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## Changes in Nature of Science Understandings of Preservice Chemistry Teachers in an Explicit, Reflective, and Contextual Nature of Science Teaching

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### Abstract

This study aimed to investigate changes in the understandings of the Nature of Science (NOS) of preservice chemistry teachers after participating in the explicit, reflective, and contextual NOS teaching. The sample of the study consisted of nine preservice chemistry teachers who attended scientific research methods course at the undergraduate level. The study was designed and conducted according to the qualitative research method. Preservice chemistry teachers' understandings of the NOS was collected through the "Views on the Nature of Science-C" (VNOS-C) questionnaire, which consists of 10 open-ended items. The questionnaire was translated and applied before and after an explicit, reflective, and contextual NOS teaching. The data were analyzed descriptively through the use of a rubric. To ensure the reliability of the collected data, interviews were also conducted with participants to clarify their answers to the questions. According to the results, it was determined that the majority of the participants had a very poor understanding of NOS before teaching. It was determined that changes in the understandings did not occur at the desired level for all NOS aspects despite some positive changes after the teaching.

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### Introduction

The vision of educating individuals as scientific literate is accepted as the vision of science education curriculums in nations around the world (AAAS, 1993; NRC, 1996; MoNE, 2018). In connection with this, scientific literacy is expressed as the vision of the chemistry curriculum recently renewed by the Ministry of National Education of Turkey as well. One of the fundamental components of scientific literacy is the Nature of Science (NOS) (Bell & Lederman, 2003). Learning NOS supports better learning of the content of science courses, interest in science, develop scientific attitudes and behaviors in giving individual and social decisions (Driver, Leach, & PhilScot, 1996). Within the framework of the vision of the chemistry curriculum, the objectives for teaching NOS are predominantly included. One of these objectives expressed as "Understands the development process and nature of scientific knowledge, the common heritage of chemical science and humanity, and the importance of using scientific knowledge following ethical values" is related to the nature of science (MoNE, 2018).

Achieving the objectives of the curriculum depends mostly on the knowledge, skills, and understandings of the teachers who implement the curriculum. However, research shows that teachers still do not have an accurate understandings and teaching skills necessary for teaching NOS effectively (Ağlarıcı, Sarıçayır, & Şahin, 2016; Mesci & Renee'S, 2017). Therefore, researches for developing teachers' NOS understandings and how to teach NOS more effectively are continuing (Abd-El-Khalick & Lederman, 2000; Cofré et al., 2019; Lederman, 2007). As one of these efforts, this study aimed to investigate changes in the NOS understandings of pre service chemistry teachers, who participated in an contextual and reflective nature of science teaching.

### Theoretical Background

First of all, it is necessary to explain what is meant by NOS. There are many models such as "Consensus View" (Lederman, 2007), "Whole Science" (Allchin, 2011), and "Family Resemblance Approach" (Irzik & Nola, 2011) in the literature that explain the concept of NOS. However, we do not attempt to examine the concept of the nature of science according to all models. One of these models is the consensus view. This model presents a

view on NOS to be integrated into science teaching without going into in-depth philosophical discussions. To this model NOS is as a concept that includes values and attitudes in scientific knowledge and the process of development of scientific knowledge (Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 2007).

According to the consensus view while it is generally accepted that scientific observations are theory-laden and that the observations of scientists are influenced by the knowledge, attitude, and values they possess, a positivist and purely experimental science view is not accepted widely (Abd-El-Khalick, Bell, & Lederman, 1998; Khishfe & Abd-El-Khalick, 2002). The aspects agreed upon about NOS reflect some of the different views on what science is and how it operates. The aspects on which consensus is agreed are not inclusive. Therefore, it is used as "nature of science" instead of "the nature of science" in the literature. However, it is widely accepted that NOS consists of the following seven aspects (Khishfe & Abd-El-Khalick, 2002; Lederman et al., 2002).

*The Tentative Nature of Scientific Knowledge:* For scientific knowledge being an obligatory generalization leads scientific knowledge to be tentative. All scientific knowledge, including hypotheses, theories, and laws, is open to change. Change in scientific knowledge is possible as a result of finding new evidence, making progress in technology, and interpreting the data with new perspectives (Abd-El-Khalick, Bell, & Schwartz, 2002; Çelik, 2009; Lederman & McComas, 2004).

*The Empirical Nature of Scientific Knowledge:* One of the most essential features of scientific knowledge is its experimental and observational nature. Science is distinguished from other disciplines such as logic, mathematics, and religion by its feature of being based on experiment and observation (Lederman et al., 2002; Lederman & Lederman, 2004).

*Observation and Inference in Science:* Observation is a scientific skill that is made directly with sense. There may be a consensus between observations of different people. The fact that the objects higher than the ground fell to the ground is an observation, while the derivation of gravity from the free fall is an inference. It is not possible to observe all the cases directly. Discussions about gravity are carried out through inferences. Therefore, it is more challenging to provide consensus on inferences compared to observations (Çelik, 2009; Lederman et al., 2002; Lederman & Lederman, 2004; Yıldırım, 2002).

*The Theory-Laden Nature of Scientific Knowledge:* Scientific knowledge is subject to some degree of subjectivity: Science is an occupation done by people like art, literature, and philosophy. This feature causes it to be affected by subjectivity. Scientists may tend to see from different perspectives because of their knowledge, theories, and other personal differences. Subjectivity is necessary for more original studies in science too (Lederman et al., 2002; McComas, 2004).

*The Creative and Imaginative Nature of Scientific Knowledge:* Scientists use their imaginative and creative ideas and other personal characteristics in every phase of their scientific research. The original studies in science depend on the creativity of scientists (Lederman et al., 2002).

*The Social and Cultural Embeddedness of Scientific Knowledge:* Scientific knowledge is influenced by the social environment and cultural values in which it is produced. Science affects both the culture in which it is done and it is affected by the various dimensions of the culture. In the history of science, accepting the concept of a world-centered universe as a necessity of religious beliefs for many centuries shows that science and culture interact. The notion that Darwin's explanations about the selection of natural species were influenced by the capitalist ideas around him is another example of the interaction between science and culture (Lederman et al., 2002; McComas, 2004).

*Scientific Theories and Laws:* Scientific theories, facts, and laws are different kinds of scientific knowledge. One of the most common misconceptions about NOS is the understandings that the theories turn into laws when sufficiently verified. Scientific laws and theories are different from each other in terms of their functions and structures. Scientific laws are brief expressions of natural phenomena. Scientific theories are explanations of both scientific laws and interrelated relations between facts (Lederman & Lederman, 2004; McComas, 2004). For example, gas-related laws describe gas behavior, while molecular kinetic theory describes the behavior of gas particles. Also, there is no hierarchical relationship between these two concepts, contrary to the common misconception. The fact that molecular kinetic theory emerged long after the laws of gas is one of the examples showing that there is no hierarchical relationship between scientific theory and law (Lederman et al., 2002; McComas, 2004).

## Research on NOS Teaching

There has been a substantial amount of research on NOS understandings of students and teachers and how these understandings can be developed (Abd-El-Khalick & Lederman, 2000; Cofré et al., 2019; Lederman, 2007). When studies on NOS is examined, it is seen that there is intensive focus on assessing NOS understandings of students (Deng, Chen, Tsai, & Chai, 2011; Dogan & Abd-El-Khalick, 2008; Leach, 1996; Lederman, 1986) and teachers (Celik & Bayrakceken, 2012; Haidar, 1999; Liu & Lederman, 2007; Mulvey & Bell, 2017) and evaluating the effect of any teaching approach on these NOS understandings (Abd-El-Khalick, 2005; Akerson et al., 2000; Bell et al., 2011; Cofré et al., 2019; Mesci & Renee'S, 2017; Parker & Rochford, 1995; Schuster, 2005). There is an emphasis on two types of approaches mainly, implicit and explicit, which are commonly used in the literature for teaching NOS (Bell, Matkins, & Gansneder, 2011; Lederman, 2007).

According to the implicit approach, it was thought that the understandings of NOS would be gained automatically by taking philosophy or history of science courses or only by doing scientific activities in the previous studies (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000). The teaching of NOS in such an indirect way is called teaching in an implicit way. However, it is thought that this implicit approach is not effective as much as an explicit and reflective approach (Abd-El-Khalick et al., 1998; Abd-El-Khalick and Lederman 2000; Akerson et al., 2000; Akerson, Elcan Kaynak & Avsar Erumit, 2019; Khishfe & Abd-El-Khalick, 2002). In the explicit approach, the scientific activities, the history of science or the philosophy of science and NOS activities are being related to the content of the courses (Peters, 2012).

It is suggested that NOS can be more effectively taught with an explicit and reflective approach in contextualized content (Burgin & Sadler, 2016). Garcia-Carmona, & Acevedo-Díaz (2018) suggested that NOS can be learned by associating research-related concepts and activities such as formulating questions, creativity and imagination, experimentation, diversity, errors as an opportunity, modeling, cooperation and teamwork, argumentation and discussion communication, and evaluation. In the teaching of NOS, the critical point of explicit and reflective teaching is to ask questions that encourage students to discuss the aspects of NOS (Khishfe & Abd-El-Khalick, 2002; Lederman & Lederman, 2019). It was found that specific focus on NOS content and multiple types of reflections are two effective components of explicit-reflective NOS instruction out of the nine other components (Adibelli-Sahin, & Deniz, 2017). In the teaching of NOS, it is recommended to give more emphasis on contextual activities instead of generic activities (Ağlarci, Sarıçayır, & Şahin, 2016).

Although there are many studies in the literature on NOS understandings of preservice teachers, it is seen that most of these studies are on preservice elementary science teachers compared to studies on preservice middle or secondary teachers (Cofré et al., 2019). Besides, it is seen that the studies aiming to improve NOS understandings of teachers among the studies carried out so far are mostly carried out within the scope of science teaching methods courses (Bell et al., 2011; Cofré et al., 2019). There hasn't been seen any study conducted within the scope of the courses such as "scientific research methods" course, which has content consists of many concepts related to scientific research and science.

In this study, to improve NOS understandings of the preservice chemistry teachers, the content of the "scientific research methods" course was used as a context for an explicit and reflective NOS teaching. For the purpose stated, the following research questions were investigated:

1. What were the pre-service chemistry teachers' NOS understandings at the beginning of explicit, reflective, and contextual NOS teaching?
2. How did the explicit, reflective, and contextual NOS teaching affect the preservice chemistry teachers' NOS understandings?

## Method

This study was designed and carried out according to the qualitative research approach. The aim was to examine preservice chemistry teachers' understandings of NOS. The qualitative research approach focuses on meanings more than numbers. The meanings that people attribute to concepts are examined (Miles & Huberman, 1994; Yıldırım & Şimşek, 2005). NOS understandings of preservice chemistry teachers were attempted to determine through their written answers to open-ended questions. Also, interviews were done to make sense of the teachers' written answers consistent with the meanings they meant ascribed.

## Study Context

This study was conducted within the scope of the "scientific research methods" course, which has been given to preservice chemistry teachers at the undergraduate education level at the Faculty of Education at a university in the eastern region of Turkey. This course lasted 14 weeks, two hours per week. A total of 17 sophomore preservice chemistry teachers, 11 females and 6 males, attended the course. The instructor of the course is the author of this study. The course aims to enable preservice chemistry teachers to gain understandings, knowledge, skills, and attitudes towards scientific research.

Course content consists of science and its underlying concepts (fact, knowledge, hypothesis, laws, and theories, etc.), necessary information about the history of science, structure of scientific research, scientific methods and different views on these methods, research problem, research model, sample and sampling in the scientific research, data collection and data collection methods (quantitative and qualitative data collection techniques), data recording, analysis, interpretation, research ethics, and reporting. The activities in the course mainly consisted of the lecturer's weekly presentations, discussions in the classroom in the context of nature of science about the concepts included in the weekly presentations, inspecting research articles with the preservice chemistry teachers, and the research proposal prepared by the participants individually. The research proposal allowed the participants to practice what they learned in class. For discussions following example, questions were asked to the participants in class during and after each lecturer's weekly presentations.

*What are the qualifications that a research problem should have when studying the concept of a research problem?* The question was asked to participants. The students discussed on the experimental nature of scientific knowledge by emphasizing that the experimental nature of scientific knowledge. The preservice chemistry teachers were asked to create a research problem for their research project. Discussions were done about the originality of the research problem and how and at which stages the imagination and creativity are used in science.

*Why do scientists work on sampling in their research? How does the study on the sample affect the generalizability or tentative of scientific knowledge?* The concept of sample and universe in scientific research was used as an excellent point to explain and argue that scientific knowledge is a compulsory generalization that is not proven true. The fact that scientific knowledge, which is a compulsory generalization together with other qualifications, is open to change, was found to be more understandable by the students.

*Why are there different methods in scientific research literature such as quantitative and qualitative?* The use of different methods in scientific research helped to state that different methods could be used according to the research problem where no single method is used in science. Discussion of different methods is emphasized to help preservice chemistry teachers understand that there is no single method in science. It was discussed to show the influences on science by culture. The preservice teachers were asked to discuss which method would be appropriate for investigating answers to different research problems.

*Why do different scientists draw different conclusions from similar data? How is this possible?* It was discussed that data collection and analysis methods stem from both the researcher and the subjects of the research in the classroom. During the discussions, it was emphasized that objectivity was aimed in science, but subjectivity is inevitable due to the effects inevitable in science.

*What difference is there between scientific laws and theories? Why are the results of some types of research more likely to be law and others to theory?* These questions were used to discuss the existence of different kinds of scientific knowledge in which the results obtained in scientific research have the potential to be theory or law. It was emphasized that scientific laws and theories are different kinds of scientific knowledge.

*How do scientists share their research results?:* To explain the socio-cultural dimension of science, the circumstances that scientists experience while sharing and publishing their results on different platforms were emphasized.

## Sample

The study group of this research consisted of 17 sophomore preservice chemistry teachers studying at the Faculty of Education at a university in the eastern region of Turkey. Eleven of them were males, and six were

females. Because nine of them, four females and three males, answered the test applied at both the beginning and end of the course, the answers of the nine were analyzed and reported.

The undergraduate education period of chemistry teaching is four years. Preservice chemistry teachers take 240 credits courses in total based on European Credit Accumulation and Transfer System (ECTS), consisting of chemistry subject courses, educational sciences courses, and general culture courses in four years. The study was carried out within the scope of the "Scientific Research Methods" course. This course is one of the general culture group courses taught in the first semester of the second year, which requires a workload of 4 ECTS. The course was two hours a week in the fall term, which lasted 14 weeks.

### Data Collection and Analysis

To investigate the preservice chemistry teachers' understandings of NOS, "Views on the Nature of Science-C" (VNOS-C) developed by Lederman et al. (2002), was used. The Turkish version of this test was adapted by Celik (2009). This form of the test is suitable for undergraduate and graduate students. The Turkish version of the VNOS-C test was applied at the beginning and at the end of the course to determine the preservice chemistry teachers' NOS understandings and the changes in these understandings. There are 10 open-ended items on the VNOS-C. It is stated that there is no restrictive one-to-one relationship between responses given to VNOS items and NOS dimensions. Only some items are associated more with one NOS aspect than others. For example, item 4 is more associated with the tentative NOS aspect, and item 10 is more associated with the creative and imaginative NOS aspect.

The data were analyzed with a descriptive analysis method, which is one of the qualitative data analysis methods. Descriptive analysis is preferred when there is a conceptual framework for analysis in the literature (Miles & Huberman, 1994). Since NOS understandings are studied intensively, there are many analysis frameworks or models in the literature for the analysis of the collected data. However, when the literature is examined, it is seen that "informed", "naive" "mixed" classification is mostly used for the analysis of data related to NOS (Jones, 2010). In this study, the data were analyzed using the analysis structure developed by Jones (2010) and the rubric, which was developed accordingly and used in the presentation of the results in the findings section. This structure allows analyzing answers given to VNOS items in a wider range than the previous models. Also, since this analysis structure was created by examining the literature related to NOS, it was predicted that it would provide a more valid analysis opportunity for this study.

The model, suggested by Jones, (2010), consists of 0=Uninformed, 1=Syncretic (-), 2=Syncretic (+), and 3=Informed levels. Syncretic was used for an understanding of the target aspects of NOS between uninformed and informed. Syncretic (-) was used for "less informed" syncretic understanding, and Syncretic (+) was used for the understanding of the target aspect of NOS may be closer to an informed understanding. In the original rubric, the tentative aspect of the nature of scientific knowledge and the role of imagination and creativity in science were presented under three levels; one additional level is added to these dimensions for this study. Since each question in the questionnaire is related to many aspects of NOS, the answers given to all questions were taken into consideration while analyzing data for each aspect. In the analysis, positive and negative change and non-change in the understandings at the end of the course compared to the understandings at the beginning of the course. To ensure reliability in the analysis, some of the data were re-analyzed by the researcher, and a certain level of consistency was obtained. For the validity of the analysis, it is generally recommended to interview the participants (Lederman et al., 2002). With the help of the interviews, participants are asked to clarify the concepts they use in their answers. Because, for researchers who use VNOS for the first time, interview is recommended with all or a large majority of the participants (Lederman et al., 2002), two preservice teachers were interviewed to understand what they meant by their answers to open-ended questions for this study. It was understood that the participants used similar concepts used in their discussions and exchange of views in during the classes no further interviews were conducted.

### Findings

In this section, the participants' understandings of NOS are examined under seven aspects of NOS. Their classified understandings at the beginning and end of the course are presented in the rubric form. In addition to these results, direct excerpts from their answers were given by coding their names (see Tables 1-7).

Table 1. Understandings about the Experimental Aspect of NOS

Code	Experimental Aspect of NOS	f Pre	f Post
0	Does not articulate that observations of the natural world are a major criterion that sets science apart from other disciplines	3	0
1	Uses terms such as concrete, the study of a physical thing alludes to observations. But also describes science as "fact" or "proven" or with other inappropriate terms	4	2
2	States the role of observation among other ideas (e.g., experiments) in the scientific process or mentions the idea of repeatability with experiments	2	5
3	State scientific knowledge is based upon observation and stresses the repeatability of those observations. Delineates scientific knowledge from religious or other types of knowledge.	0	2

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

According to the results in Table 1, it was determined that the majority of the preservice chemistry teachers (seven out of nine) had "syncretic (-)" and "uninformed" understandings of the experimental nature of scientific knowledge. At the beginning of the course, none of them had any understanding that could be classified as "informed". As a result of the analysis, it was found that five of the participants had positive changes in their understandings according to the beginning of the course, and four of them insisted on their understandings. Below, two excerpts from answers of one of the participants before and after the instruction, classified as "uninformed" and "informed", are presented respectively:

*"Experiment is a method that has been done many times by trial and error to find whether a judgment is right or wrong." (P.1-Pre)*

*"The necessary materials are used to verify that an existing phenomenon is true or false and to reach a clear result as a result of experiments and observations. There is not any scientific knowledge can be developed independently of experiment and observation. The lack of scientific knowledge can be completed and improved through experiments and observations. Finding the diagnosis and treatment methods of some diseases in today's world as a result of experiments and observations." (P.1-Post)*

Table 2. Understandings about the Inferential Aspect of NOS

Code	Inferential Aspect of NOS	f Pre	f Post
0	Knowing is seeing, does not distinguish between observations and inference-making. Do not use the term "interpret". "Facts speak for themselves"	5	0
1	Speaks of interpreting, interpretations, but includes misconceptions such as "facts speak for themselves," or "atoms are seen," "can test what a species is," etc.	3	7
2	Articulates the role of interpretation, inference in several responses. However, the term is limited primarily to use with a scientist's "worldview" or "religious background." It does not apply proper use of the term in the context of constructs such as species or atoms.	1	2
3	Articulates distinction and relationship between observations and inferences consistently throughout responses and in the appropriate contexts.	0	0

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

It is understood from the results of Table 2 that none of the preservice chemistry teachers had an informed understanding of the inferential nature of scientific knowledge at the beginning and end of the instruction. One of them talked about the concept of interpretation in science at the beginning of the instruction and two of them at the end of the instruction. At the end of the instruction, some weak changes were detected in the understandings of five participants. The responses of one of the participants, classified as "uninformed" and "syncretic (-)" respectively before and after the instruction, about this aspect of NOS are presented below:

*"They are things that are done to find new things to meet people's needs. To extract new things from existing to facilitate human life." (P.7-Pre)*

*"Experiments are studies to verify the truth of scientific knowledge. By experimenting with something, we can both develop new information and expand the information we have, so we need to do experiments."* (P.7-Post)

Table 3. Understandings about Theory-laden Aspect of NOS

Code	Theory-laden Aspect of NOS	f	f
		Pre	Post
0	Claims scientists are objective. Differences in views due to unclear data. Further discoveries or study will lead to one correct view or explanation of phenomena.	4	0
1	Articulates that different viewpoints of scientists may influence interpretations or views theory-laden aspect in religious terms only; uses "bias" in a negative context or application; contains several contradictions in responses.	5	5
2	Consistent use of "bias" in a broad and neutral context when speaking of interpretations. Do not articulate educational, motivational, interest differences, etc. as reasons for different scientific views.	0	4
3	Articulates several differences including educational, motivational, interest differences, etc. as reasons for different scientific views. Responses are not contradictory.	0	0

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

It was determined that all of the preservice chemistry teachers had "uninformed" and "Syncretic (-)" understandings about the theory-laden aspect of NOS. According to the beginning of the instruction, it is seen that there is some improvement in these understandings, although not at the desired level. At the end of the instruction, seven out of nine participants had a positive change in their understandings while there was no change in the understandings of two. The responses of one of the participants, classified as "uninformed" and "informed" before and after the instruction respectively, about this aspect of NOS are presented below:

*"They are confident in theories and the results of experiments. The Cathode rays have been proven by experimenting with oil drops."* (P.5-Pre)

*"The social environment of man may broaden or narrow his thinking, or may or may not support his / her work, and these reasons affect scientific work."* (P.5-Post)

Table 4. Understandings about Distinction between a Scientific Law and Scientific Theory

Code	Distinction between a Scientific Law and Scientific Theory	f	f
		Pre	Post
0	Inappropriate description for both law and theory. Scientific theory not "set in stone," it can change; a scientific law is "set in stone" and can change.	9	2
1	Properly describes either scientific law or scientific theory but not both. Includes misconceptions such as a hierarchical relationship between the two.	0	2
2	Properly describes a scientific law and scientific theory, but responses include contradictory statements and/or misconceptions.	0	4
3	Properly describes a scientific law and scientific theory. Contradictory statements and/or misconceptions are absent.	0	1

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

At the beginning of the instruction, it was determined that all nine preservice chemistry teachers had an "uninformed" understanding about the relationship between scientific theories and laws. As in the other aspects of NOS, it is seen that no one has "informed" understanding at the beginning of the instruction. At the end of the instruction, it was found that there was a positive change in the understandings of the seven of them, while there was no change in the understandings of the two of them. At the end of the instruction, it was determined that only one preservice chemistry teacher had an understanding which was classified as "informed". The responses of one of the participants, classified as "uninformed" and "informed (-)" before and after the instruction respectively, about this aspect of NOS are presented below:



*"Scientific law is something that is accepted true by everyone. The theory is constantly changing. When something is said about the same subject, the other changes. (P.8-Pre)*

*"There are, while theories are dependent on inference, laws are usually based on numerical data. Theories consist of tested hypotheses. On the other hand, the law has the process of specifying the relations rather than the explanations. (P.8-Post)*

Table 5. Understandings about Social and Cultural Embeddedness Aspect of NOS

Code	Social and Cultural Embeddedness Aspect of NOS	f	f
		Pre	Post
0	There are no references to science influencing culture or culture influencing science. Science processes are seen as standing apart from culture, transcending culture.	4	1
1	Affirms culture and societal norms influence science, but some responses are contradictory. Lack of examples indicates a limited understanding.	4	4
2	Affirms culture and societal norms influence science without contradictions but do not provide examples or elaboration.	1	4
3	Affirms culture and societal norms influence science without contradictions. Elaborates on the relationship with examples or elucidates the relationship in detail.	0	0

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

It is seen that four of the preservice chemistry teachers have an "uninformed" understanding about the relationship between scientific knowledge and social and cultural values, and the other four have "syncretic (-)" understandings. Also, it was found that at the end of the instruction, seven of them had positive changes in their understandings, and one of them had no change in his/her understanding. The responses of one of the participants, classified as "uninformed" and "syncretic (+)" before and after the instruction respectively, about this aspect of NOS are presented below:

*"Science is universal; it does not vary from person to person, from place to place, or from culture to culture. It is a whole. It is a basic thing, and it is universal, it is objective." (P.4-Pre)*

*"It reflects because the research topic or subjects we deal with is from the realities of life. Not necessarily affected. Since the area we are interested in is 'human', the issues of human beings are handled from within life. Society has to have social values, political values, philosophical assumptions because there is a society where there is a human being, there are social relations, there is also a policy that is why it can be affected." (P.4-Post)*

Table 6. Understandings about Tentative Aspect of NOS

Code	Tentative Aspect of NOS	f	f
		Pre	Post
0	States science is "proven"; If there are repeated observations or experiments this will establish scientific facts, theories as absolutely true or truth.	3	1
1	Stated theories changes in science, but laws do not. There are conflicting answers like this. There is no statement of how scientific knowledge has changed.	6	6
2	States all scientific information, including scientific laws and theories, are open to change. However, there is no statement about how and under what circumstances the scientific knowledge changes.	0	2
3	Stated all scientific knowledge, including scientific laws and theories, are open to change. Science cannot give absolute truth, only confidence. New data, new perspective on the data, cultural influences are listed as agents of change.	0	0

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

According to the results in Table 6, it is seen that all participants have "uninformed" or "syncretic (-)," understanding about the tentative aspect of NOS at the beginning of the instruction. At the end of the instruction, it is seen that there are improvements in their understandings. On the other hand, it was determined that only one of them had a positive change in their understandings compared to the beginning of the instruction, and eight of them maintained their current understandings. The responses of one of the participants,

classified as “uninformed” and “syncretic (+)” before and after the instruction respectively, about this aspect of NOS are presented below:

*"Laws are definitive, and theories are not. Theories like Bing Bang and the theory of evolution are not precise and can be disapproved." (P.11-Pre)*

*"Theories are scientific knowledge that is accepted as a result of the data obtained as a result of investigations. It is not certain; it may change and may be falsified. Laws are scientifically proven information, and they can be enhanced with new information." (P.11-Post)*

Table 7. Understandings about Creative and Imaginative Aspect of NOS

Code	Creative and Imaginative Aspect of NOS	f	f
		Pre	Post
0	Denies the use of creativity or imagination in science, considered as bias.	2	0
1	Creativity and imagination may be used but only in limited areas such as developing experiments or data collection techniques. Creativity and imagination are to be avoided in other areas, such as data analysis.	6	4
2	State imagination and creativity are used in all stages of the scientific process.	1	4
3	State imagination and creativity are used in all stages of the scientific process. Imagination and creativity are needed, especially in theory development.	0	1

0: Uninformed, 1: Syncretic (-), 2: Syncretic (+), 3: Informed

The majority of the preservice chemistry teachers admitted the importance of imagination and creativity in science as it is seen the results in Table 7. However, it is seen that these understandings are mostly in the “syncretic (-)” category. They thought that imagination and creativity are used in science in only a few steps of the scientific process. At the beginning of the instruction, only one of them thought that imagination and creativity were used in all stages of the scientific process. Although there were some improvements in understandings, according to the beginning of the instruction, they were weak. At the end of the instruction, it was determined that six of the participants had a positive change in their understandings, while the other three had no change in their understandings. Two examples answers showing no improvement from one participant, classified as “syncretic (+),” and “syncretic (+)” both for before and after the instruction about this aspect of NOS are presented below:

*"Scientists use their imagination and creative thinking to make a difference in science. Otherwise, everyone can experiment." (P.2-Pre)*

*"Using their imagination, they can produce a good idea after the method they apply to research problems." (P.2-Post)*

## Conclusion and Discussion

According to the results of the beginning of the instruction, it was determined that most of the preservice chemistry teachers' understandings of NOS were categorized as Syncretic (-). It was determined that none of them had an understanding of the relationship between scientific theories and laws that could be classified as informed. All of the preservice chemistry teachers stated that the scientific theory could change because the scientific theory was not proved, but the scientific law would not change because it was proved. Five of the preservice chemistry teachers thought that knowing about the inferential nature of scientific knowledge was equivalent to seeing and could not distinguish between observation and inference. Also, four of the preservice chemistry teachers stated that social and cultural values had no any effect on science; three of them thought that scientists' studies are not affected by their personality attributes, three of them thought that because scientific knowledge is proved true it will not change and three of them did not mention the factual aspect of science in any way in their answers to distinguish science from non-science fields. At the beginning of the instruction, it was determined that the preservice chemistry teachers had relatively realistic ideas about the use of imagination and creativity in science.

Regarding this dimension, most of them thought that scientists use their imagination and creativity in their studies. However, they seem to limit the use of imaginative creativity in science to the beginning of the scientific process. These understandings that the preservice chemistry teachers exhibited at the beginning of the

course are consistent with the results of similar studies in the literature (Aydeniz & Bilican, 2014; Koksal & Sahin, 2013; Schwartz & Lederman, 2008; Tira, 2009).

Although the preservice chemistry teachers exhibit understandings that are classified as informed in some answers about NOS, they cannot endure these understandings in their answers to other related questions. While the preservice chemistry teachers express the tentative nature of scientific knowledge in their answers, they are still citing that scientific theories are open to change, but laws are not open to change to express their understandings about the relationship between scientific theories and laws. To classify any understanding about NOS, it should be exhibited in all answers consistently.

Also, as stated by Cofré et al., (2019, although the improvements in the understandings of NOS are not at the same level for all NOS aspects and some aspects of NOS are easier to change, it was found that there were improvements in uninformed NOS understandings of the preservice chemistry teachers after the explicit, reflective and contextual NOS teaching. After the instruction, it was determined that only two of the preservice chemistry teachers had enough development in their understandings about the experimental nature of scientific knowledge, one of them about the relationship between scientific laws and theories, and one of them about the understanding of creativity and imagination in the scientific process. Although understandings of a few of the preservice teachers' were improved, these understandings were still insufficient according to the rubric classification. After the instruction, it was determined that five of the preservice teachers about the experimental aspect of NOS, four of them about aspects of NOS such as theory-laden, distinction between scientific theories and laws, social and cultural values in science and imagination and creativity in science still had uninformed understandings. It was found that the preservice teachers' understandings of the distinction between a scientific law and scientific theory changes more difficult than the other aspects of NOS. Similar results were found in another study (Cofré et al., 2019; Mesci, & Renee'S, 2017) in the literature. It was seen that they mostly resisted in changing their current understanding about distinctions between theories and laws.

Given that teachers are more successful in teaching NOS when they are sufficiently equipped to teach NOS (Schwartz, & Lederman, 2002), their understandings of NOS should develop in the teacher education process. Although there are some changes in the preservice teachers' understandings at the end of this study, for these changes to be permanent, explicit, reflective, and contextual approaches should be integrated into the teacher education courses from the beginning to the end of teacher education programs. As indicated in other researches (Abd-El-Khalick, 2005; Bell et al., 2011), only the knowledge of NOS alone is not sufficient to develop a deep understanding of NOS.

The results of this study are limited to 9 preservice chemistry teachers attending the "scientific research methods" course. In this sense, it is not possible to generalize a wide universe. For more general results, new and more comprehensive studies are needed to improve the preservice of chemistry teachers' understandings of NOS. As determined in the most recent review (Cofre et al., 2019) on NOS, it is seen that the studies of teaching NOS to preservice teachers are generally done within the scope of science methods courses. As the results of this study showed, other courses in the chemistry education curriculum could be used as a context to teach NOS to preservice chemistry teachers. Preservice teachers should be supported during their undergraduate education in order to gain the knowledge and teaching approaches required for teaching NOS. This support will be more effective if the effective NOS teaching approaches, determined by researches, could be applied in the course with different content. Determining what kind of course or content is more appropriate for teaching NOS to preservice teachers could be investigated in future studies.

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