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ABSTRACT

Developing an understanding of the nature of science (NOS) among students is one of the goals of scientific literacy. According to research, K-12 students do not have contemporary views of NOS and teachers' views of NOS generally are not consistent as well. This paper presents a study investigating the effects of different types of NOS interventions with elementary preservice teachers in order to address the issues regarding student and teacher understanding of NOS and various NOS interventions. (Contains 15 references.) (YDS)

Developing Pre-service Elementary Teachers'Views of the Nature of Science (NOS): Examining the Effectiveness of Intervention Types

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Introduction

The achievement of scientific literacy is a well-established goal of K-12 science education (Abd-El-Khalick, Bell, & Lederman, 1998; AAAS, 1989, 1993; CMEC, 1997). While scientific literacy has been defined in various ways, it is generally agreed that it encompasses a broader range of goals than traditional science education (Abd-El-Khalick et al., 1998, AAAS, 1989, 1993). In particular, one of the goals of scientific literacy is the development of students' understanding of the nature of science [NOS] (AAAS, 1993; CMEC, 1997; Driver, Leach, Miller, & Scott, 1996; Hodson, 1999). Student understanding of NOS has been identified as an important educational goal in its own right (Driver et al., 1996; AAAS, 1989, 1993), as well as a necessary feature for the reasoned construction/adoption of science concepts (Cochrane 2002; Duschl & Gitomer, 1991).

While the development of a contemporary view of NOS is a stated goal of science education (AAAS, 1989, 1993; CMEC, 1997; NRC, 1996), current research generally indicates that K-12 students do not have such views (Driver et al., 1996; Lederman, 1992; Solomon, Duveen & Scott, 1994). However, in order for teachers to assist students in developing a greater understanding of NOS they must first have a relatively well-developed view of NOS themselves (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001). However research indicates that teachers' views of NOS are generally not consistent with current understanding of the scientific enterprise (Duschl & Wright, 1989; Lederman, 1992; Meichtry, 1992). Lederman et al. (2001) have identified three instructional approaches to developing students' understanding of NOS in K-12 science curricula and in pre-service science education courses: 1) an implicit approach based on the assumption that having students do science will also result in them developing an understanding of NOS; 2) a historical approach that documents historical episodes in science that illuminate aspects of NOS; and 3) an explicit approach to NOS instruction. According to Lederman et al. research indicates that the first two approaches have not consistently shown significant results.

Lederman et al. (2001) define an explicit approach as one in which NOS understandings are, "intentionally planned for, taught, and assessed rather than expected to come about as the by-product of teaching science content or process skill or of engaging students in science activities" (p. 137). Lederman et al. indicate that an explicit approach is not necessarily didactic and advocate an approach that "intentionally draws learners' attention to relevant aspects of NOS through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples intended to improve students' conceptions of NOS" (p. 137). Lederman et al. thus advocate the existence of two aspects or criteria: a) explicitly addressing aspects of NOS "through discussion, guided reflection, and specific questioning" (p. 137) and b) that this occur "in the context of activities, investigations, and historical examples intended to improve students' conceptions of NOS" (p. 137).

Obviously, if we are to improve students' understanding of NOS, we must first improve teachers' understanding of NOS. We must also determine what types of interventions are effective in achieving these goals. This study attempts to address the latter of these issues by examining the effects of various types of NOS interventions with elementary pre-service teachers. Specifically, this study attempts to:

1. Describe some of the views of NOS held by pre-service elementary teachers prior to and after their elementary science methods course,

2. Examine the effectiveness of various types of interventions at developing elementary pre-service teachers' views of NOS,
3. Evaluate the criteria of explicit treatment of NOS advocated by Lederman et al. (2001).

Procedures

The initial sample in this study consisted of 15 elementary education students enrolled in a pre-service elementary science methods course at a small mid-western liberal arts college. The VNOS-C (see Appendix 1), an open-ended questionnaire designed to elicit participant's views of NOS (Abd-El-Khalick, 2001), was administered as a pre- and post-course instrument. The VNOS-C consists of a series of 10 questions plus demographic and educational information about the respondent. Following the second administration of the instrument, a portion of the sample was interviewed to ensure the validity of term use and meaning and to provide additional opportunities to investigate students' views of NOS.

During the elementary science methods course particular topics related to NOS were explicitly featured in lessons in a variety of ways, including:

1. Direct Instruction (DI)—For the purposes of this study, direct instruction refers to the explicit treatment of NOS concepts and ideas by having students ask and/or answer questions and/or engage in discussions or assignments. This intervention type meets the first criterion established by Lederman et al. (2001).
2. Process Skills Activities (PSA)—These include process skills activities that provided the context for the explicit treatment of aspects of NOS.
3. Open Inquiry Activities (OIA)—These include open inquiry activities that provided the context for the explicit treatment of aspects of NOS.

Treatment of aspects of NOS within the context of process skill activities and open inquiry activities usually consisted of providing an explanation or entering into a brief discussion on the issue or topic, but did not include having all students engage in answering questions or completing assignments related to the topic at that time. For example, the difference between a scientific theory and a law was dealt with through direct instruction by including definitions and explanations in a handout, discussing the differences between the two in a whole-class discussion, and having students provide multiple examples of scientific theories and laws and explain why they constituted a theory as opposed to a law or vice versa. Later in the course as students were developing scientific explanations in the context of open inquiry activities they engaged in whole-class discussions regarding whether those student-generated explanations constituted scientific theories or laws. When a particular aspect of NOS received treatment both through direct instruction and also through either process skill activities or open inquiry activities, the activities provided the context to either introduce the concept or apply it depending on whether the direct instruction followed or preceded the activity. Aspects of NOS that received treatment both through direct instruction and also either process skill activities or open inquiry activities were deemed to have met both of the criteria established by Lederman et al. (2001).

Those aspects of NOS receiving the greatest attention in the pre-service elementary science methods course were represented in the VNOS-C by items 1, 2, 4, 5, 6 and 10. A mapping of the various intervention types and combinations to the VNOS-C questions is provided in Table 1.

NOS Concept Addressed in Survey	Intervention Type			
	Implicit Only	Explicit		
		DI	PSA	OIA
1. What is science? How is it different from other disciplines?		√		√
2. What is an experiment?			√	
3. Does the development of scientific knowledge require experimentation?			√	
4. Do scientific theories ever change?		√		√
5. Is there a difference between a scientific theory and a scientific law?		√		√
6. What evidence do scientists use to evaluate theories? (observation vs inference)		√	√	
7. What evidence do scientists use to determine what a species is?	√			
8. How are different conclusions possible when scientists have				√

access to the same data?				
9. Is science universal, or does it reflect social and political vales and assumptions?	√			
10. Do scientists use creativity and imagination during their investigations? If so, when?		√		

DI = Direct Instruction, PSA = imbedded in a Process Skills Activity, IA = imbedded in an Open-Inquiry Activity)

Table 1: V-NOS Questions versus Intervention Type

Results

Results of the VNOS-C surveys were coded using criteria developed for this study. The coding scheme had four levels, with a zero score representing no knowledge of the particular aspect of NOS, a 1 representing a naïve view, a 3 representing a well-developed or sophisticated view, and a 2 representing some identifiable position between 1 and 3. A blind analysis was assured by having the coding performed by a separate researcher who was unaware of whether the VNOS-C responses were from the pre-or post-test.

Coded results of the VNOS-C student responses indicate that students began the course with a wide range of understandings of NOS. Possible scores for each individual ranged from a low of 0 (no knowledge of any aspect of NOS) to a high of 30 (sophisticated understanding of all 10 areas of NOS addressed in the VNOS-C). Actual scores in the pre-test ranged from a low of 6 to a high of 23. Post-test scores ranged from a low of 16 to a high of 26. The pre-test mean individual score was 17.4. This rose to a score of 22.1 on the post-test. This increase was statistically significant ($p \leq .002$) using a t-test for independent samples.

Responses indicate that prior to the course many students held typical misconceptions regarding many aspects of NOS. For example: "I was always taught that scientific theories were proven fact and could not change." (S2.1); "A theory is something that is always being tested and updated. A law is when it has been tested many times and has been proven. It is the answer." (S8.1); and, scientists do not use imagine and creativity during their investigations, instead they, "...rely on empirical evidence and facts...." (S12.1). Post-test results show some development, with fewer instances of such misconceptions.

Sample student responses for VNOS-C items 1, 2, 4, 5, 6, and 10 are provided in Table 2. Student responses are identified as "Sn.1" or "Sn.2", where "n" represents the subject number (1-15) and ".1" identifies the response as coming from the pre-test and ".2 " as coming from the post-test.

Item 1	**What is science? How is it different from other disciplines?**
Naïve View (1)	Science is the study of how living and non-living things work...Science is different from religion and philosophy because science is based on fact, whereas religion and philosophy are based on belief. (S9.1)
Intermediate View (2)	To me, science incorporates everything within us and around us. It explains or attempts to explain how things work and how things exist. Science is knowledge. It is discovering, testing, and proving ideas. It is different from other subjects because it can be tested. It gives proof, whereas religion and philosophy usually provide factual explanations. (S14.2)
Developed View (3)	Science is a useful and necessary tool for understanding the world and the origin of things. Science relies on facts and empirical evidence to form conclusions, whereas religion and philosophy rely on faith and opinion. Science is most concerned with matter, how it works and exists. Religion and philosophy touch on things that science cannot, i.e. soul, spirit, God. (S12.1)
Item 2	**What is an experiment?**
Naïve View (1)	An experiment is a process to test a hypothesis (prove or disprove). The process can be repeated by following a particular sequence of instructions. (S7.1) An experiment is a course of action taken by a series of steps to find something out or prove a theory. (S11.1)
Intermediate View (2)	An experiment is a project that is conducted to answer a question. Usually there is a hypothesis, or educated guess, toward what the outcome would be. The experiment or

	process is then done to answer the hypothesis. Was the guess correct or incorrect? Usually conducted in controlled conditions. (S1.1)
Developed View (3)	An activity performed to answer a question. It is based on a theory. From the theory scientists conduct activity to make observations. Observations of activities lead to inferences...Theories are developed to expel existing theories, and new experiments are developed to dispute these. (S1.2)
Item 4	**After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?**
Naïve View (1)	I was always taught that scientific theories were proven fact and could not change. (S2.1) Scientific theories generally do not change because they have been tested so many times and received the same results. (S2.2) I would think that most theories don't change. Newton's laws and other famous theories are solid and reliable and can be tested and found true and correct. (S11.1)
Intermediate View (2)	Scientific theories change all the time as we gather more and more information about the world around us. This ever-increasing information is due in large part to our exponentially expanding technology. (S13.1) Theories are constantly changing and developing, as a theory can be tested and retested and have varying results. Theories are the best explanations that we have so far. (S11.2)
Developed View (3)	Yes. Scientists base theories and laws on current information or interpretation. New information can come along, new technology can be developed to see new things, and old information can be reinterpreted. The theory of _____is constantly changing with new discoveries and new interpretations. (S6.2)
Item 5	**Is there a difference between a scientific theory and a scientific law?**
Naïve View (1)	A theory is something that is always being tested and updated. A law is when it has been tested many times and has been proven. It is the answer. (S8.1)
Intermediate View (2)	A theory is why something happens and a law is what actually happens. The theory attempts to explain why and how something happens. A law is more factual because it is just saying what exactly something is. (S2.2)
Developed View (3)	A scientific theory explains something, or why it happens. A scientific law explains what happens. Evolutionary theory explains how humans evolved. The law of gravity tells us what happens, not why it happens. (S6.2)
Item 6	**What specific evidence do scientists use to determine what an atom looks like? (observation vs inference)**
Naïve View (1)	Scientists are sure about the structure of an atom now. They can actually look at an atom under a microscope and see the structure. The visualization is their proof. (S14.2)
Intermediate View (2)	I don't believe they are certain of what the structure of an atom looks like. I believe that they have theories about what an atom looks like. (S15.1)
Developed View (3)	Scientists are reasonably certain about atomic structure due to decades of research. I think that scientists have based their findings on indirect observations and experiments that seek to determine how atoms interact with other atoms and how they respond to positive and negative electrical charges, etc. I do believe atomic structure is...a best guess based on much hypothesizing, experimenting and inferring, but with no actual concrete first-hand observations of the actual protons, neutrons and electrons. (S13.1)
Item 10	**Do scientists use creativity and imagination during their investigations? If so, when?**
Naïve View (1)	Scientists rely on empirical evidence and facts in their investigations. (S12.1)
Intermediate View (2)	Yes. They use their imagination and creativity when planning and designing what they want to investigate. (S8.2)
Developed View (3)	Scientists use imagination and creativity during the planning and designing process, as well as in coming up with theories. Data collection should be straight forward, but may be creative—the same with conclusions...Trying out different theories and finding out what works. Imagining what things might look like, like atoms. (S6.1) ...and again, they use creativity and imagination in inferring what the data represents. (S6.2)

Table 2: Selected Student responses to VNOS-C Items

In order to determine the effectiveness of particular intervention types and to evaluate the criteria of explicit treatment of NOS provided by Lederman et al. (2001) Pre- and post-test coded results of VNOS-C items were compared using a t-test for independent samples. Pre-and post-test student results on individual VNOS-C items are shown in Table 3.

	Pre-test		Post-test			
Question	**Mean**	**Std. Deviation**	**Mean**	**Std. Deviation**	**t-value**	**Sig. (2-tailed)**
1	1.7333	.45774	2.4667	.74322	-3.254	.003**
2	2.2000	.67612	2.6000	.63246	-1.673	.105
3	1.6000	.63246	1.4000	.63246	.866	.344
4	2.4000	.73679	2.8667	.35187	-2.214	.039*
5	1.4667	.83381	2.4000	.63246	-3.454	.002**
6	1.3333	.81650	2.1333	.63994	-2.987	.006*
7	1.3333	.72375	1.6000	.73679	-1.000	.326
8	1.5333	.83381	2.0667	.96115	-1.623	.116
9	1.6667	.81650	2.0667	.79881	-1.356	.186
10	2.1333	.83381	2.4667	.51640	-1.316	.201

* = t-test is significant at the 0.05 level (2-tailed)
** = t-test is significant at the 0.01 level (2-tailed)

Table 3: T-test for independent sample for pre- and post-test of VNOS-C (n= 15)

VNOS-C items 1, 4, 5, and 6 showed significant improvement in student understanding of NOS as measured by the VNOS-C pre- and post-tests. These four items were also the only items whose treatment met the conditions established by Lederman et al (2001). Implicit interventions, as well as explicit interventions that included only direct instruction, or process skills activities, or open inquiry activities did not cause significant gains in students understanding of NOS as measured by the VNOS-C.

Discussion and Implications

While many questions and issues remain in this area, this study indicates that significant improvements in pre-service elementary teachers' views of NOS can be achieved as a result of the explicit treatment of NOS in elementary science methods classes. Whether this improvement contributes to improvements in elementary students' views of NOS is, of course, a separate issue that was not evaluated in this study.

The results of this study also support the position of Lederman et al. (2001) that improvements in NOS are generally not achieved through an implicit instructional approach but can be achieved if the desired changes are "intentionally planned for, taught, and assessed " (p. 137). Results of this study also support the suggestion that explicit interventions that, "intentionally draws learners' attention to relevant aspects of NOS through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples intended to improve students' conceptions of NOS" (Lederman et al., 2001, p. 137) can cause significant gains in understanding of NOS. While the Lederman et al. criteria makes pedagogical sense, it must be noted that the VNOS-C items meeting the Lederman et al. criteria in this study received multiple explicit treatments. Thus the experimental design does not allow us to determine if the improvements in students' views of NOS are a result of the specific types of treatments used or simply the amount of treatment.

Appendix 1: VNOS-C Questions

1. What, in your view, is science? What makes science (or a scientific discipline such as physics. biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?
   If yes, explain why. Give an example to defend your position.
   If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence **do you think** scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

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