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Exploring Impacts of the EED 420 Science Methods Course on Pre-service Elementary Teachers' Views Regarding the Nature of Science*

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Abstract

This study explores the impact of a semester-long science methods course examining pre-service elementary teachers' views on the nature of science (NOS). Also examined were NOS characteristics that pre-service teachers incorporated into their science lesson plans and peer teachings, during the course. Data used for this study were obtained from 21 pre-service teachers who participated in the pre/post card exchange game, pre/post VNOS interviews, 5E lesson plans, and peer teaching performances. The results of the study showed that some changes were made as a result of EED 420—such as starting to view science as a data-gathering experimental endeavor, rather than just a theory-driven endeavor. None of the groups explicitly designed or taught their lesson's NOS aspects. The study posits that a mere one semester-long science method's course is insufficient to adequately improve understanding of the NOS, and to establish a sufficiently robust desire in pre-service teachers for them to implement NOS into their lessons.

Keywords: Pre-Service Elementary Teachers, Nature of Science, Science Methods Course, Science as Inquiry, 5E Instructional Model.

Introduction

There has been an awareness among people in science education that a deeper understanding of the history and philosophy of science (HPS) would greatly contribute to improving the quality of science teaching and learning (Matthews, 1994; McComas, Clough, & Almazroa, 2000). Some go even further by positing that a deeper comprehension of the

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true meaning of the concepts of fact, law, theory, observation, and experimental process are imperative to a full enhancement of science teaching (Gardner, 1972; Hainsworth, 1956; Hodson, 1988; Rhodes & Schaible, 1989; Trusted, 1979). Along with this attention to HPS, science teachers have received considerable criticism for failing to possess adequate conceptions about the nature of science (NOS) itself, especially the tentativeness of scientific knowledge (Lederman, 1992). Specifically, pre-service elementary teachers tend to hold a positivist view of knowledge, a lens through which they perceive that science, as a body of empirical knowledge about the world around us, is absolute (Southerland & Gess-Newsome, 1999). This is a critical problem within the viewpoint of constructivist philosophy, and inclusive science teaching. The most fundamental assumption of constructivism is that learners come to the classroom with prior concepts, and teachers must identify these concepts, and construct new knowledge from such existing points (Hodson, 1988).

Some studies identify solutions to help teachers understand the NOS better by addressing it explicitly (Abd-El-Khalick & Lederman, 2000; Bell, Matkins, & Gansneder, 2011), by educating novice science teachers who have not yet constructed solid conceptual frameworks about science teaching (Brickhouse, 1990), and finally by exposing pre-service teachers exhaustively to the NOS in science methods courses (Abd-El-Khalick & Lederman, 2000; Southerland & Gess-Newsome, 1999). Therefore, the study has been designed from the outset to determine whether pre-service elementary teachers can adequately rectify their NOS concepts by taking an inquiry-based science methods course.

The study explored what changes the pre-service teachers made after engaging in a semester-long science methods course, in terms of their views of the NOS. Seven characteristics of the scientific views that the study used as a coding scheme were adopted from Abd-El-Khalick and Lederman's (2000) study:

> Scientific knowledge is: (a) tentative (subject to change); (b) empirically-based (based on and/or derived from observations of the natural world); (c) subjective (theory-laden); (d) partially based on human inference, imagination, and creativity; and (e) socially and culturally embedded. Two additional important aspects are the distinction between observation and inference, and the functions of, and relationship between scientific theories and laws (p. 1063).

The following three questions are the main foci of the study;

1. What views of science does EED 420 impart to pre-service elementary teachers?
2. As a result of EED 420, what changes have they made in terms of their NOS views?
3. What kinds of NOS characteristics did teachers incorporate into their lesson plans and peer teachings?

Methods

Participants

Twenty-one pre-service teachers, fifteen female and six male, who enrolled in EED 420: *Elementary Science Methods, Managements and Assessments*, at an accredited, state university, participated in this study. EED stands for Elementary Education Major, and the three digits, 420, followed by the letter prefix, is course number given assigned to this program of study which is available to senior level undergraduate students. All the participants in the elementary teacher education program were taking EED 420 as a required course, and were interning at their own placement schools as student teachers during the data collection period of this study. Their intern schools were varied from K-7.

Context

The science methods course. EED 420, in which the study was conducted, was an inquiry-based science method's course. The main emphasis of EED 420 rests on developing a community of active learners, and designing a student-centered and inquiry-based curriculum. Throughout the fifteen weeks of the course, eleven explicit—and implicit—NOS activities were implemented, in order for pre-service teachers to better understand the characteristics of the NOS views in play (See Table 1).

Among the activities, there were two long-term projects where participants observed seed germinations and the moon every day, while recording their observations as data. All participants were asked to abstain from looking at any references, so that they might obtain specific facts regarding the germination of seeds, or the phases of the moon during this project. Therefore, when they consolidated their data with others, they had to use their personally obtained data in order to answer the various questions generated. Most importantly, their answers could be either posited in either scientific or non-scientific terms, when they reported results to the class, and it was totally at the community's discretion to be satisfied or insufficiently satisfied with their findings—or to direct them to pursue more definitive evidence. The instructor personally did not deliver any facts or "right answers."

Table 1. *Overview of EED 420 and Data Gatherings*

Week	NOS Topics	Long-term Projects	General Agenda	Data Collection
W1	Inquiry Cubes Mystery Tubes		Intro to concept maps 5E model of instruction Concept map of history of physical science	VNOS The card exchange
W2	Buttons, leaves, & rocks Mystery Tracks (Observations & Inferences)		Direct, guided, and open inquiry Classification Advance Organizers	
W3	Best Paper Towel (Controlled investigation)		Inductive and deductive reasoning	
W4	Mystery Bones Fossils	Plant Log Seed Germination (Descriptive investigation) Light vs. Without light (Controlled investigation)	Standards Grouping Techniques Material management Misconceptions Safety rules Form a group for 5E lesson plan & Placement Teaching	
W5	Never Cry Wolf by Farley Mowat		Concept maps 5E model of instruction Aligning objectives & assessments	
W6	Science in Social & Personal perspective		Assessment techniques Questioning skills Talking science Modeling (Day and Night)	

Table 1 (Continue). *Overview of EED 420 and Data Gatherings*

Week	NOS Topics	Long-term Projects	General Agenda	Data Collection
W7	Multicultural aspect of science (Native Indian case study) Vee map--How to interpret data (plant logs)		5E model of instruction experience (Magnets) Lost on the moon	
W8	Exam 1			
W9	Spring Break	Moon Chart		
W10	Batteries & bulbs Hypothesis	Starting moon observation	Pictorial presentations Poster assessment (Circuits)	
W11	Galileo's Story Argumentation: Ptolemy vs. Copernicus			Lesson plan, observation notes
W12	How to interpret data (moon charts)		Vee map Moon Modeling	Lesson plan, observation notes
W13	Facts, Laws, & Theories (adhesive & cohesive) 10 Myths about science		Peer Teaching & Placement Teaching	VNOS The card exchange
W14	Presentation (placement teaching experience) Field trip (Mars Space Flight Facility Center on campus)			
W15	Exam 2			

The contents, such as *Day & Night,* and *Series and Parallel Circuits,* have been used for primarily utilitarian purposes. However, the participants were encouraged to investigate these more thoroughly after each concept had been introduced. Two activities on the NOS were explicitly presented to the participants. These included the multicultural aspects of science, including Native American worldviews, and the tentativeness of science as illustrated in Galileo's story. The instructor purposefully tried to focus pre-service teachers' attentions on specific NOS characteristics through these activities. With the remaining activities, the NOS was implicitly introduced—where all participants were directed to address certain characteristics of the NOS, but the instructor did not explicitly introduce what those were.

An example of the 5E instructional model: Batteries and Bulbs. 5E stands for Engage, Explore, Explain, Elaborate, and Evaluate. This model provided the pre-service elementary teachers a structure for the inquiry process during the EED 420 class. The 5E instructional model is also considered as one of the inquiry-based methods of instruction, in that it is consistent with the way people spontaneously construct knowledge (Bybee et al., 2006). For instance, when the topic of any given week was "batteries and bulbs," pre-service elementary teachers began talking about the flow of electricity, Ohm's law, types of circuits, etc. while they were modeling the five stages. Student interest and prior knowledge can be exposed by offering the brief theoretical dilemma below.

> Three campers had strayed deep into the woods, far from their campsite. Night had fallen, and they had no flashlight to find their way back in the darkness. However, one camper had a spare battery in his backpack, another had a flashlight bulb, and a third had a few pieces of copper wire. Unfortunately, they did not know how to connect the battery, bulb, and wire to light the bulb (Bass, Contant, & Carin, p. 99).

Pre-service elementary teachers will be given a core question, share some safety issues, and form collaborative learning roles (e.g. facilitator, recorder, reporter, materials manager, and time keeper). During the exploration stage, students are given time and materials to undergo a physical, hands-on experience to find ways in which to electrify/light a bulb, manipulate materials, make observations, and collect and analyze data—while the teacher acts as an observer, a guide, and a question-poser. Then, the students use the data they have gathered during the exploration to explain the idea, concept, or phenomenon they have been examining, using inductive reasoning, before the teacher helps the students learn about the core, and related scientific concepts about electricity. During the elaboration stage, the pre-service elementary teachers were asked to design a device that used a closed circuit with a switch. They were required to describe its name, use, and arrangement, make a diagram, and prepare a story to share their experience with the experiment. This is the stage where the teacher provides an opportunity for students to apply science concepts learned during the previous stages. During the last stage, the teacher uses performance-based assessments to evaluate student learning.

An example of the using the history of science. After pre-service elementary teachers completed their own moon observations over the semester, and learned about the relationship between the Sun, the Earth, and the Moon, using the 5E instructional model, they read the true-life story of Galileo Galilei's astonishing experiences from the book entitled *Galileo's Daughter* (Sobel, 2000). Then, they shared what they learned from these resources: the class constructing a short play, which was 5 to 7 minutes long.

The instructor provided a basic script, which pre-service elementary teachers could add to; or had them write their own complete script, depending on the grade level assigned to them as a group. Each group member had one of the following roles: director, writer (two), plot developer, costume artist (three), make-up artist, actor, or actress. They then presented their short play to the class, demonstrating the most intriguing part of Galileo's story.

Figure 1. Two classroom artifacts illustrating the engagement stage (left), and the elaboration stage (right).

Figure 2. A scene of the trial of Galileo played by pre-service elementary teachers.

After the entire experience, pre-service elementary teachers were involved in classroom discussions related to the aspects of NOS (e.g. How did he develop a spyglass based on knowledge established by other scientists? How did Galileo collect data and how did he use these data?)

Data/ Analysis

There are four types of qualitative data from the study, 1) pre and post card exchange game results, 2) pre and post answers from the VNOS questionnaire-Form B and C, 3) class room artifacts such as the 5E lesson plans, 4) and finally, observational notes of peer teachings.

During week 1, participants were asked to complete the card exchange game which was adopted from Cobern and Loving (1998). Three sets of cards (53 cards per set) were distributed to the class, and each person received about six or seven cards. They then started the card game as explained in Cobern and Loving's paper (1998). This activity had a two-fold impact. First, the pre-service elementary teachers were naturally guided to the HPS, and secondly they realized that each held different definitions about what science is—thus, they had to negotiate. They were asked to perform this activity again during week 13.

Second, the "View of the Nature of Science" questionnaire (VNOS), was administered both before and after the course. The questionnaire was adopted and modified from the VNOS form B (seven questions), and C (ten questions), (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). For the purpose of the study, only eight open-ended questions from these two forms were used. Finally, the aforementioned seven aspects of the NOS were assessed.

The researchers also collected the course artifacts—namely, the six groups' lesson plans and the field notes of six groups' peer teachings—in order to determine what aspects of the NOS had been implemented, either implicitly or explicitly (Abd-El-Khalick, Bell, & Lederman, 1998). Informal interviews were frequently conducted throughout the course by the researchers.

Results

The card exchange game

In order to answer the first question of the study, what views of science does EED 420 impart to pre-service elementary teachers? Changes were made as a result of EED 420. Most participants relinquished their previous views and theoretical emphasis, and moved mainly toward empirical emphasis. In short, the pre-service teachers initially perceived science as a rationalistic and theory-driven endeavor, then started to view science as a data gathering experimental endeavor in pursuit of physical evidence. Seven out of eight pre-service teachers who initially held a balanced view of science changed their views after the EED 420 course. Finally, only one pre-service teacher held a "cultural view" after the course.

Table 2. *The Results of the Card Exchange Game*

Categories	Pre (*N* = 21)	Post (*N* = 18)
Theoretical Emphasis: Science is primarily a rationalistic, theory-driven endeavor.	13	0
Empirical Emphasis: Science is primarily a data gathering experimental endeavor in pursuit of physical evidence.	0	16
Anti-Science View: Science is overrated. One should not give much credence to the aims, methods, or the results of science.	0	0
Scientism: Science is the way of knowing; it is the perfect discipline.	0	0
Cultural View: Science is embedded in a social, historical, and psychological context which affects all that goes on in science.	0	1
Balanced View: Science is a complicated affair that cannot easily be reduced to one or even a few simple descriptions.	8	1

The main categories and its definitions have been adopted from Cobern & Loving's study (1998, p. 76).

The Views of Nature of Science

The second question was to find out what changes were made after EED 420 in terms of the NOS. The study failed to find any conspicuous changes in the NOS. The following are the aspects where the majority held normative views of the NOS, the empirical nature of scientific knowledge, the nature of scientific theories, the subjectivity in science, and related social and cultural influences.

Although the pattern among these aspects was similar before and after EED 420, some aspects were normatively broadened, whereas some aspects were non-normatively skewed. None of them understood the relationship between "theories" and "laws" correctly. This was the aspect that showed prominent misconceptions, followed by a creative element in science. The following are the results of each NOS aspect (See Table 3).

Table 3. *Pre-service Elementary Teachers' Views of Nature of Science*

NOS Aspects	Pre (*N* = 21) %	Post (*N* = 18) %
Empirical nature of scientific knowledge		
Observations used to make scientific claims	71.43	82.35
Science does not rely solely on empirical evidence	4.76	0.00
Supports rather than proves scientific claims	4.76	5.88
n/a	14.29	11.76
Nature of scientific theories		
Theories change due to new evidence	95.24	58.82
Theories change due to new ways of looking at existing evidence	9.52	35.29
Theories do not change (naive NOS view)	0.00	5.88
Explanatory power of scientific theories	0.00	0.00
Scientific theories vs. laws		
Nonhierarchical relationship	4.76 (wM)*	5.88 (wM)*
Hierarchical relationship (naive NOS view)	9.52	23.53
Laws may change	0.00	5.88 (wM)*
Laws are proven and cannot change (naive NOS view)	76.19	64.71
n/a	4.76	0.00
Creativity in science		
Creativity permeates scientific processes	66.67(wM)*	52.94(wM)*
Inferential nature of science	0.00	5.88
No single scientific method	0.00	0.00
No creativity needed in science (naive NOS view)	9.52	0.00
n/a	4.76	5.88

Table 3 (Continue). *Pre-service Elementary Teachers' Views of Nature of Science*

NOS Aspects	Pre (*N* = 21) %	Post (*N* = 18) %
Subjectivity in science (theory-ladenness)		
Differences in data interpretation	95.24	94.12
Science is necessarily a mixture of objective and subjective components	4.76	0.00
Different environments offer different data (naive NOS view)	4.76	5.88
Social & Cultural influences		
Science as a cultural within itself	42.86	58.82
Peer review limits subjectivity	0.00	0.00
Society as an influence on science	14.29	5.88
Both (Universal & Social) and (naive NOS view)	9.52	17.65
Science is universal (naive NOS view)	19.05	11.76
n/a	14.29	5.88

The categories have been adopted and modified from the Lederman et al.'s study (2002, p.506).
* wM: with misconceptions.

Empirical Nature of Scientific Knowledge. Most of the participants held normative views of the NOS in this aspect; however, the only attention they gave included observations. Pre and post VNOS showed similar patterns.

Nature of Scientific Theories. Before EED 420, all pre-service teachers thought that theories changed due to new evidence or due to the development of technology. There was only one participant who indicated that changes could result from observations being made differently. However, after EED 420, five participants thought that theory could change simply by thinking about it differently. There was one pre-service teacher who thought that theory did not change. However, that teacher failed to provide normative rationales for her assertion.

Linda: Yes, even though theories have data and evidence to support them, they can change as we discover new ideas, things, and thoughts (pre-VNOS).

Linda: Yes, so others can either develop the theories further or think of a new theory to discredit or change the other theory (post-VNOS).

Scientific theories vs. laws. There were conspicuous misconceptions surrounding the relationships between theories and laws. None of the teachers articulated this aspect of the NOS correctly. Although, some pre-service teachers thought that theories and laws were nonhierarchical, and that laws may change, their rationales were all non-normative.

Anne: Yes, there is a difference. Scientific theory is like a "best guess." For example, a theory can change with new discoveries. A scientific law is what we use to create theories. We may use many laws to create a theory (pre-VNOS).

Anne: Yes, a theory is something proven and always the same. Scientific laws can vary in the outcome (post-VNOS).

Creativity & Inference in Science. Most of the pre-service science teachers indicated that creativity permeates scientific processes. However, some of them limited the use of creativity to during and after the data collection period during experiments, or to certain fields of science, such as astronomy. This misconception increased after the course. Two pre-service teachers who thought that there was no creativity needed in science, changed their views of the NOS to those classified as "normative" after EED 420.

Katie: Yes, scientists use creativity and imagination during and after data collection...They must think about new ways to research and seek understanding (pre-VNOS).

Sam: I feel that after the experiments/observations are complete, there is not much more room for creativity, because the investigation either proves or disproves the theory it is testing. So, there is little left to the imagination (pre-VNOS).

Sam: Yes, they use creativity and imagination, because if they didn't, then we wouldn't have theories and laws today (post-VNOS).

Subjectivity in Science (theory-ladenness). The majority of the pre-service elementary teachers held normative views of the NOS, in terms of its theory-ladenness before and after the course. They thought that each scientist had a different opinion about the meaning of the data.

Social & Cultural Influences. Approximately over half of the participants espoused the social and cultural aspects of the NOS. Some thought that there was a universal science, while some believed that both universal and socially and/or culturally influenced sciences could exist at the same time.

Dale: I believe both to be true. There are those universal theories that cannot be affected by society. Then there are others that are clearly affected by society and culture (pre-VNOS).

Ellen: I believe that science is universal. Nature does not change according to social and cultural values, but the people might. For example, a flower grows in one place, just like it would in another place. The only difference is the way people interpret science (pre-VNOS).

Sam: I believe science is universal because all cultures have some kind of scientific knowledge and belief. Science is known throughout the world, and is not limited to one culture (post-VNOS).

Finally, the study analyzed the teachers' lesson plans and peer-teaching observation field notes, in order to answer the third question: "What kinds of NOS characteristics did teachers incorporate into their lesson plans and peer teachings?" Evidence from the lesson plans and field notes identified that none of the groups explicitly designed or taught their lessons. Although their peer teachings mostly demonstrated either directed or guided inquiry, the aforementioned seven aspects were barely implemented into observed lesson plans and instructions. However, creativity in science and the empirical nature of science were implicitly found in two peer teachings. Furthermore, all of the lessons and peer teachings placed a disproportionate emphasis on scientific process skills.

Conclusions

The study found three important messages by using extensive qualitative data. First, as a result of the two long-term projects in which the pre-service elementary teachers kept plant and moon-phase logs over a one-month period, their views were moved toward empirical emphasis. Science was defined as a data gathering process, an experimental endeavor in pursuit of physical evidence. The two long-term projects were designed to implicitly impart the empirical nature of science. Pre-service teachers were able to unpack related NOS elements through these activities. This is an unusual finding, since explicitly taught NOS was previously found to be effective (Abd-El-Khalick & Lederman, 2000). The study asserts that if implicitly designed activities were exposed to learners for a sufficiently long period of time, they can be effective in teaching NOS aspects.

However, having two explicit activities and nine implicit activities, including the aforementioned long-term projects, did not result in any conspicuous differences between groups. Although some progress was found, evidence showed that there was scarcely any impact of EED 420 on enhancing the understandings of NOS for the pre-service elementary teachers. Surprisingly, none of them adequately understood the normative aspects about the relationship between theories and laws and furthermore, demonstrated significant *misconceptions* as well. This finding is similar to those of Abell, Martini, and George (2001). They explored pre-service elementary teachers who were involved in the moon-phase observations for six weeks, while they were exposed to explicit NOS teaching activities. They found that such long-term activities provided opportunities for teachers to understand that scientific knowledge is empirically based and socially embedded. Yet, they failed to find evidence of pre-service teachers being aware of the fact that scientists are also involved in the conception and innovation of theories.

The results of the study also urge teacher educators to constantly reflect upon the aspects of their curricula that address reform-based science. The study also suggests that teacher educators should establish frameworks for their science education curricula that include the following elements; 1) teaching science through inquiry practices, 2) a variety of authentic assessments, 3) the social context of science *teaching* and 4) the social context of the *science* itself (Abell, Martini, & George, 2001). It should be mentioned that Riedinger, Marbach-Ad, McGinnis, Hestness, and Pease (2011) also suggested that the inclusion of innovative informal science activities within the science methods curriculum helped pre-service elementary teachers understand the normative views of science.

Upon exploring the areas where the pre-service elementary teachers were implementing the NOS concepts, the study failed to identify any lesson plans or peer teachings that espoused NOS elements explicitly. However, creativity in science and the empirical nature of science were found in two peer teachings. Therefore, the results of this study reinforce the findings of other studies that conclude that a single semester-long science methods course will not adequately improve teachers' understanding of the NOS. Furthermore, a single course failed to impart a sufficiently robust desire within teachers for them to adequately implement elements of the NOS into their lessons.

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