The structure of cell	Empirical	HOS-based reading text NOS question	Exemplary	Exemplary
			Tentative	HOS-based reading text NOS question	Exemplary	Exemplary
			Creative	Lecture	Exemplary	Needs development
Mine	7	Physical and chemical digestion	Inferential	Case	Needs development	Needs development
			Creative	Case	Needs development	Needs development
Sıla	5	Propagation of light and sound	Empirical	Lecture	Exemplary	Needs development
			Inferential	Generic activity	Exemplary	Exemplary
			Creative	Lecture	Exemplary	Needs development
Yeşim	6	Physical and chemical change	Tentative	Lecture	Needs development	Poor
			Inferential	Lecture	Needs development	Poor
Dilara	5	Solar system and beyond	Inferential	Generic activity Concept map	Needs development	Needs development

Based on the study, it was understood that the participants' lesson plans became more integrated in terms of NOS instruction (5/13), and only the participant codenamed Dilara could not show substantial progress in terms of integration.

When examined in terms of the coherence between instructional objectives and activities, which is one of the subcomponents of integration, it was observed that more than half of the participants showed progress in terms of instructional objectives for various NOS components (Table 6). To put it another way, these participants were able to integrate the instructional objectives for the NOS into activities in a content-embedded manner. Only four participants were able to achieve it before the support. However, only three of the 8 participants were able to simultaneously integrate into the activities specific NOS questions, clear/explicit connections between NOS and science content, and the coherence/consistency between NOS objectives and NOS components. Only 3 participants were able to do this before the support. After the support, there was a substantial change in the subcategories of clear connections between NOS and science content, and the coherence between NOS objectives and NOS instruction. In summary, it was understood that the participants demonstrated signs of development in terms of clear connections between NOS and science content (Abd-El-Khalick et al. 1998) and coherence between NOS objectives and NOS instruction, rather than using specific NOS questions. Prior research confirms the result that NOS pedagogical support is needed both by in-service teachers and prospective teachers (Akerson & Abd-El-Khalick, 2003; Demirdöğen et al. 2016; Hanuscin et al. 2011; Park & Chen, 2012; Wahbeh & Abd-El-Khalick, 2014).

Table 5. *Findings on participants' NOS integration level prior to support*

Participant	NOS objective	Evaluation	Integration			Integration Level
			Specific NOS question	Explicit connection	Consistency	
Arzu	Poor	Poor	-	-	-	Poor
Aslı	Poor	Exemplary	+	+	+	Exemplary
Ceyda	Poor	Poor	-	-	-	Poor
Begüm	Poor	Exemplary	-	+	-	Needs development
Defne	Needs development	Poor	-	-	+	Needs development
Beyza	Poor	Exemplary	+	+	+	Needs development
Ali	Poor	Poor	-	+	-	Needs development
Dilek	Poor	Exemplary	+	-	-	Needs development
Duygu	Exemplary	Exemplary	-	-	-	Poor
Mine	Poor	Exemplary	-	-	-	Poor
Sıla	Needs development	Poor	-	-	-	Poor
Yeşim	Poor	Poor	+	+	+	Exemplary
Dilara	Poor	Exemplary	-	-	-	Poor

It is widely acknowledged that lacking PCK for NOS hinders NOS translation (Hanuscin, 2013; Hanuscin et al. 2011; Supprakob et al. 2016; Wahbeh & Abd-El-Khalick, 2014; Ward & Haigh, 2016). Similarly, in the present study, there was limited progress in terms of PCK for NOS. This limited progress was described in terms of explicit-reflective NOS instruction as well as NOS integration before and after the support. In contrast, Bilican (2014) found that all prospective science teachers planned explicit-reflective lessons after a science methods course. History of science examples, feedbacks and the analysis of lesson plans were shown as the source of this progress. These contributed to the development of both NOS understandings and NOS translation. According to her, through the chance to prepare lesson plans, participants were offered opportunities to learn how to design an explicit-reflective NOS instruction and how to assess the impact of it on instructional objectives. Demirdöğen et al. (2016) found that prospective chemistry teachers had advanced from the knowledge level to the application level through lesson plans after two semesters of PCK for NOS instruction. One of the successful participants conducted the explicit-reflective NOS instruction in a content-embedded manner in the scientific method, theory-laden and creative NOS components. When the PCK for NOS maps were reviewed, it was observed that knowledge of orientation and knowledge of instructional strategies were at the core of integration and that these components were the only components commonly reflected by all participants in their lesson plans. Pedagogical instruction framed by PCK for NOS made sure that the prospective teachers internalized that NOS was an important learning outcome and that it was available to students. By this means, all participants were found to develop knowledge of instructional strategies. In the findings of the present study, a more modest development was detected in contrast to the previous two studies, and it was seen that different components could be integrated at the exemplary level. It was common that knowledge of instructional strategies improved, whereas contrasting findings were attained in the improvement of knowledge of evaluation. Hanuscin et al. (2011) and Hanuscin (2013) also found that a prospective teacher's knowledge of instructional strategies has improved. Knowledge of instructional strategies is known to develop more easily than other PCK components (Hanuscin, 2013).

Table 6. *Findings on participants' NOS integration level after support*

Participant	NOS objective	Evaluation	Integration			Integration Level
			Specific NOS question	Explicit connection	Consistency	
Arzu	Poor	Exemplary	-	+	+	Needs development
Aslı	Poor	Exemplary	+	+	+	Exemplary
Ceyda	Needs development	Exemplary	-	-	+	Needs development
Begüm	Needs development	Exemplary	-	+	-	Needs development
Defne	Exemplary	Exemplary	-	+	+	Needs development
Beyza	Poor	Exemplary	-	+	+	Needs development
Ali	Poor	Poor	-	+	-	Needs development
Dilek	Needs development	Exemplary	+	+	-	Needs development
Duygu	Exemplary	Exemplary	+	+	+	Exemplary
Mine	Needs development	Exemplary	+	-	-	Needs development
Sıla	Exemplary	Exemplary	-	+	+	Needs development
Yeşim	Needs development	Poor	+	+	+	Exemplary
Dilara	Needs development	Exemplary	-	-	-	Poor

In the present study, it was observed that the knowledge of evaluation of most of the participants improved. Similar findings have been found in the relevant literature (Demirdöğen et al. 2016). However, what is reflected in research findings is that the knowledge of evaluation of prospective teachers is more difficult to improve than that of experienced teachers. This is because prospective teachers do not teach regularly, nor does knowledge of learners improve. This raises the uncertainty about what they should evaluate.

It can be argued that the developments reflected in these findings were shaped by a variety of factors. As noted earlier, it is highly important to provide pedagogic support in terms of

PCK for NOS instruction (Akerson & Abd-El-Khalick, 2003). Support provided in terms of NOS instruction may be considered under two main categories as individual and social support for assisting and modelling the professional development process of prospective science teachers. In the development of NOS views, when considered in the sense of individual support, the instruction performed in line with the first module was found to improve particularly the NOS understandings. It can be said that with the help of the highly-contextualized explicit-reflective NOS instruction conducted in the first week of the second module, the participants both had the opportunity to deepen their NOS learning processes and were motivated about NOS translation during the discussions on lesson planning in the last week of this module. In addition, the participants received highly-contextualized explicit-reflective NOS instruction, which may have been instrumental to make them recognize the importance of informed NOS understandings that are essential for an exemplary NOS translation. Indeed, the draft lesson plans prepared by the participants showed traces of contemporary scientific examples they designed and especially NOS materials composed of generic activities, rather than the examples of the history of science used for the first 5 weeks. This suggests that the explicit-reflective NOS instruction performed in line with the context continuum can boost the development of PCK for NOS reported by prospective teachers, particularly in terms of knowledge of instructional strategies (Bell et al. 2016). Given that the participants reviewed exemplary lesson plans in line with the second module together with their classmates, and that they discussed what qualifications they should have for lesson plans offered them social support through peer feedback. In this way, the participants can be said to have raised their awareness of what kind of lesson plans they should prepare during their actual practice in the future. It was seen that on the basis of this awareness, the core science concepts implemented in the exemplary course plans presented to them were explicitly reflected in the process of preparing the course content of their own lesson plans. It was ensured that the participants received support both individually and predominantly socially in the third module, which is the most important module for NOS translation. This process, which was planned in the form of workshops that lasted for two sessions, was enriched through reviews of lesson artifacts for NOS lessons modeled by researchers, teacher-generated specific NOS questions, reflections and self-critiques, as recommended by Akerson and Abd-El-Khalick (2003). Prior to the sessions, they were reminded that they must integrate NOS to all sections (objectives, activities and evaluations) of lesson plans. In addition, the participants were frequently encouraged to check the conformity of their own lesson plans with the curriculum through peer evaluations during the discussions. The participants were found to improve their knowledge of instructional strategies and knowledge of evaluation in terms of PCK for NOS, with the help of this social support, which was offered in an intensified way over a period of two weeks. In terms of knowledge of objectives, however, the expected progress was not accomplished. As noted earlier, it is easier to improve knowledge of instructional strategies than to enhance other PCK components. Therefore, the improvement in terms of this component can be misleading. Knowledge of objectives did not show substantial progress, which may be because this type of knowledge is linked to the science teaching orientations of the participants. This is because science teaching orientations accommodate educational beliefs in issues such as why science education is valuable and why it should be done. It is expected that science teaching beliefs would not develop only during a NOS-PD professional program that lasted only approximately 2 months. Orientations also accommodate decisions on teaching in the classroom. However, prospective teachers are deprived of the opportunity to teach and their teaching decisions do not develop spontaneously. Therefore, it can be argued that it is acceptable the participants' knowledge of objectives did not improve.

5. Conclusion

The following conclusions — which were limited to the participating prospective science teachers, the Nature and History of Science Course they attended, and the practices implemented in the course — were obtained in line with the study following the discussion:

- Prospective science teachers who did not receive explicit-reflective NOS instruction had naïve understandings in terms of several NOS components.
- It is hard to reach a common conclusion about which NOS components improved better after the explicit-reflective NOS instruction, because many contexts can easily affect NOS understandings.
- NOS understandings, which are improved following explicit-reflective NOS instruction, do not guarantee an effective NOS translation.
- Explicit-reflective NOS instruction based on the context-continuum approach can offer a variety of opportunities to enhance understandings of NOS components that are especially difficult to enhance.
- Compared to experienced teachers, prospective science teachers need more comfort in their improved NOS understandings and commitment to teaching NOS on a continuous basis before teaching the NOS as they are likely to teach science in the near future.
- Even though the prospective science teachers took part in an intensive program like NOS-PD, very few of them demonstrated the ability to achieve a high level of NOS translation.
- Socially-mediated contextual support contributed most to the development of knowledge of instructional strategies and knowledge of evaluation in terms of reported PCK.

6. Recommendations

In line with the conclusion, this section presents several recommendations for the improvement of science teacher education programs specifically in terms of NOS instruction. To begin with, explicit NOS instruction taught at universities to enhance prospective teachers' NOS understandings should be made more inquiry-based by drawing the learner's attention to key NOS components through discussions and through written work following engagement in hands-on activities. Prospective teachers may thus have the opportunity to face NOS understandings that comprise fallacies about science. As frequently indicated in the relevant literature, understandings of some NOS components appear to be more difficult to improve. In order to resolve this challenge, future NOS courses may concentrate on improving naïve NOS understandings in relation to challenging NOS components by providing introductory sessions in which these NOS components are explicitly and reflectively introduced to prospective teachers before core NOS activities. Specific NOS questions, examples from the history of science or contemporary history of science or use of concept maps may be useful in this respect. Explicit-reflective NOS instruction needs to be conducted under a variety of contexts known to be effective. Explicit-reflective NOS instruction, especially that conducted within the context of course content, can offer opportunities for prospective teachers to gain experiences in preparing content-embedded lesson plans. Considering the challenges faced by teachers and the importance of contexts when conducting highly-contextualized NOS courses, the use of activities that have varying levels of context can provide prospective teachers with an effective context for NOS teaching. The idea of a context continuum may be helpful to prevent limitations that arise from the context itself. An effective NOS translation requires consideration of many factors at the same time, but it does not always guarantee effective results by definition. NOS courses should therefore be based on PCK models widely acknowledged in the relevant field, especially those taught in teacher education programs. The pentagon and hexagonal models of PCK (Park & Oliver, 2008) can be said to offer effective scaffolding in terms of addressing the interaction between the PCK components in question in a cycle based on reflective thinking skills, as well as covering all these components at the middle school science teaching level. Implementing these complex PCK models requires educative curriculum materials (Beyer & Davis, 2009; Davis & Krajcik, 2005). It may therefore be recommended that researchers working in the field of NOS instruction and teaching these courses participate in the processes of developing educative and curricular NOS materials together with prospective teachers and work collaboratively with them to offer them socially-mediated contextual support.

7. Conflict of Interest

The author declares that there is no conflict of interest.

8. Ethics Committee Approval

The author confirms that the study does not need ethics committee approval according to the research integrity rules in their country.

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