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TEACHER EDUCATION & DEVELOPMENT | RESEARCH ARTICLE

Nature of science instruction to Turkish prospective chemistry teachers: The effect of explicit-reflective approach

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Abstract: The purpose of this study is to investigate the effect of explicit-reflective nature of science (NOS) instruction on Turkish prospective chemistry teachers' (PCTs) views of NOS. In the research, case study as a qualitative design was used and PCTs' views were examined thoroughly. The participants of the study consisted of 22 senior PCTs. Data collection tools were Views of Nature of Science Questionnaire-Form C and interviews conducted with the participants. Content analysis was used for the examination of the data. The findings of the study showed that there was a major development in PCTs' views of NOS. Before the instruction, the majority of the participants held naive ideas and had misconceptions regarding NOS. After the explicit-reflective NOS instruction, their misconceptions were reduced and their views of NOS became more informed. The developments in their NOS views were the most significant in empirical, theory-laden, and creative-imaginative NOS aspects as well as social–cultural embeddedness in science. However, the changes were the least significant in views of the tentative NOS and the relationship between scientific theories and laws. Some implications for teaching NOS were discussed in light of these findings.

Subjects: Educational Research; Higher Education; Secondary Education

Keywords: nature of science; explicit-reflective approach; teacher education; science education; prospective chemistry teachers

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PUBLIC INTEREST STATEMENT

Understanding science has a vital importance for people's lives. Even though science addresses all people who are interested in it, there are a lot of misconceptions and myths about science in minds. Reducing these misconceptions will help to improve citizens' images of science. In this manner, science education programs and teachers play a key role in this improvement, as they are mostly responsible for educating people. Nature of science (NOS) is an important concept for science education. NOS searches for answers to the questions of what science is, how it operates, how scientists work as a social group, and how society itself both directs and reacts to scientific studies (McComas, Clough & Almazroa, 1998). In this study, we develop Turkish prospective teachers' views of NOS with generic and context-based activities. Results have shown that prospective teachers' views of NOS have become more informed prior to intervention.

1. Introduction

Science has a vital role in our lives. We search answers to questions of the natural world with the help of scientific studies. Our knowledge of health, transportation, agriculture, technology, education, and industry depends heavily on scientific research. Even though science addresses everyone who are interested in it, there are a lot of misconceptions and myths about science in people's minds (Abd-El-Khalick, 2004; McComas, 1998). Reducing these misconceptions will help improve citizens' images of science. In this manner, science education programs and teachers play a key role in this improvement, as they are mostly responsible for educating people.

Turkish educational reform, launched in 2007 for secondary education, has underlined constructivist philosophy instead of behaviorist learning approaches in Turkey. The philosophical changes in science teaching programs also affected the meaning attributed to science and underlined that students should change their viewpoints from the traditional to the contemporary. The aim of Turkish science teaching programs is to raise scientifically literate students (Ministry of National Education (MNE), 2013).

1.1. Scientific literacy and nature of science

Scientific literacy is defined as "the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (National Research Council, 1996, p. 22). Citizens who understand the characteristics of science will be able to use scientific knowledge in everyday life decision-making processes (Bell & Lederman, 2003). When the number of scientifically literate citizens increases, it is considered that society will have positive views toward science (Driver, Leach, Millar, & Scott, 1996). Nature of science (NOS) is an important concept for scientific literacy (Ministry of National Education (MNE), 2013; National Research Council, 1996).

Studies related to students' and teachers' views of the NOS have been conducted for nearly 60 years and NOS has become a desired outcome for science education ever since (Lederman, 1992). Teaching NOS increases students' understanding of and interest in science (Bell, 2008). Also, teachers can teach NOS in their science classes as well as they can teach science with NOS concepts (Abd-El-Khalick, 2013). There is no one specific description of NOS that science educators and philosophers of science agreed on. However, one of the most comprehensive definitions was given by McComas, Clough, and Almazroa (1998). According to them, NOS is a fertile hybrid area which combines certain aspects of different disciplines including philosophy, sociology, and history of science as well as psychology and searches for answers to the questions of what science is, how it operates, how scientists work as a social group, and how society itself both directs and reacts to scientific studies. As it can be seen from this definition, NOS is closely related to different disciplines. For this purpose, it is more appropriate to define the characteristics of NOS, instead of a certain description in science education. There is a consensus among academics on NOS aspects as presented below (Abd-El-Khalick & Lederman, 2000; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002):

- Scientific knowledge is empirically based (based on and/or derived from observations of the natural world).
- Scientific knowledge is tentative (subject to change).
- Scientific knowledge is theory laden (subjective).
- Scientific knowledge is partly the product of human inference, imagination, and creativity.
- Scientific knowledge is socially and culturally embedded.
- There is a distinction between observation and inference.
- Scientific laws and scientific theories have different functions in science.

Studies have shown that many teachers and prospective teachers do not possess adequate understanding of NOS and have traditional science views (Abd-El-Khalick, 2013; Abd-El-Khalick &

Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Dickinson, Abd-El-Khalick, & Lederman, 2000; Irez, 2006; Küçük, 2008; Liang et al., 2009). Also, teachers do not consider teaching NOS as important as teaching traditional subject matter knowledge (Lederman, 2007). Therefore, teachers who fail to emphasize NOS and/or possess an inadequate understanding of NOS are less equipped to help students to construct an adequate and contemporary conception of NOS. Science teachers' conceptions of science and their learning teaching approaches are constructed in their earlier educational years as students and they are resistant to change (Hewson & Hewson, 1989). At this point, teachers' teaching experiences are based on their own experiences as learners. Therefore, it is a necessity to identify and prevent these misconceptions before they are rooted when educating prospective teachers. Most of the studies that focus on improving NOS understanding underline that NOS should not be considered as a "by product" or "hidden" outcome. These studies have shown that explicit-reflective NOS instruction is more effective than implicit approaches (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Bilican, Çakıroğlu, & Öztekin, 2015; Dickinson et al., 2000; Eastwood et al., 2012; Khishfe & Abd-El-Khalick, 2002). In the view of implicit approach, NOS understandings are gained implicitly by inquiry-based activities and/or developing science process skills. However, in the view of explicit-reflective approach, NOS understanding should be targeted directly, and inquiry-based activities or teaching science process skills are not sufficient for teaching NOS. NOS characteristics should be specified explicitly and be understood by students. Also, students should be promoted to reflect their views of NOS during teaching (Abd-El-Khalick, 2013).

1.2. The significance of the study

In light of these points, this study aims to assess and develop prospective chemistry teachers' (PCTs) views of NOS. Prospective teachers have a key role in educating scientifically literate citizens of the future and their views will affect their students' understanding of NOS. Therefore, it is important to determine and develop prospective teachers' misconceptions of NOS. Most of the studies in Turkey have generally examined prospective and/or in-service science teachers' views of NOS and the studies conducted with prospective and in-service chemistry teachers are limited (Bayır & Köseoğlu, 2010; Cakmakci, 2012; Celik & Bayrakçeken, 2006; Köseoğlu, Tümay, & Üstün, 2010; Önen, 2011; Turgut, 2005; Turgut, Akçay, & Irez, 2010). In this direction, more studies should be planned with them in order to determine and develop their NOS understandings. Contextualized activities are found to be more effective than generic (decontextualized) activities for teaching NOS (Cakmakci, 2012; Clough, 2006). Generic NOS activities are isolated from science content and aim to teach directly about NOS, whereas contextualized activities are embedded in science content (Clough, 2006). Contextualized activities give insights to NOS as well as the nature of the scientific discipline (chemistry, biology, and physics). In the study, generic activities from NOS literature as well as specific activities combining both NOS and chemistry concepts together were designed and implemented. Thus, we tried to develop "NOS" as well as "nature of chemistry" understandings together.

Also, participants' views of NOS were presented by individual profile analysis. This meant that the changes from pre-instruction to post-instruction were portrayed in a more detailed way.

1.3. Purpose of the study

The objective of this study is to examine the effect of explicit-reflective NOS instruction on Turkish PCTs' views of NOS. The main question of this study is "Do Turkish PCTs' views of NOS change after an instruction based on explicit-reflective NOS activities?" In light of this objective, the research questions of this study are given below:

- What are Turkish PCTs' views of NOS before the instruction?
- How do Turkish PCTs' views of NOS change after the instruction?

2. Method

In the study, case study as a qualitative research design was used to enlighten the research questions in a detailed way. According to Yin (2003, p. 13), case study "investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident".

Turkish PCTs who were in their final year of education were investigated in the study. Seventeen female and 5 male PCTs aged between 22 and 23 participated in the research voluntarily. Randomly assigned numbers were used to keep the participants' identities anonymous.

The PCTs took pedagogical content courses as well as chemistry content courses. However, they did not attend any classes on NOS, history of science, or philosophy of science. These participants were at the end of their teaching training program. In Turkey, graduate chemistry teachers can work in private schools or state schools. However, they have to pass entrance exams to become teachers in state schools and nearly most of our participants were studying for these exams. Our participants were seniors, and they wanted to be chemistry teachers. Those who didn't want to become teachers had left the chemistry education program before their last year. They were aware of the need to teach NOS because NOS aspects were involved in Turkish chemistry education programs after the educational reform was launched in Turkey. They were also familiar with the chemistry curriculum; in fact, they prepared a lot of materials and lesson plans in their pedagogical content courses. Moreover, they had the opportunity to use their lesson plans and work with high school students during their school practices.

2.1. Data collection
The data of the study were collected via Views of Nature of Science Questionnaire-Form C (VNOS-C) and interviews with the participants.

PCTs' views of NOS were determined by VNOS-C questionnaire. The questionnaire was designed and validated by Lederman et al. (2002). It consists of 10 open-ended questions that aim to determine the participants' views of NOS aspects (empirical, tentative, creative-imaginative and theory-laden NOS, social and cultural aspects of science, observation vs inference, and difference and relationship between scientific theories and laws). Below, there are a couple of questions from the questionnaire as examples:

- *What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g. religion, philosophy)*? (Item 1, Empirical NOS)
- *Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example*. (Item 5, Difference and relationship between scientific theories and laws)

The aim of using an open-ended questionnaire instead of a standardized forced-choice instrument was to gain more insight of the participants' views and to examine the effect of the instruction in this manner. In the study, the version that was translated and adapted into Turkish by Turgut (2005) was used. The questionnaire was adapted to Turkish by reverse-translation technique. Firstly, original form was translated into Turkish by two high school English teachers and one university professor. This form was translated into English by three high school English teachers who did not participate in the first translation. Finally, original form and reverse-translated form were compared by three English teachers and the translation process was completed (Turgut, 2005). The questionnaire was used before and after the implementation to assess the changes in participants' views.

Also, the first author conducted semi-structured interviews with the all of the participants before and after the implementation. The findings gathered from the interviews helped to establish the validity of the PCTs' answers to the VNOS-C questionnaire. The interviews all lasted between 30 min and 1 h. In the interviews, participants were handed their VNOS-C responses and asked to explain their thoughts in a detailed way and elaborate on their answers if possible. The interview process was recorded with participants' permission and then was transcribed for further analysis.

2.2. Instruction

The implementation was conducted by the first author. “Science Teaching Methods” in fall semester and “History of Science” in spring semester were the courses chosen for the implementation. These two courses had the appropriate qualifications for NOS instruction in Chemistry Education program. Generic NOS activities were practiced in “Science Teaching Methods” course, while context-specific activities were implemented in “History of Science” course (Appendix 1). All of the implementation phase was recorded digitally. The first eight activities in Table I were conducted in “Science Teaching Methods” and the last six activities in “History of Science” course. The relationship between the activities and NOS aspects that they targeted is presented in Table 1.

Two of the activities designed by the researchers for the courses are introduced below as examples of the NOS instruction:

- **Documentary:** In this activity, PCTs watched a documentary named $E = mc^2$: Einstein’s Big Idea (Johnstone, 2005) about Einstein and the development of his famous equation ($E = mc^2$). The documentary also made references to other scientists’ (including Faraday, Lavoisier, Lise Meitner, and Otto Hahn) scientific work as well as their personal lives. After introducing NOS concepts, PCTs and the researcher discussed the difficulties that scientists face, gender roles in science, and social and cultural perspectives of science. Therefore, the targeted NOS aspects were explicitly underlined and participants had the opportunity of revealing their views of NOS.
- **History of Thermometers:** PCTs were introduced the differences between heat and temperature and the invention of thermometers in the activity. The purpose was to develop PCTs’ understanding of NOS as well as to teach them the historical evolution of an instrument, which they frequently used in their laboratories. The creative and imaginative NOS, the subjectivity, and tentativeness of science were discussed with PCTs, and the targeted aspects of NOS were underlined in class discussion. The link between the targeted NOS aspects and the historical development of thermometers was highlighted by the instructor.

2.3. Data analysis

The data gathered from VNOS-C questionnaire and interviews were analyzed by content analysis. The authors categorized participants’ answers to the questionnaire and their responses in interviews in terms of each NOS aspect to determine the changes in their views of NOS. The data were categorized according to Lederman et al.’s (2002) study and divided into three categories including naïve, eclectic, and informed for each NOS aspect (Appendix 2). If the participant’s view was not consistent with the accepted NOS understanding, then the participant was coded as “naïve” for the relevant NOS aspect. If the participant’s view was consistent with the accepted NOS understanding, he/she was coded as “informed”. If the participant’s view was consistent, but he/she gave no further explanation (or if he/she had both adequate and inadequate views about the aspect), then he/she was coded as having “eclectic” views. At the last stage, individual profile analyses were presented in order to show the changes in each of the participants’ views. Changes in participants’ views have been determined using frequency and/or percentage analysis in researches about NOS (Abd-El-Khalick & Akerson, 2004; Akerson et al., 2000; Dickinson et al., 2000; Khishfe & Abd-El-Khalick, 2002). In these analyses, the changes in views of NOS for one participant cannot be determined easily. In this study, changes in participants’ views were presented by mapping out participants’ individual profiles. It is possible to combine collective and individual assessments together by individual profile analysis. Individual profiles represent the changes in the relevant theme for each participant. The changes from pre-instruction to post-instruction can be determined via examining individual profiles. Also, total assessment could be seen for each category and aspect in the representation.

2.4. The validity and reliability of the research

A colleague who studied NOS analyzed the data independently from the authors to establish inter-rater reliability. In order to determine the agreement between the codifications of the authors and the colleague, the percentages of agreement between codifications were calculated for each

Table 1. The relationship between the activities and NOS aspects they targeted

	Empirical NOS	Tentative NOS	Relationship between theories and laws	Observations vs inferences	Theory laden NOS	Social and cultural embeddedness	Creative and imaginative NOS
Documentary	+	+	+	+	+	+	+
Tricky tracks![1]	+	+		+	+		+
That's part of life!					+	+	
Young? Old?					+	+	
Observation or inference? You decide	+		+	+	+		
New society	+	+	+	+	+	+	+
Is astrology science?	+					+	+
The card exchange	+	+	+	+	+	+	+
Tubes	+	+	+	+		+	+
Hypothesis box	+	+	+	+		+	+
History of thermometers	+	+	+	+	+	+	+
From phlogiston theory to oxy-gene theory		+	+	+		+	
Periodical table	+	+	+	+		+	+
Critical incidents	+	+	+	+		+	+

[1]The activities written in italics were from the NOS literature. Their references are given in Appendix 1. The other activities were designed by the authors.

question in the questionnaire. According to Miles and Huberman (1994), the analysis is considered to be reliable when there is 80% or over coherence between two codings. The aforesaid analysis in the study was considered reliable since the coherence between the researchers was found to be 82–100% (the mean value is 87.4%) on the basis of questions.

The validity of the study was ensured by explaining data collection, implementation, and data analysis processes in detail. Also, direct quotations from participants' answers were given in the findings section to establish the validity of the study.

3. Findings

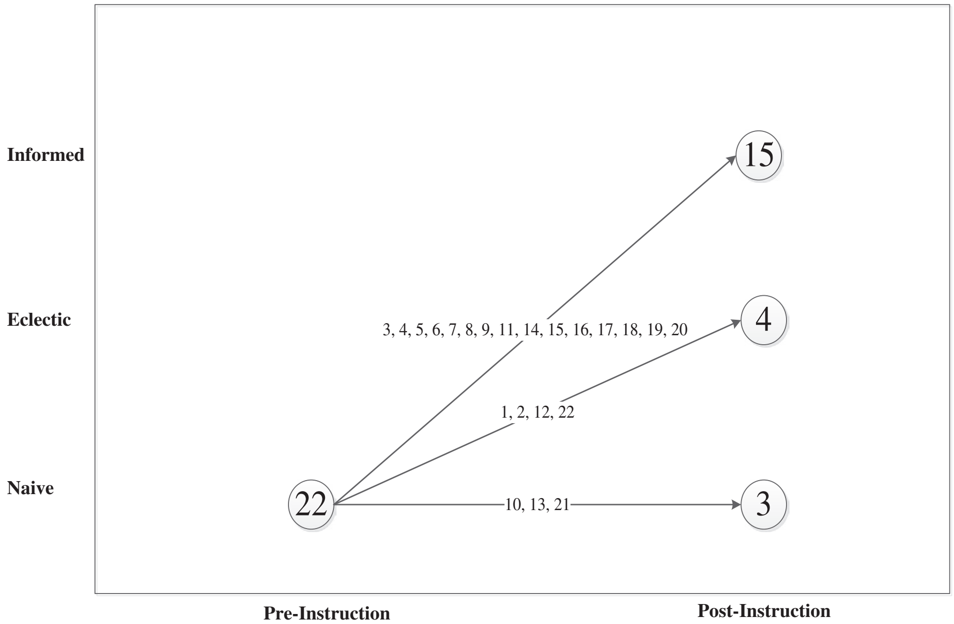
PCTs' pre- and post-instruction NOS views are presented in terms of seven aspects of NOS in the subsections.

3.1. PCTs' views of empirical NOS

Participants' views of empirical NOS were assessed with the first three questions in the VNOS-C questionnaire. These questions investigated PCTs' definitions of science and experiment as well as their ideas of whether experiments were required in science. The changes in participants' views of empirical NOS are presented in Figure 1.

Figure 1. The change in views of empirical NOS.

Notes: The numbers in the circles represent the number of participants for the relevant aspect and theme. The numbers above the arrows are participants' ID numbers and they show the changes in their views (in figures).



Before the instruction, PCTs stated that science was proven by experiments and observations (n = 14, 64%), based on absolute facts and conclusions (n = 9, 41%), a production of objective and universal knowledge (n = 7, 32%), and dependence on quantitative data (n = 6, 27%).[1] Also, the PCTs defined experiment as proving scientific knowledge, hypothesis, or theory (n = 14, 64%), seeking absolute truth (n = 3, 14%), reaching conclusions (n = 2, 9%), and ensuring the permanence of what is learned (n = 2, 9%). Also, nearly all of the participants (n = 20, 91%) stated that scientific knowledge absolutely required experiments by underlining the idea that the validity of scientific knowledge could be guaranteed by proofs (n = 10, 45%). Some examples of their pre-instruction responses are presented below:

> Science is the purpose of **reaching absolute knowledge** by testing the reality of findings and investigating nature. PCT 12

> Experiment is an important process in science. Experiment is **reaching certain conclusions** after different processes. Scientific knowledge requires experiments. Experiments should be performed to test whether a **theory is accurate or not**. In a scientific study, if a scientist only speculates about an idea or theory, it is not worthy. On the other hand, if he shows that he has found it after conducting experiments and he could prove it, the idea will gain value. PCT 1

After the instruction, the PCTs expressed that science was an attempt to interpret the world (n = 16, 73%), a human endeavor and embedded in society and culture (n = 13, 59%), dynamic, and continuous (n = 6, 27%). Besides, tentative and interpretable NOS were counted among the aspects that made science different from other disciplines of inquiry (n = 15, 68%). Most of the PCTs defined experiments correctly (n = 17, 77%). Moreover, 18 participants (82%) stated that there were some disciplines of inquiry that did not require experiments; observations and inferences were as important as experiments for scientific research.

> Science is an attempt to **explain** and **understand** the **universe**. Experiment is to control variables while keeping the independent variable the same. No, I don't believe that science always requires experiments. Experiment is not the center of science; it supports scientific ideas. PCT 9

3.2. PCTs' views of tentative NOS

The findings of participants' views of tentative NOS are presented in Figure 2. Their views related to the tentative NOS were mostly collected from their answers to the fourth question in VNOS-C. However, participants' answers to other questions (especially Item 1 and 5) in the questionnaire presented their ideas of the tentative nature of both scientific theories and laws.

Before the instruction, most of the PCTs (*n* = 19, 86%) stated that scientific theories could change and 15 of the participants (68%) explained their answers by presenting different reasons:

> I believe that scientific theories will change. Past knowledge has changed so far. Scientists will continue their researches. The search for new knowledge will begin when the existing knowledge becomes insufficient. PCT 8

Even though most of them implied that scientific theories could change, all participants (*n* = 22, 100%) stated that scientific laws did not change.

After the instruction, all of the participants stated that scientific theories could change, and most of them (*n* = 20, 91%) proposed strong and acceptable reasons and examples:

> Scientific knowledge can change. Scientific theories can change or evolve with **different ideas, points of view and experiments advanced through technological development.** PCT 12

On the other hand, some participants' views about the tentative nature of scientific laws (*n* = 7, 32%) did not change after the instruction. These participants stated that scientific laws were absolute. Also, three of the participants (14%) thought that scientific theories would become laws when proven. However, more than half of the participants stated (*n* = 12, 55%) that scientific laws could change or modify with new evidence/existing evidence.

3.3. PCTs' views of scientific theories and laws

The findings about the participants' views related to the functions of and relationship between scientific theories and laws are presented in Figure 3.

Before the instruction, participants stated that scientific laws were proven and absolute (*n* = 11, 50%), scientific theories could be disproved (*n* = 7, 32%), and theories would become laws after they were proven (*n* = 6, 27%).

Figure 2. The change in views of tentative nature of scientific knowledge.

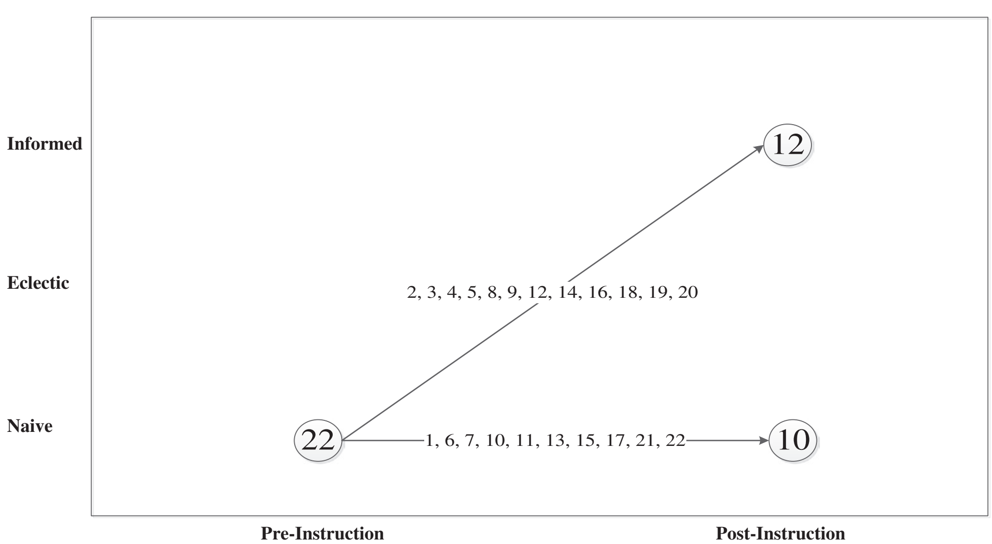
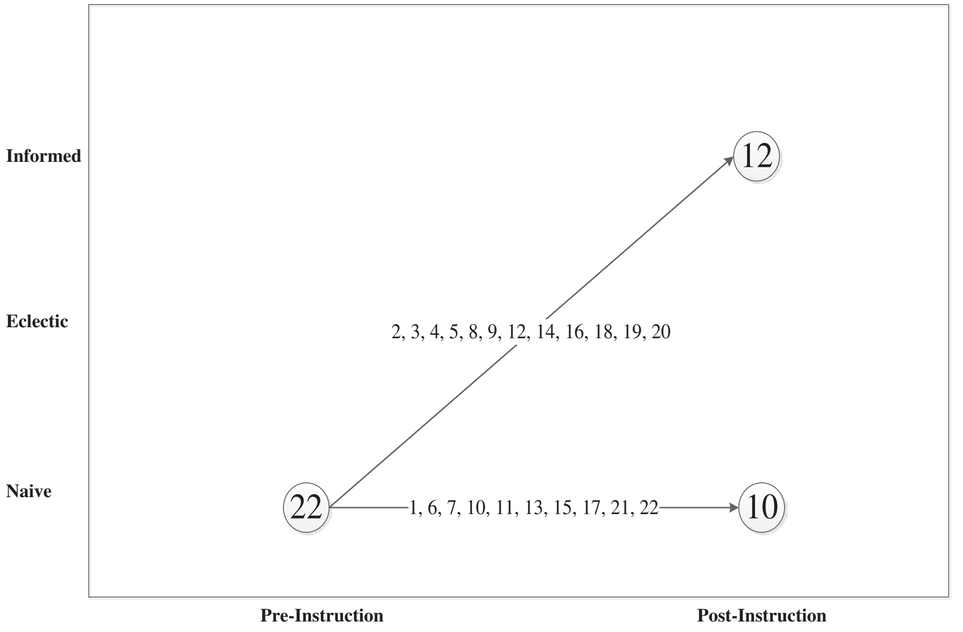


Figure 3. The change in views of functions of relationship between scientific theories and laws.



> As I learned from the courses in high school, a theory can change because **it is not proven yet**. On the other hand, scientific law cannot be changed and it is **universally accepted as a scientific truth**. For example, atomic theories have changed over time. But in physics, there are a lot of examples of laws that did not change over years. PCT 12

After the instruction, 12 of the participants (55%) stated that scientific theories and laws were different kinds of knowledge and one could not become another.

> Both scientific theories and laws can change. We can't say that laws are absolute and true. In fact, theories are **more complex** and **dynamic than laws**. Besides, theories don't become laws when they are proven. There is **no hierarchical relationship** between them. PT 14

On the other hand, some participants still stated that scientific theories would change and laws were absolute and universal (n = 7, 32%) and theories would become laws after they were proven (n = 3, 14%).

3.4. PCTs' views of the relationship between observations and inferences

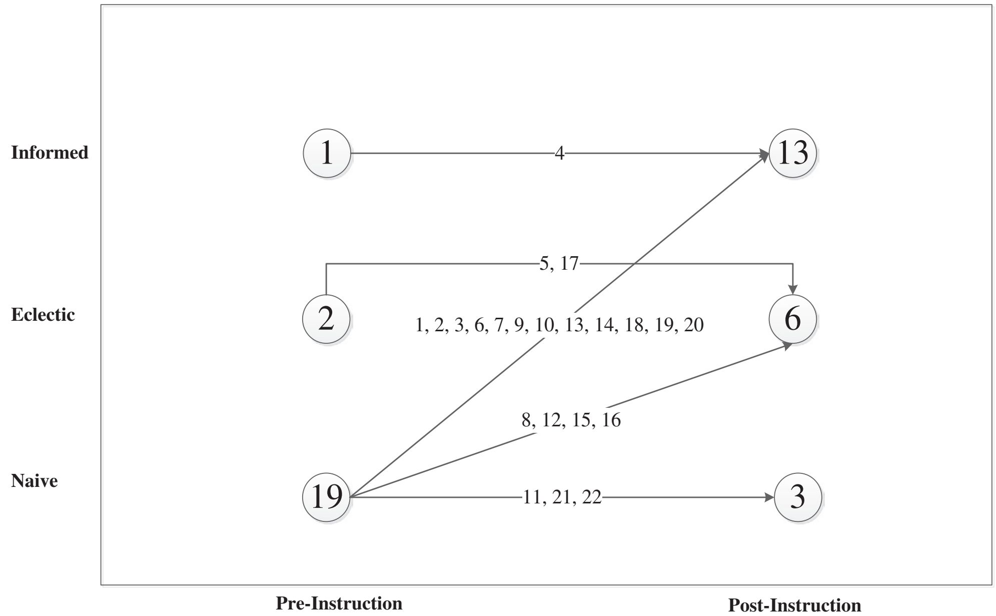
The views related to the relationship between observation and inference were determined with two questions in VNOS-C and findings are presented in Figure 4.

Before the instruction, most of the participants (n = 19, 86%) stated that atomic structures were observed/seen with experiments and scientists were very certain of this structure:

> Scientists have to **observe the particles** and conduct experiments **to be certain about the structure**. Once the experiments are concluded and repeated several times, and after the same results are obtained, they can be certain about the structure of the atom. PCT 18

Before the instruction, PCTs stated that scientists could determine the characteristics of what a species is, using experiments and/or observations (n = 13, 59%) and classifying them in terms of similar features (n = 8, 36%). Also, eight of the participants (36%) underlined that scientists were certain of what a species was because they observed or performed experiments.

Figure 4. The change in views of the relationship between observations and inferences.



> Scientists can be certain of the characteristics of a species by o**bservations** and **experiments.** For example, scientists observed that donkeys and horses which they classified as different species did not interbreed to produce fertile offspring. This is an example that proves scientists' ideas about species. PCT 6

After the instruction, 15 of the participants (68%) stated that atomic structures could not be observed and inferences helped scientists determine the structure. Also, nine of the participants (41%) said that scientists could not be certain about the structure because atomic structures have changed and could change over the years.

> Scientists cannot be certain about the structure of the atom. They can interpret the results of experiments and determine atomic structures. PCT 3

On the other hand, after the instruction, there were a small number of participants (n = 3, 14%) who stated that atomic structures could be observed (with high power microscopes).

In addition to these findings, 10 of the participants (45%) stated that scientists defined the characteristics of what a species was by classifying each based on similarities. Six of the participants (27%) underlined that scientists defined the term "species" by experiments and observations. They proposed different ideas about scientists' certainty of the characteristics of species. Some of them (n = 4, 18%) still believed that the characteristics of a species could not be changed, whereas some (n = 4, 18%) believed that the term "species" was a product of human creation and inference; therefore, the characteristic of species could change with new evidence or inferences:

> Scientists determine the characteristics of what a species is by research results and their inferences. When they gain a new perspective, the characteristics can change. It is a result of human creation. PCT 16

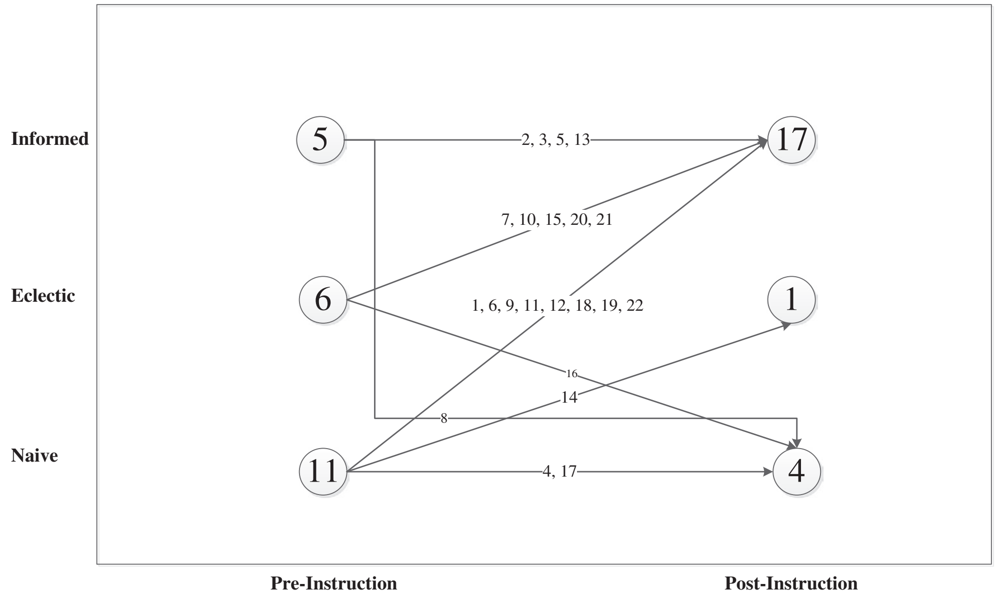
3.5. PCTs' views of theory-laden NOS

The findings about the participants' views of the theory-laden NOS are presented in Figure 5.

Before the instruction, PCTs stated that different conclusions were possible because

- there was no definite information about the extinction of dinosaurs (n = 10, 45%),

Figure 5. The change in views of theory-laden nature of scientific knowledge.



- hypotheses were not proven (*n* = 5, 23%) and
- it would not be possible to perform an experiment about this phenomenon (*n* = 1, 5%).

> This phenomenon cannot be repeated. Therefore, scientists can propose different hypotheses to explain the extinction. Scientists cannot repeat or conduct an experiment about it. PCT 14

Besides this, some participants underlined that scientists' ideas and creativity played a part in different conclusions (*n* = 10, 45%). However, some of these participants stated that hypotheses were not proven and there was no evidence.

After the instruction, most of the prospective teachers (*n* = 18, 82%) stated that scientists' different interpretations and explanations were the reasons for different hypotheses.

> Eventually, scientists' education, past knowledge, even prejudgment and social settings have an important role in scientific research. It is usual for different scientists to reach different conclusions. PCT 1

On the other hand, after the instruction, a minority of the participants (*n* = 4, 18%) reported that there was no definite knowledge about the extinction of dinosaurs.

3.6. PCTs' views of socially and culturally embedded NOS

The findings about the participants' views related to the social and cultural embeddedness of scientific knowledge are presented in Figure 6.

Before the instruction, most of the prospective teachers (*n* = 15, 68%) stated that science was universal and provided their reasons:

> I believe that science is universal. Cultural and social values do not affect science, because generally science is universal. An experiment or a theory gives the same results independently from cultural and social norms. PCT 20

Among these 15 prospective teachers, some of them stated that science was universal, but sometimes it was affected by social and cultural values (*n* = 4, 18%).

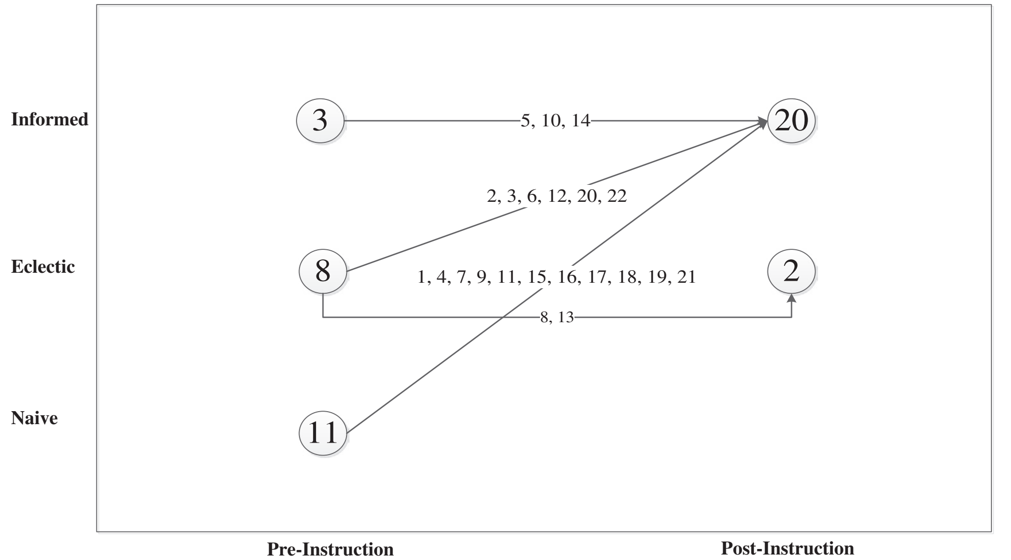


Figure 6. The change in views of social and cultural embeddedness of scientific knowledge.

> Yes, science is universal. Scientific knowledge is accepted all over the world when it is proven. Social and cultural norms only affect scientific processes, not the findings. PCT 2

After the instruction, most of the prospective teachers (n = 20, 91%) reported that science was influenced by social and cultural values.

> Science is influenced by cultural and social values because it is a product of human culture. Scientists are influenced by their social settings; their experiences affect their studies and observations. PCT 5

3.7. PCTs' views of creative and imaginative NOS

The change in views of creative and imaginative nature of scientific knowledge is presented in Figure 7.

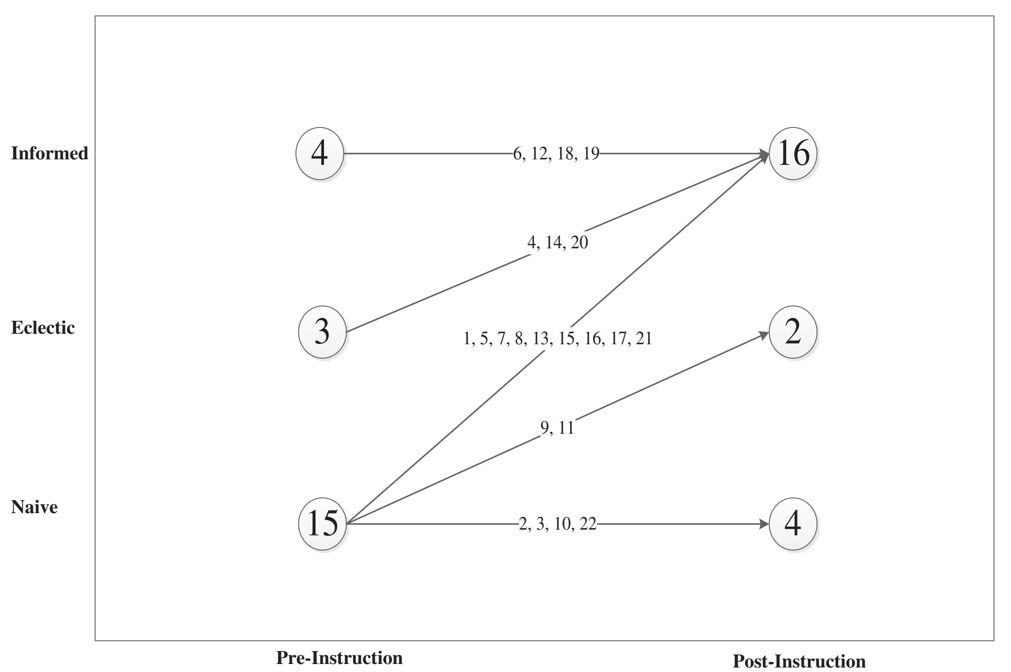


Figure 7. The change in views of creative and imaginative nature of scientific knowledge.

Before the instruction, all of the participants stated that scientists used creativity and imagination in their scientific studies. Only four of the participants (18%) believed that scientists used creativity and imagination in every part of their scientific research. Twelve of the participants (55%) expressed that scientists used their creativity and imagination only in planning and designing their investigations.

> Scientists use their imagination at some point in their scientific studies. Especially when designing and planning their investigations. However, it is not possible to use imagination when collecting data. Scientists have to base their scientific views upon evidence. PCT 3

After the instruction, most of the participants (n = 16, 73%) believed that scientists used their creativity and imagination in all parts of their studies.

> Yes, they use their creativity and imagination in every part of their scientific studies; in planning, designing, researching and interpreting results. This is the reason for different interpretations of the same data set. Also, their imagination helps them to be unique in their area of studies. PCT 12

4. Discussion

Developing people's images of science and NOS is a key goal of science education. Especially teachers have an important role, for they are mostly responsible for educating students. Review of the related literature suggests that students and teachers have misconceptions and naive understanding of science as well as NOS prior to instructions. Science educators and science education programs need to focus on these problems, as the program's major objective is scientific literacy.

PCTs in our study were seniors and they all completed chemistry content courses. This might bring the idea that they had informed views of NOS because they were taught about science and chemistry and studied like scientists in their laboratory classes. However, researches about NOS have shown that doing science and/or teaching process skills does not adequately help students learn NOS. Therefore, even though the PCTs were expected to be more informed than the rest of the public in terms of what NOS was, they had naïve views of NOS in the beginning of the study.

After determining PCTs' views of NOS, explicit-reflective NOS instruction was administered based on their misconceptions and naive ideas. PCTs' changes in views from pre-instruction to post-instruction have shown that explicit-reflective NOS instruction is effective in reducing misconceptions and developing correct views of NOS. Implicit approach suggests that students will learn NOS by doing science. The use of hands-on inquiry-oriented activities or science process skills instruction will enhance students' NOS understandings. However, this approach lacks direct references to NOS. In explicit-reflective approach, students are explicitly introduced with NOS aspects and they have the chance of reflecting on NOS aspects in the context of the science-based activities (Khishfe & Abd-El-Khalick, 2002). Several studies that adopted an explicit-reflective approach examined the development of participants' views. The results of these studies support the findings gathered from our study in some aspects (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Cakmakci, 2012; Dickinson et al., 2000; Khishfe & Abd-El-Khalick, 2002; Önen, 2011). In our study, the development of NOS views was the most significant in the empirical nature, theory-laden nature, creative-imaginative NOS, and social and cultural embeddedness of scientific knowledge. Participants' definitions of science and experiments changed significantly from pre-instruction to post-instruction. Before the instruction, most of the participants made a connection between scientific knowledge and experiment by proving/verification (*Scientists perform experiments to prove scientific ideas/scientific knowledge*, PCT 22). Their naive ideas related to science were involved in McComas's study (1998) about "myths of science". Two myths he expressed [Myth 5: Evidence accumulated carefully will result in sure knowledge and Myth 10: Experiments are the principal route to scientific knowledge] were the two main misconceptions adopted by our participants in the beginning of the research. Most of the participants' views about science and experiments changed to informed after the instruction. Most of the participants in this study reported that science was a point of view/an effort to understand

and interpret the natural world. These views are very consistent with the science descriptions given by NRC (1996, 2012, 2013) and Matthews (2012). Also, most of the PCTs defined experiments as "controlling the variables by keeping one variable the same" and "exploring the relationship between dependent and independent variables". In addition, the majority of the participants stated that experiments were not always required for scientific knowledge and there were some disciplines of inquiries that did not need experiments. PCTs came to realize that some scientific activities could be performed without experiments after the instruction and we think that some of the explicit-reflective NOS activities (e.g. New Society) might have changed their minds.

Before the instruction, half of the participants had naive views about the theory-laden NOS. The participants who possessed naive ideas stated that scientists had no clue regarding the extinction of the dinosaurs and it was not possible for scientists to turn back in time and observe the phenomenon and/or perform experiments about it. Their statements also supported the naive ideas that they presented in empirical NOS. PCTs' answers to this question also presented their misconceptions of scientific concepts (hypothesis, scientific theory, and law). Similar statements appeared in Abd-El-Khalick's study (2004). Abd-El-Khalick reported participants' statements such as "Scientists were not around when dinosaurs became extinct, so no one witnessed what happened. The only way to give a satisfactory answer … is to go back back in time to witness what happened, P89" and claimed that these participants had "a misunderstanding of the logic of hypothesis testing" (p. 412). After the instruction, most of the PCTs' views became more informed in theory-laden NOS tenet. Most of the participants stated that hypotheses put forward by different scientists were the result of their different backgrounds and points of view. Furthermore, these participants thought that the variables including academic background, culture, traditions, and belief systems played a role in different hypotheses. In Irez's study (2006), most of the participants stated that different interpretation of the same data is the result of different backgrounds, education, and worldviews of scientists. In our study, the participants started to think the same and their views were regarded as informed.

Most of the participants had naive ideas about the relationship between observation and inferences before the instruction. They did not mention the roles of observations and inferences when explaining the structure of the atom and biological species. Most of the PCTs' views became more informed (especially when explaining the determination of atomic structures) after the instruction. They stated atomic structures could not be observed directly (with microscopes) and inferences were the key to their determination. In addition, they stated atomic theories would evolve and change with time because of the tentative NOS. The same distinction exists between observation and inferences like the distinction between scientific theories and laws (Lederman et al., 2002). We believe it is possible that misunderstandings about these concepts might support each other.

Before the instruction, half of the participants had naive views regarding the social and cultural embeddedness of NOS. Most of the participants stated science had universal values. Some participants who had naive views also stated that scientists should not be affected from other fields or resources by offering scientists as "an authority figure". Their naive ideas related to scientists are involved in McComas's study (1998) (Myth 15: Science is a solitary pursuit). Most of the participants who possessed naive views transferred to informed category after the instruction. Our first activity, The Documentary, constituted an appropriate basis for the discussion of this tenet with the participants. Also, participants experienced the importance of social and cultural values in scientists' studies in "New Society" activity. Results similar to our study's findings were presented by Turgut et al. (2010) and Akerson et al. (2000).

Most of the participants had naive views in the tenet of creative and imaginative NOS before the instruction. Even though all of them stated that creativity and imagination are necessary for scientific studies, they thought that scientists had to be objective at some point. After the instruction, most of them defined that scientists used their creativity and imagination in all parts of their scientific studies. One of the reasons for the development of their views is the emphasis on scientists' creativity and imagination during the instruction. Secondly, the participants used their creativity and imagination in the explicit-reflective activities (especially in New Society, The Tubes, and The Hypotheses Box) and these personal experiences might have led them to change their views to informed. Similar results that support our findings have been obtained by Khishfe and Abd-El-Khalick (2002) and Cakmakci (2012), who aimed to increase NOS understandings with explicit-reflective activities.

However, the changes were the least significant in the views about the tentative NOS and the relationship between scientific theories and laws. Actually, we believe that prospective teachers' views of the relationship between scientific laws and theories and tentative NOS are closely related to each other. Their misconceptions about the relationship between theories and laws usually arise from their misunderstandings of the tentative NOS. Before the instruction, most of the participants stated that scientific theories could change over time for different reasons and all of them said that laws could not change because they were proven. Most of the PCTs stated that scientific theories became laws after they were proven. Therefore, we considered these ideas as naive in both tenets. Review of the related literature has also shown us that the most challenging parts of teaching NOS are the tenets about scientific theories and laws. In our study, we specifically focused on this problem by considering their existing knowledge and put a strong emphasis on scientific theories and laws. In class discussions, some participants expressed that the difference between these concepts took their attention because they had learned these naive ideas in their early school years. After the instruction, there was an increase in the number of participants who had informed views of both tenets. More than half of the participants adopted informed ideas by saying laws and theories were different forms of scientific knowledge and one could not transform into the other. Also, more than half of the participants reported that all kinds of scientific knowledge could change/were open to change and supported their idea by giving strong reasons. In spite of this, nearly half of the participants still had naive views. Önen's (2011) study also presented that the development in participants' views was the least significant in the aforesaid tenet. Also, Liang and others' studies (2009) have shown that the misconceptions about scientific theories and laws were present not only in Turkish participants' minds but also in participants' views from other countries. Among the other tenets, the most naive views of NOS are related to the relationship between theories and laws. This result points out that misconceptions regarding scientific theories and laws are more deeply rooted than other naive ideas about NOS tenets and more time as well as practice is needed to change these naive views.

5. Implications for teaching NOS

Considering the aforementioned problems in science education, science teachers need activities and sources specifically designed to teach NOS. It is hard to reduce misconceptions because students' and teachers' views are resistant to change. Directing teachers to the reliable sources on NOS should be a priority for teacher education programs.

Each discipline of science is unique and different from others. A chemist and biologist cannot do science in the similar way because both have different paradigms. Therefore, the relationship between the aforesaid discipline and NOS is unique. In light of this argument, the emphasis on NOS should be placed in the context (field of study) using contextualized activities rather than generic activities. In our study, we used generic activities (Tricky Tracks!, That's Part of Life!, and Young? Old?) as well as contextualized activities (History of Thermometers, From Phlogiston Theory to Oxygene Theory, and Periodical Table) and we were able to discuss about NOS in chemistry content with the participants. In this direction, context-based activities (based on the nature of chemistry, the nature of physics, the nature of biology) can be planned and designed by science educators and specialists in that field. In this way, it would be possible both to teach about NOS and to teach with NOS as suggested by Abd-El-Khalick (2013). In our study, we examined how prospective teachers' views of NOS had changed with the explicit-reflective approach. However, we didn't investigate whether having learned about NOS helped them teach it better or helped them understand why it should be taught. Therefore, in addition to determining and developing prospective teachers' views of NOS, the effect of these views on lesson plans and classroom practices can be examined in further studies.

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Note

1. The PCTs did not simply give a single answer and/or example to the questions but rather explained their answers in a detailed way. Their answers were included in more than one category and the total sum of frequency percentages was more than 100.

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Appendix 1. Activities reference list

Activity	Reference
Tricky tracks!	Avoiding de-natured science: Activities that promote understandings of the NOS (Lederman & Abd-El-Khalick, 1998)
That's part of life!	
Young? Old?	
New society	Experiencing the NOS: An interactive beginning of semester activity (Cavallo, 2008)
Is astrology science?	How's your horoscope? (Flammer, 2002)
The card exchange	The card exchange: Introducing the philosophy of science (Cobern & Loving, 1998)
Tubes	Avoiding de-natured science: Activities that promote understandings of the NOS (Lederman & Abd-El-Khalick, 1998)
Hypothesis box	
Critical incidents	A program for developing understanding of the NOS in teacher education (Nott & Wellington, 1998)

Appendix 2. Assessment criteria for views of NOS

NOS tenets	Category	Examples of responses to VNOS-C items
Empirical NOS (VNOS-C-1. Question)	Naive	Scientific knowledge is objective/absolute/universal/proven/Science has definite answers and results/ Science is only based on experiments and observations/There are no personal comments and ideas in science
	Eclectic	Science has many different aspects (No explanation is given about these aspects)/Informed about what science is but inadequate views about what makes science different from other disciplines of inquiry
	Informed	Scientific knowledge is not proven/is not definite/is open to change/Science is a human endeavor to understand the universe and natural world
Empirical NOS (VNOS-C: 2 and 3. Question)	Naive	Experimenting means proving/Scientific knowledge requires experiments because it is proved with experiments/Without experiments, science is meaningless and useless. Experiments are necessary for scientific knowledge
	Eclectic	Statements such as "Experiments are controlled ways of testing and manipulating dependent variables while keeping independent the same" (by adding "Science requires experiments")
	Informed	Experiments are controlled ways of testing and manipulating dependent variables while keeping the independent the same/Experiments are just one way to do science. In some disciplines of inquiry, you cannot perform experiments and conduct different procedures such as observation, classification, and review printed sources
Tentativeness of NOS	Naive	Scientific knowledge is hard to change/It doesn't change after it is proven (theories can change but laws don't)
	Eclectic	Scientific knowledge can change (no explanation or example)
	Informed	Scientific knowledge (theories and/or laws) can change (in light of new evidence or reinterpreting the existing evidence)
Functions of Relationship between scientific theories and laws	Naive	There is a hierarchical relationship between scientific theories and laws/Laws are more important than theories
	Eclectic	There is a difference between scientific theories and laws (no explanation about what the difference is)
	Informed	Scientific theories and laws are different sources of knowledge/Theories don't become laws (with correct definitions of scientific laws and theories)
Relationship between Observation and Inference (What does an atom look like?)	Naive	Scientists can see atoms (high powered microscopes, etc.) and they are very sure about atomic structure (...because they observe it)
	Eclectic	Atomic structures cannot be seen currently, but in future, it can be observed with the development of technological devices and scientists can be sure about it
	Informed	Atomic structures cannot be seen or observed. It is determined by indirect observation and mostly with inferences. Atomic structures have changed over the years and scientists cannot make sure of the structure
Relationship between Observation and Inference (Determination of Species)	Naive	Scientists are certain about species by experiments and/or observing/They are certain that no other species will appear in the future because they didn't observe any
	Eclectic	Scientists cannot be certain about their characterization of what a species is (No reason/justification)
	Informed	Inferences are as important as observations and experiments in scientific studies/The characteristics of what a species is are determined/constructed by scientists and they can change
Theory-laden NOS	Naive	Data are not adequate and clear for scientists to give a satisfactory explanation/Scientists might have examined the different remnants/Scientists have to go back in time to observe the incident
	Eclectic	Statements such as hypothesis are not proven/experiments cannot be performed/there is no clear evidence (even though participants emphasized scientists' differences)
	Informed	Different interpretations of the same data-set are possible in science because scientists are influenced by their academic backgrounds/prior knowledge/imagination
Social and cultural embeddedness of Science	Naive	Science is universal/It has to be universal
	Eclectic	Science is embedded with social and cultural values, but eventually it is universal/it must be universal
	Informed	Science is a human endeavor. It reflects social and cultural values
Creative and Imaginative NOS	Naive	Scientists use creativity and imagination when they design their researches. But they must be/are objective when collecting data and analyzing
	Eclectic	Scientists use creativity and imagination at some stages of their investigations
	Informed	Scientists use creativity and imagination at every stage of their scientific investigations (support their answers with examples)