

Tracking the Footprints of Nature of Science in the Path of Learning How to teach it

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The present article aimed at understanding those unvoiced biases pre-service teachers may have that conflicts with their integration of nature of science in their science lessons. Three senior pre-service science teachers' views on NOS with regard to their decision making on critical incidents and their reflections about how they contextualize science teaching were investigated in science method course. The findings indicated that, pre-service science teachers varied in reflective their nature of science understanding in different contexts related to their science teaching approach. Therefore, current study suggested that efforts to improve science teachers' nature of science views and practice need to consider science teachers' unvoiced biases such as their approach towards science teaching and their decision making related to science teaching.

Keywords: Nature of science teaching, nature of science understanding, pre-service teacher education.

INTRODUCTION

The interest on Nature of Science (NOS) has been developing gradually since the concept has been first introduced in early 1950s (Robinson, 1965; Wilson, 1954). Since then, the research on NOS has become so comprehensive that there are lots of studies across the world about assessing students' and teachers' views of NOS (e.g. Lederman, Wade, & Bell, 1998; Quigley, Pongsanon, & Akerson, 2011), developing and investigating instructional materials (e.g. Irez, 2009) and pedagogical strategies to help students (e.g. Lederman,

1992; Yacoubian & BouJaoude, 2010) and teachers (e.g. Bell, Matkins, & Gansneder, 2011) internalize understandings of NOS, and investigating possible factors and approaches translating teachers' understandings of NOS into instructional practice (Akerson, Cullen, & Hanson, 2009, Hanuscin, 2013). Science teachers have a significant role to help students gain desirable NOS understanding. Putting straight, students could have adequate understanding of NOS, if they have been taught about it in science courses. However, recent studies indicate that teachers (Dogan & Abd-El-Khalick, 2008; Ozgelen, Yilmaz-Tuzun, & Hanuscin, 2012) continue to ascribe to positivistic views of NOS, which are thought to be inadequate compared to the post-positivistic paradigm (Abd-El-Khalick, 2012). These inadequate conceptions have resulted in science teachers' avoidance of addressing NOS in their instruction explicitly and reflectively (Akerson, Buzzelli, & Donnely, 2008; Bilican, Cakiroglu, & Tekkaya, 2012).

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State of the literature

- The study aims to develop a scale instrument to allow us to determine the self-efficacy perceptions of primary education teachers regarding their use of technology when educating students.
- The developed scale instrument was obtained in the wake of the data gathered from primary education teachers.
- According to the conducted analyses of the developed scale instrument, it was determined to have validity and reliability.

Contribution of this paper to the literature

- The developed scale instrument is going to contribute to the literature in that it will make the information technologies coherent with the education, thus creating a model for teachers developing and designing the learning environment.
- That the developed scale instrument on information technologies included numerous expressions about different aspects is vital in terms of it being intended for the use of all education instruments.
- It is thought that the scale instrument puts forth the self-efficacy perceptions regarding the use of information technologies from the point of view of basic skills and the anxiety state.

Moreover, even teachers categorized as holding informed views of NOS have difficulty in translation of their views in their instructional practice to help their students achieve the desired understandings of NOS (Abd-El-Khalick, 2012). The research and development efforts provided answers to the question of what could be the constraints on translation of the NOS concepts into instructional practices from the perspective of teachers (e.g. Akerson, Donnelly, Riggs, & Eastwood, 2012; Clough & Olson, 2012). For example, besides having inadequate views of NOS, intentions to teach NOS, lack of PCK for NOS and pressure to cover content have been other factors asserted to inhibit NOS. However, the research investigating the factors inhibiting translation of NOS views into teaching mostly focused on teachers' pedagogical content knowledge (PCK) for teaching NOS. Yet, very few research explored the relationships among science teachers' beliefs about teaching science and nature of science and views about nature of science. Such research shows that teachers' beliefs of teaching science, their NOS conceptions and translation of these conceptions into practice were not independent from each other (Abd-El-Khalick, Bell, & Lederman, 1998; Koballo et al.,

2000). Many science educators agreed that teachers' beliefs and their teaching practice has a complex relationship (Pajares 1992). Concerning NOS, research claimed that teachers' beliefs related to how science developed might mediate how they teach science and how they learn science (Bell & Lederman, 2003; Nott & Wellington, 1995; Tsai, 2002; Waters, 2006).

For instance, Tsai (2007) showed that teachers' with more adequate NOS views used more student-centred instructional strategies while teachers with inadequate NOS views revealed more teacher-centred instructional strategies. In another study conducted with 37 pre-service science teachers', however, Tsai (2002) found that teachers with traditional conceptions of teaching science and learning science also held naïve conceptions of NOS.

For long time, researchers claimed an assumed relationship between teachers' conceptions on science and science teaching practice (Bell, Lederman, & Abd-El-Khalick, 2000; Brickhouse, 1990; Mellado, Bermajo, Lorenzo & Blanco, 2008; Tsai, 2002). The empirical research generally revealed that there might be an association between NOS views and science teaching views. In other words, teachers' nature of science views were generally consistent with their orientation toward science teaching for example, teachers with the contemporary of science revealed constructivist orientation of science teaching, whereas teachers with naïve understanding of nature of science tended to employ traditional views of teaching science. Some other research, however, not report any coherence between NOS views and classroom practice. Therefore it is important to further investigate studies in different context to get insightful understanding of relationship between conceptions of nature of science and teaching of science to shape pre-service teachers' practice. Although it seems there is a linear relationship between NOS views and instructional practices, Nott and Wellington (1996) pointed out the complex relationship by claiming that teachers' science teaching and science learning shape their NOS views. However, we still know less about how teachers' approach to science teaching is in conflict with NOS teaching, or what their decision making in critical incidents that may occur in a typical science classroom tells us about their understanding of science and scientists (e.g. Shah, 2009). This study aimed to find answers to these questions in relation to how NOS views related to teachers' conceptions of teaching science and how teachers' conceptions of science teaching facilitate translation of NOS views into practice. Hence, our hypothesis is that teachers' beliefs on science and science education might be influential on how they teach science, and how students learn science. Additionally, their perceptions on science teaching might moderate translation of their NOS views into practice. Consequently, changing teachers' views of

science teaching and views of nature of science could be an essential component to be adopted in efforts for improving teachers' NOS views and NOS teaching practice. In this study, therefore, we tracked the footprints of pre-service science teachers' NOS concepts in the path of learning for teaching NOS by several tools, such as critical incidents and teaching approach drawings, which gave us idea about pre-service teachers' unvoiced orientations and biases regarding NOS teaching.

RESEARCH FOCUS AND DESIGN

The current study was a case study aimed at understanding those unvoiced biases pre-service teachers may have that conflicts with their integration of NOS in their science lessons. We began with the assumption that teachers' teaching approach and their internalization of NOS concepts may interfere with their integration of NOS concepts into their teaching. We based our assumption on first, the empirical evidence from research stating that teachers have difficulty in teaching NOS and second, the review of the research that shows the constraints teachers experience are rarely related to the teaching approach or their internalization of NOS concepts. Therefore, in this study, we investigated 3 junior pre-service science teachers' views on NOS with regard to their decision making on critical incidents and their reflections about how they contextualize science teaching.

Research questions driven the current study were as follows:

- (1) *How do pre-service elementary science teachers' views of NOS change over the course of an intervention aimed at teaching the integration of NOS concepts in to science lesson plans?*
- (2) *How are pre-service elementary science teachers' views of NOS reflected in critical incidents related to science teaching in elementary classrooms?*
- (3) *How are pre-service elementary science teachers' views of NOS related to their approaches to teaching science?*

In this study, we considered NOS as a part of the epistemology of science addressing values and assumptions inherent to development of scientific knowledge (Lederman, 1992) including understanding of what science is and how it works, interaction between science and society, and epistemological and ontological underpinnings of science (Clough, 2006; McComas, 1998). Therefore, we built this study up on the following perspectives proposed by the NOS researchers (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) and evaluated by Views on Nature of Science Questionnaire: appreciation of empirical evidence and subjectivity of the scientists in the development of scientific knowledge, tentativeness of scientific knowledge, appreciation of creativity having a

partial role on development of scientific knowledge, its being socially and culturally embedded, beside the recognition of the difference between observation and difference and function of theories and laws (Lederman et al., 2002).

Context of the study

The study was conducted in a 10 week science methods course. The aim of the course was to reinforce concepts of science process skills, scientific inquiry, nature of science, scientific literacy, and to provide insight about science teaching methods for conceptual understanding such as graphical organizers and their applications to elementary science education. The course was supported by two-hour a week recitations where PST were provided practical micro-teaching opportunities and various activities related to features of science and scientific inquiry.

The NOS activities were selected from the literature provided an explicit reflective venue for students to revise their NOS conceptions. Sequencing event activity (Collins, 2002), 'black box' (Lederman & Abd-El-Khalick, 1998), and card exchange (Cobern & Loving, 2000) were some of them. In order to reinforce the integration of NOS views into elementary science teaching practice, beginning from the second week, each week, PST were asked to prepare a lesson plan with integration of nature of science (NOS). These lesson plans were reviewed and evaluated to provide feedback about the integration of NOS into elementary science teaching.

Participants

There were 3 third-grade pre-service elementary science teachers (PST) participated in the study. They had completed several science courses so they had a successive background in science. All PST consented to participate in the study and agreed to be involved in interviews, complete the questionnaires and classroom tasks. Their names were anonymous and labelled as Case I- Ege, Case II- Deniz and Case III- Sanal.

Data Collection

We relied on four sources of data explained in detail below:

Views of Nature of Science Questionnaire (VNOS-C). *The VNOS-C (Lederman et al., 2002) was utilized at the beginning of the course to determine PSTs' initial understanding of NOS and at the end of the intervention to assess change in their NOS views over an explicit reflective NOS instruction. The VNOS-C consists of 10 questions related to several features of science including subjectivity, tentativeness, and being empirically-based. The*

time spent to answer the questionnaire was about 40 minutes. Additionally, associated semi-structured follow-up interviews were conducted with the participants who were consented to schedule pre- and post-interview.

Critical Incidents. "Critical incidents" was a survey instrument developed by Nott and Wellington (1998). Critical incidents are events that may occur in any science classroom and force science teacher to make a decision on a course of action, which gives a clue about teacher's approach to the scientific enterprise. The critical incidents used in this study were either an example of a practical work which doesn't work or a situation which concerns with moral and ethical issues about scientific knowledge or work of scientists (Nott & Wellington 1998). The responses to the practical incidents indicate teachers' knowledge of the procedures of science, scientists' practice and values inherited in development of scientific knowledge (Nott & Wellington, 1998). The participants completed the survey in approximately 30 minutes. The survey was given at the end of the intervention.

Draw a Science Teacher Test. In order to answer to the third research question, which asks for how pre-service elementary science teachers' views of nature of science is related to their approaches to teaching, at the end of the intervention, participants were asked to draw themselves as a teacher in their science classroom and explain what they are doing in the classroom (Thomas, Pedersen, & Finson, 2001). The drawings and explanations took almost 15 minutes. This test were used to understand pre-service science teachers' science teaching conceptions.

Reflection Paper. In addition to VNOS-C, the

improvement in participants' NOS views was also tracked by their reflections. Participants were asked the following three questions: What have you learned during the class regarding NOS, which ideas reinforce or diverge from your ideas about NOS, and which ideas have been changed about NOS after the instruction. Reflections were presented evidence to support changes in PST's NOS views.

Data Analysis

Data analysis of the study was completed in four stages. At the first stage, the responses to VNOS-C questionnaire of three participants were compared to their interview responses for inconsistencies. At the second stage, the analysis of VNOS-C questionnaires was done by researchers independently. The researchers generated participants' profiles in terms of their NOS views as inadequate, adequate, or informed. The profile categories were adapted based on the descriptions of inadequate and informed views identified by Lederman et al. (2002).

At the third stage, participants' responses to the classroom situations were examined regarding to how participants reflected their NOS views while handling challenging situations provided in critical incidents. Before the analysis, researchers collaboratively determined which features of science can be reflected in each critical incident and how they can be reflected. The responses to critical incidents were coded if the determined NOS aspects are reflected in the answer. The analysis was done by independent researchers and

Table 1. Data collection over science method course.

Stage	The instrument	Categories	Description
1	VNOS-C and Interviews		Whether the views expressed in each source were comparable.
2	VNOS-C	<i>Inadequate</i>	Have limited or naïve views of NOS
		<i>Adequate</i>	Have more desirable NOS views but cannot provide elaboration or examples
		<i>Informed</i>	Have more desirable NOS views and can provide elaboration or examples
3	Critical Incidents		If the determined NOS aspects are reflected in the answer
4	Science Teaching Approach	<i>Student-centered</i>	Students are in charge of their learning, constructing knowledge; teacher is a facilitator or guide.
		<i>Towards teacher-centered</i>	Students are partially in charge of their learning, they perform activities under the supervision of teacher, while teacher do most of the job by demonstrations or explanations.
		<i>Teacher-centered</i>	Students are passive learners listening and taking notes, teacher is the source of knowledge.
5	Reflection Paper		To back up participants' NOS views revealed in VNOS-C and interview responses

the achieved inter-rater reliability was 95%.

At the last stage of data analysis, participants' drawings and explanations were analyzed. Before the analysis, researchers collaboratively determined which features of teaching context and teachers' role can be classified as student-centered, teacher-centered or towards teacher-centered. For example, if a participant drew him/herself in front of a class explaining a science topic and students are in the position of listening and taking notes, and if the classroom is arranged so that students sit back to back, then the teaching approach is classified as teacher-centered. If a participant drew herself somewhere in class checking or guiding student work and students are in the position of doing a classroom task, and if the classroom is arranged to allow students work in groups, then the teaching approach is classified as student-centered. If a participant drew him/herself in class checking students' work or encouraging students work in groups but s/he is doing most of the work by means of demonstrations, explanations, then the teaching approach is classified as towards teacher-centered. The drawings and explanations were coded by independent researchers and achieved inter-rater reliability was 100%. Data collection and constructed categories for each data collection tools were summarized in Table1.

RESULTS AND DISCUSSION

Each participant's views of NOS, reactions to critical incidents, and their science teaching approach were presented in this section as separately via three different cases.

Case I- Deniz

Views of NOS

Pre and post analysis of VNOS-C revealed Deniz's development regarding NOS understanding. Prior to the science method course, she held inadequate views concerning empirical NOS, inferential NOS, theory and law as well as single scientific method. At the outset of the science method course, she achieved adequate understanding of all these aspects. For instance, regarding empirical NOS, while Deniz described scientific knowledge as proven facts prior to science method course, she was able to articulate science as a distinct discipline because of evidences sourced by experiments, observations and inferences at the end of the course. Additionally, Deniz also pointed out that scientists interpret data collected through the experiments to reach conclusions. This response revealed that she recognized that science is not what we see but it is mainly scientists' inferences based on experiments and observations (Table 2).

At the beginning of the course, the definitions Deniz made for theory and law were not adequate. However, she was able to define theory and laws as different kind of scientific knowledge and she can give examples to a theory and a law in her response in the post-VNOS-C. Therefore, Deniz shifted her view from inadequate view towards informed view:

"Scientific law generalize the natural phenomena but theory explains the natural phenomena. Theories do not evolve to laws in time. Theory is not a prerequisite for of law. For example, gravitational law generalizes the events but there are no theories about gravitation"

In her reflection paper, Deniz was aware of her misconception about the pseudo- hierarchy between theory and law prior to science method course, although she did not make any point related to her misconception in her VNOS-C responses. However, she stated that there was change in her views regarding this aspect of NOS in the reflection paper:

"I had some misconceptions about nature of science. One of them was the belief that before a law, scientists should formulate a theory. I believed that in time the validity of a theory is ensured by new evidences and finally this highly validated theory is considered to be a law. However, [I realized that] the development of theories and laws are not dependent on each other."

Deniz achieved informed view for subjective NOS understanding as well. She articulated that scientist could make different interpretations due to different points of view and background. This was revealed in responses both in VNOS-C and reflection paper (Table 2).

Concerning her understanding on "single scientific method myth" Deniz shifted her views from inadequate to adequate one. Although she mentioned about the experiments as the only way to collect data at the beginning of the course, she added observations at the end (Table 2).

In her reflection paper at the outset of the study, about the belief that asserts there is a single scientific method to be followed in all scientific investigations, Deniz indicated that she learned that there is no rule that a scientist must follow in the same order each time when performing a scientific investigation. This view was considered to be adequate since her view was incomplete and lack of additional explanations:

"Scientific methods do not require a strict order"

Deniz revealed adequate views on creative, tentative and socio-cultural NOS aspects both at the beginning and at the end of the science method course. That is, she described science as tentative and an endeavor, which is influenced by scientists' creativity and the culture where it is practiced in. However, she could not provide detailed explanations or examples to support her views at both prior to and outset of the study. For instance, regarding tentative NOS, Deniz stated that

Table 2. Sample quotas for change in NOS views regarding NOS aspects for Case I

NOS aspects	Sample Statements	
	Pre NOS views	Post NOS views
Empirical NOS	<i>Scientific knowledge is proved by experiments.</i>	Science is based on empirical evidence, observation and inferences. But other disciplines of inquiry do not have an empirical ground.
Inferential NOS	<i>By doing experiments.</i>	After experiment, we collect data and we interpret these data to conclude the experiment, and we make some inferences to reach conclusions.
Subjective NOS	<i>These two groups of scientists have different views. They interpret data in different aspects. They conclude their experiment differently because these people don't think in the same way.</i>	The scientific knowledge is subjective. That means, scientists look at the same data but they make different conclusions, inferences about the issue. Every scientist can make different inferences because of different points of view and different previous knowledge. NOS explains why all scientists reach different conclusions although they have the same data. Because scientists have different background, culture and social situation (response in reflection paper).
Theory-Law	<i>Scientific theory can change and can be replaced with another theory. However, scientific law does not change.</i>	Scientific law generalize the natural phenomena but theory explains the natural phenomena. Theories do not evolve to laws in time. Theory is not a prerequisite for of law. For example, gravitational law generalizes the events but there are no theories about gravitation
Multiple Scientific methods	<i>The development of scientific knowledge requires experiments. Because if scientific knowledge is supported by experiments, it is reliable.</i>	Scientific knowledge has an empirical base that is, making experiments, observations and inferences. For example, Mendel tried to explain population genetics so he made some experiments, collected data, and made observations.

scientific knowledge could change but she did not deepen her answer with further explanations:

"Science is tentative; scientific knowledge can change in time."

Similarly, Deniz stated that science reflected socio-cultural values without any further explanation:

"I believe that science reflects social and cultural values"

Regarding creative NOS, Deniz did not change her view on creative NOS. She kept her adequate views on this aspect. She argued that scientists used their imagination and creativity in some parts of scientific investigation in the post-VNOS-C:

"Scientists use their creativity and imagination during investigation, especially when they design their experiments".

Table 4 depicted for sample quotas for the NOS aspects that improvement revealed.

Critical Incidents. Deniz reflected her NOS understanding in her responses in three incidents out of six incidents. Two of these incidents were related to laboratory work and one of them was related to how science and scientist works. For instance, there was a critical incident that exemplifies a laboratory experiment

where students prepare specimen and observe onion cells by a microscope, but a student comes up with irrelevant drawings. In her response to this critical incident, Deniz reflected her understanding regarding creative and inferential NOS:

"Each student has a different creativity. If the microscopes the students use function appropriately, all students would observe the same thing. However, they could draw what they see in different ways. We cannot say that their drawings are wrong. They just used their creativity while drawing the structure of onion cells they observed. I don't think it is fair enough to expect all students draw the same structure. Everyone does not have the same level of creativity"

In another similar laboratory work incident, Deniz was provided with a case that students had to change their predictions throughout the scientific investigation they encounter. In her response, Deniz pointed out one of the incidents as a context to address NOS. She stated that in such an incident she would exemplify how scientists worked. Additionally her response to this incident also revealed that Deniz had an informed understanding of empirical NOS. She stated that science

require repeated experiments and reformulation of predictions.

"In such an incident, teacher can have a chance to emphasize that predictions are not absolute truths. She can give an example of how scientists work. For instance, she can explain that scientists make predictions before doing an experiment. In the meanwhile of a scientific investigation, either scientists review their predictions or they start to work on those pre-formulated predictions with different viewpoints and they refine those predictions."

Last incident that Deniz reflected her NOS understanding was related to how science and scientists work. The critical incident involved a case that students were challenged by existence of two different theories about atom models and asked teacher which one to believe. In response to the incident, Deniz demonstrated her adequate understanding on tentative NOS, and additionally, she also revealed that she would address tentative NOS in such a classroom situation:

"In such an incident, I, as a teacher, can tell them (the students) that scientific knowledge can change. The research may be acceptable by now. However, when more research is done on the same issue, new discoveries can be made and these new discoveries may add to our current knowledge or may shift our knowledge to a new perspective."

Science teaching approach. In Draw a Science Teacher Test, she showed student-centred approach. That is, she portrayed students as studying collaboratively in groups and drew herself as monitoring them. Consistently, she explained herself as a teacher guiding and controlling students while the students were working in groups:

"There are four groups and all groups discuss a subject and one student in each group explains what they think about this subject. I provide guidance to them"

In general, Deniz revealed more student-centered teaching approach. She achieved either adequate or informed understanding of NOS. She revealed informed understanding concerning inferential, subjective NOS or understanding on theory and law. In her responses to critical incidents, she reflected her NOS understanding on creative, inferential and tentative NOS via three incidents. Deniz revealed adequate view on these NOS aspects in her responses to critical incidents. The overall summary of her science teaching approach, change in NOS understanding and NOS views reflected in responses to critical incidents were presented in Table 3.

Case II- Ege

Views of NOS

Pre and post analysis of VNOS-C revealed substantial improvements in Ege's views of NOS. Prior to the science method course, Ege had already held adequate views on tentative NOS. In other words, she

was aware of that scientific knowledge is tentative, but had difficulty in providing examples regarding this aspect, so we cannot say that she had an informed view but adequate. After the course, she appreciated tentativeness of scientific knowledge due to new evidences in the light of examples from history of science that were provided in class. Therefore, in the post-test she was categorized as adequate view of tentative NOS (Table 4).

Additionally, in her reflection paper she also talked about the improvement in her tentative NOS understanding:

"Before taking the course, I believed that scientific knowledge can change, but I couldn't explain it [means she could not give any example]. But now, when somebody asks me 'give an example to show the scientific knowledge can change' I can say the model of atom."

Ege, on the other hand, had inadequate view on concepts related to theory and law prior to the course. She considered laws as certain knowledge and theories as less reliable than laws. However, Ege realized theories and laws as different kind of scientific knowledge at the outset of the science method course (Table 4).

Regarding subjective NOS, she improved her adequate understanding of subjective NOS towards informed views on the issue. That is, at first, she did not recognize different interpretations of scientists' are due to different background, preconceptions and beliefs. However, at the outset of the course, Ege appreciated scientists' background, perspectives, and creativity as factors influencing their work.

Although Ege made substantial improvements on some of the NOS aspects, she failed to recognize inferential nature of scientific knowledge in an informed way. Even though she mentioned observations, she could not able to refer scientists' inferences based on observations to make sense of data:

"...Scientists classify the organisms according to their [the organisms'] natural appearance. They observe everything [about them] by a using variety of techniques"

In her reflection paper, although she stated that she learned how to make observation and inference, she failed to provide any evidence for her claim. Therefore, her view was categorized as inadequate:

"We know how to make observations, inferences, and predictions and how to design experiments"

Concerning empirical NOS, at the beginning of the science method course, Ege held the view that scientific knowledge distinguished from other disciplines by experiments. She kept the same view and stated scientists should conduct experiments to validate scientific knowledge at the outset of science method course:

"Unless tested, knowledge just stays as an assumption, a forecast or a prediction. However, if tested, it becomes a knowledge that is accepted as real"

Table 3. Case I- Science teaching approach, change in NOS understanding and reflected NOS views in response to critical incidents

Aspect of NOS	Pre	Post	Teaching approach	Approach revealed in responses to critical incidents
Tentative NOS	adequate	adequate	Student-centered approach	*Connection to the NOS
Empirical NOS	inadequate	adequate		*Reflection of NOS views in responses
Subjective NOS	adequate	informed		*Use of incidents as a venue to address NOS in instruction
Inferential NOS	inadequate	informed		
Socio-Cultural NOS	adequate	adequate		
Creative NOS	adequate	adequate		
Theory& Law	inadequate	informed		
Multiple Scientific methods	inadequate	adequate		

Regarding “myth of single scientific method”, Ege did not write anything in VNOS-C. However, her response in reflection paper revealed that she thinks that there is no step by step procedure in scientific investigation. Therefore, her view was categorized as adequate (Table 4).

Table 4 below depicted some sample quota for the NOS aspects that improvement revealed.

Critical Incidents

Out of six incidents, Ege reflected on the ones related to laboratory work, ethical and moral issues concerning to science and scientists’ work. Although these incidents are potential venues to address NOS in classroom environment, participant did not reveal any of her NOS understanding while dealing with these challenging situations. For instance, in her response to an incident related to laboratory work, she was presented with a situation where students come up with unexpected results in their experiments. She responded as she would ensure that procedure works, or she would make students retry the experiment until achieving the expected conclusion:

“I would ask the student to repeat the experimentset up a new specimen of onion cells to examine their structure and make careful observations of the specimen. If necessary, I ask the student to examine the specimens made by other students and draw their structure again. If the student cannot reach the result [draw the onion cells as shown in the textbook], I suggest drawing altogether.”

Teaching approach

As understood from the Draw a Science Teacher test, Ege tended to adopt a teacher-centered approach. She drew students sitting and listening to their teacher. Accordingly, she also explained herself (as teacher) as a main agent of the teaching, transmitting the factual knowledge to students:

“..I am reading a scientific article from a newspaper to my students. I am doing this before starting a new topic. My aim here is to show the students that the situation mentioned in the article is a part of our daily life and to promote their understanding. Students are sitting around me in U shaped desks. I am standing in the middle. After reading, I will make a small discussion.”

Table 3 indicated overall summary of her science teaching approach, change in NOS understanding and reflected NOS views in response to critical incidents. Briefly, Ege showed teacher-centred approach for teaching science. At the outset of the science method course, she revealed mostly adequate NOS understanding in NOS aspects related to tentativeness, empirically-based nature of science, understanding on theory and law as well as single scientific method. She achieved informed view on subjective NOS, and kept inadequate view on socio-cultural aspect of NOS. Regarding critical incidents, she did not reflect any of her NOS understanding in responses to critical incidents.

Case III- Sanal

Views of NOS. Analysis of pre VNOS-C questionnaire revealed that Sanal had already adequate views on most of the NOS aspects such as tentative, empirical, subjective and creative NOS. She kept adequate views on these aspects over the science method course, too. That is, Sanal appreciated science as tentative, evidence-based, and an endeavor influenced by scientists’ beliefs, pre-conceptions and creativity.

For instance, in her response to pre-VNOS-C, regarding tentative NOS, Sanal recognized science as not certain but reliable:

“Actually scientists are not sure about the structure of the atom. They accept the most accurate knowledge which they found and present this knowledge to the society”

At the outset of the study, in her responses to reflection paper, Sanal stated that she learned more about tentative NOS during the course:

Table 4. Sample quotas for change in NOS views regarding NOS aspects for Case II

NOS aspects	Sample Statements	
	Pre NOS views	Post NOS views
Tentative NOS	<i>Laws are certain. Laws are confirmed by theories, and new evidence proves the validity of the laws. Law cannot change. Therefore, everyone must accept them as they are.</i>	Scientific knowledge can change and improve. Every piece of scientific knowledge is valid by now but if more rational knowledge is achieved, it shifts the old one. Therefore, as in the case of atom, scientific knowledge changed: the old model was not adequate compared to the new model so the more appropriate one was realized.
Subjective NOS	<i>Scientific knowledge could be subjective in case that scientist does not have enough evidence to achieve certain results so they use their imagination to fill the blanks in data. That is why they may come up with different results.</i>	I mean, scientists are influenced by many factors while constructing theories. Their creativity, social qualifications, their background, their viewpoints are all different and so they make different explanations... Scientific knowledge is subjective. As in the fossil example, scientists are influenced by their creativity, background, and other environmental factors. Therefore, they do have different explanations.
Theory-Law	<i>Scientists might rely on different scientific theories to explain the same phenomena. However, scientific laws are certain. Therefore, all scientists must rely on the same laws.</i>	Theory and law are completely different kinds of knowledge. Law only states existing facts without an explanation of any reason but theories try to make explanations. We cannot say that theory and law transform to each other but some theories may explain some laws.
Multiple Scientific methods	<i>Scientists always need to do experiments. Science is based on the evidence gathered by experiment that is what differentiates science from other disciplines.</i>	Before taking this course I believed that we should follow some steps during the experiment. But now, I know that there is not one way to do an experiment. It depends on the view of scientists.

Table 5. Case II- Science teaching approach, change in NOS understanding and reflected NOS views in response to critical incidents

Aspect of NOS	Pre	Post	Teaching approach	Approach revealed in responses to critical incidents
Tentative NOS	inadequate	adequate	Teacher-centered approach	No accurate reflection of NOS views in responses
Empirical NOS	adequate	adequate		
Subjective NOS	inadequate	informed		
Inferential NOS	inadequate	inadequate		
Socio-Cultural NOS	inadequate	adequate		
Creative NOS	adequate	adequate		
Theory& Law	inadequate	adequate		
Multiple Scientific methods	inadequate	adequate		

"I already know that science is a process. However, I did not know much about how this process works. During the course, I learned how scientists work in this process and thus change existing information"

Additionally, in her response to pre- and post-VNOS-C, Sanal also stated clearly that scientists use their imagination as well as their background to propose explanations, which was categorized as adequate. For instance, her response in post-VNOS-C was that:

"These are different conclusions because scientists use their imagination, creativity observation and background"

Distinctively, Sanal shifted her views on science being socially and culturally embedded from inadequate to adequate views. That is, she began to appreciate science as a human endeavor influenced by culture in which it is practiced at the end of the course (Table 6). Similarly, at the end of the course, Sanal achieved appreciation of theory and laws as different kinds of scientific knowledge. She recognized laws as generalization and theories as explanations, which was categorized as adequate (Table 6).

Sanal achieved informed views only regarding "myth of single scientific method" over the course. In her post

Table 6. Sample quotas for change in NOS views regarding NOS aspects for Case III

NOS aspects	Sample Statements	
	Pre NOS views	Post NOS views
Socio-Cultural NOS	<i>Science is universal because all students in the world learn the same scientific knowledge.</i>	Everybody knows that scientists are like everyone. Surely, they are affected by social and political environment as well as philosophical assumptions. Therefore, science reflects these values of scientists.
Theory& Law	<i>Scientific theory is not exactly true. It can change by time or by a new discovery. Scientific law is exact knowledge, does not change.</i>	Scientific law is the generalization of natural events. However, scientific theory is an explanation or an idea related to natural events.
Multiple Scientific Methods	<i>By the help of experiments, we can achieve certain results. Scientific knowledge requires experiment.</i>	Scientific knowledge does not always require experiments. It depends on what scientists try to find. If a scientist tries to explore the evolution theory, s/he could not conduct an experiment. However, if s/he tries to find an answer for electricity circuits, s/he can conduct an experiment. Following a scientific method does not require following each step. We can easily pass any step if it is not necessary for our work.

Table 7. Case III- Science teaching approach, change in NOS understanding and reflected NOS views in response to critical incidents

Aspect of NOS	Pre	Post	Teaching approach	Approach revealed in responses to critical incidents
Tentative NOS	adequate	adequate	Between student-teacher centered	No accurate reflection of NOS in responses
Empirical NOS	adequate	adequate		
Subjective NOS	adequate	adequate		
Inferential NOS	inadequate	inadequate		
Socio-Cultural NOS	inadequate	adequate		
Creative NOS	adequate	adequate		
Theory& Law	inadequate	adequate		
Multiple Scientific methods	inadequate	informed		

VNOS-C, she was able to articulate that experiments were not the only way to gather data. She also elaborated her explanation by an example. Additionally, her response to reflection paper also demonstrated her understanding of the view that there is no step by step procedure of scientific investigation (Table 6).

The only aspect that Sanal had inadequate view was the inferential NOS. That is, she could not display any recognition of scientists' inferences to make conclusions explicitly neither at the beginning nor at the end of the course. For instance, in response to a question "how scientists determine what an atom look like", in the post-VNOS-C questionnaire, Sanal claimed that scientists use their background, imagination and previous information but she did not refer anything regarding inferences.

Critical Incidents. Sanal did not reflect her NOS understanding appropriately throughout the incidents.

Similar to Deniz, Sanal stated that she would handle the situation stated in critical incidents by retry or redesign of the experiments or by ensuring ways to reach expected results in her responses related to laboratory work. Additionally, she stated that unexpected results were due to either experimental or procedural errors:

"Maybe they did experimental error during experiment (onion cell case). Therefore, first of all, experimental errors should be checked to find out why the drawing (of an onion cell structure) of the student is different. If there is any chance to have the expected structure unless there would not be an error, teacher should make a well-founded explanation and end the experiment"

In other incident related to how science and scientist work, Sanal could not be able to reflect adequate and/or informed views, although she revealed adequate views in her responses to post-VNOS-C. The incident was on presentation of two different atom theories to students,

and how teacher would deal with students' questions on which one to believe. Sanal stated that as a teacher, she would tell the students that science was cumulative, and they need to believe the current one:

"I would ask the students to believe the one I told as recent because science is a progress, which develops in time by accumulation of information".

Please see the Table 6 below for sample quotas for the NOS aspects that improvement revealed.

Science teaching approach. In Draw a Science Teacher test, Sanal's approach to teaching was found to be between teacher- and student-centered. That is, although Sanal portrayed teacher as giving information and students listening to their teachers in her drawing, she stated that students explore things in her explanation of what teacher do:

"Students are doing observation and they are so crazy but it is not a problem for me. I want them to be free in class to explore something new for them. Thus, they can understand all easily"

In sum, Sanal revealed a science teaching approach between student-centered and teacher-centered approach. She achieved mostly adequate NOS understanding at the outset of the science method course about such aspects that science is empirical, tentative, subjective, creative, socially and culturally embedded, in addition to informed understanding about theory and law. She achieved informed NOS view related to scientific method but kept inadequate view regarding inferential NOS. None of the responses to critical incidents reflected adequate understanding of NOS. Brief description of her science teaching approach, change in NOS understanding and NOS views, and reflected NOS views in responses to critical incidents were presented in Table 7.

DISCUSSION AND CONCLUSIONS

Current research was a case study exploring (1) the change in three pre-service science teachers' NOS views over an explicit reflective NOS instruction, (2) translation of these views in different contexts by means of critical incidents in this case and (3) possible relationship between this reflection of NOS views in different contexts and in association with science teaching approach. Consistent with previous studies, all three participants improved their NOS understanding mostly on adequate or informed level of sophistication through the intervention. That is, explicit reflective NOS instruction through science method course provided them with opportunities to refine and revise their NOS views (Hanuscin, Lee, & Akerson, 2011).

Regarding participants' teaching approach to science, "drawing yourself as a science teacher" and written explanation related to how they drew themselves as teachers revealed that participant varied at three type of

teaching approaches as teacher-centered, between teacher- and student-centered and student-centered. The participant with student-centered science teaching approach was the one with informed views on subjective, inferential NOS and the role and function of theories and laws. Additionally, this participant held adequate views of other NOS aspects and did not any inadequate NOS views. The participant with between teacher and student-centered approach held informed view only on "myth of single scientific method" and held inadequate view on inferential NOS. Yet, she kept adequate NOS understandings for the other aspects of NOS. Similarly, the participant with teacher-centered approach, held informed view only one NOS aspect which was subjective NOS and held inadequate view on inferential NOS. She revealed adequate NOS views for the rest of the NOS aspects. In sum, participants with more robust understanding of NOS revealed student-centered science teaching approach. Given the fact that, importance of NOS view for teaching and learning science (Lederman, 1992; Tsai, 2007), this finding was also aligned with the literature claiming teachers with more adequate NOS views tended to use more constructivists teaching strategies (Tsai, 2002). Therefore, teachers' NOS views played a crucial role in creating learning environments which shape students' perceptions of scientists and how science works. Conversely, because it is difficult to establish a cause-effect relationship here, it can also be said that teachers' teaching approaches might be a constraint on integrating NOS.

Another interesting point was participants' reflection of views of NOS in different contexts such as in critical incidents. Only the participant, who had more robust NOS understanding, and student-centered science teaching approach, revealed her understanding in responses to possible class incidents while the other participants did not reflect any NOS understanding in response to critical incidents. This finding might be related with the claim that teachers' ideas related to science teaching could be part of their NOS conceptual ecologies (Akerson & Donnelly, 2008; Tsai, 2002) which raised the issue of importance of adequate views of NOS for science teachers to achieve more reform-based instructional strategies suggested in science education reform documents (Sariieddine & Boujaoude, 2014).

Concerning, holding vigorous NOS understanding for science teachers, consensus view on NOS suggested that NOS aspects were interdependent to each other rather than being distinct from one another (Lederman, 1999). Correspondingly, connection between NOS aspects resulted in more robust understanding of NOS (Hanuscin, Phillipson-Mower, & Akerson, 2006; Ozgelen, Hanuscin & Tuzun, 2012). In current case, disconnection between their NOS views might have kept the pre-service teachers from developing more

robust NOS understanding resulting in lack transferring adequate NOS views in different contexts.

It has been found that, the participant with a student-centered teaching approach had an intention to address NOS explicitly in his/her instruction as revealed through responses to critical incidents. She indicated inferential, creative and tentative NOS emphasis while dealing with potential critical incidents in her class. Yet, these NOS emphasize circumstances were appeared in response to critical incidents mostly in the context of laboratory work. However, she did not show any intention to emphasize NOS in her responses to critical incidents in the context of ethical and moral issues. Additionally, she indicated intention for NOS emphasize in only one critical incident in the context of how science works. Although s/he had robust NOS understanding, s/he could translate these understanding into practice in limited context. That is, pre-service science teachers need to learn how to teach NOS within variety of context which resulted in knowledge of variety of instructional activities, examples, demonstrations and historical episodes (Clough, 2006; Kim & Irving, 2010). In that sense, development of pedagogical content knowledge for teaching NOS have been raised as another important factor influencing effective NOS instruction (Akerson, Cullen, & Hanson, 2009; Hanuscin, Lee, & Akerson, 2011).

The implications of the current study suggested that efforts to improve science teachers' NOS views and practice need to consider science teachers' unvoiced biases such as their approach towards science teaching and their decision making related to science teaching. In that sense, this study implies that exploring pre service science teachers' NOS views and science teaching approach was significant to shape students' views of science in a way that is aligned with current science education reform documents (Akerson & Donnelly, 2008).

Accordingly, the future research might be directed to improve science teachers' understanding and practice of NOS within science teaching orientations perspective. As Lederman pointed out that "testing assumptions", such as the relationship between teachers' and students' knowledge that still exist in the literature is a possible area for extension and improvement (Tasar, 2007). Therefore, the studies investigating the interconnectedness between the teachers' implicit biases addressed in this study and the students' views of science might be significant for future planning of NOS integration in reform documents.

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