INTEGRATION OF NOS INSTRUCTION INTO A PHYSICAL SCIENCE CONTENT COURSE FOR ELEMENTARY TEACHERS: ENHANCING EFFORTS OF TEACHER EDUCATION PROGRAMS?

Abstract:This study investigated the effectiveness of integrating explicit-and-reflective NOS instruction into a physics course for pre-service elementary teachers. Reflective discussions, student scenarios, and content-generic NOS activities were incorporated into both lecture and laboratory components of the course. The VNOS-C was used to assess students' views of NOS prior to and upon completion of the course. Significant and favorable changes in students' views were evident for all the aspects of NOS emphasized, however there were also negative shifts in views apparent in students' views of the socio-cultural embeddedness of science. While positive changes in NOS views resulted from the explicit-and-reflective interventions, there is also evidence that implicit messages about NOS played a role in the development of students' ideas. The results of this study suggest that content courses may be a productive venue for improving preservice teachers' views of NOS.

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Introduction

Understanding the nature of science (NOS) or the values and assumptions inherent in the construction of scientific knowledge (Lederman, 1992) has been promoted in numerous reforms including Science for All Americans (AAAS, 1990), Benchmarks for Science Literacy (AAAS, 1993), and the National Science Education Standards (NRC, 1996). This goal is consistent with recommendations for the teaching of science as inquiry. According to the Standards, inquiry refers to "…the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NRC, 1996, p 23). Scientific literacy, then, is not merely comprised of understanding the facts, concepts, or theories of science, but also understanding both NOS and scientific inquiry. A challenge in meeting the vision of these reforms throughout the past several decades, however, has been that teachers themselves lack understandings consistent with contemporary views of inquiry and the nature of science (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Lederman, 1992).

In order to achieve the goal of scientific literacy outlined in the reforms by helping their students come to understand inquiry the nature of science, teachers must first understand these concpepts themselves. Over the past decade, improving teachers' understandings of NOS has been a focus of science teacher education. Recent work shows that an explicit-and-reflective approach (see Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson & Hanuscin, 2003; Schwartz & Crawford, 2003) has met with some degree of success in helping teachers (both inservice and preservice) develop appropriate conceptions of NOS. Reflective approaches provide structured and guided opportunities for learners to examine and discern discrepancies between their NOS conceptions and those presented to them, clarify the presented NOS ideas and framework for themselves, and reflect on how specific aspects of NOS are illustrated by the curricular activities in which they participate through discussion and/or reflective journaling (see, for example, Abd-El-Khalick, 2001). However, many efforts to improve teachers' conceptions of NOS have met with only limited success in helping teachers retain views of NOS that are consistent with current reforms (see, for example, Abd-El-Khalick, Bell, & Lederman, 1998). This may be, in part, due to a lack of emphasis on NOS across preservice teachers' college preparation.

Abd-El-Khalick & Lederman (2000) propose that efforts undertaken within teacher education programs to enhance teachers' conceptions of NOS can be further enhanced by relevant coursework in other academic departments and programs, such as history of science or science content courses. Following this recommendation, the researchers investigated the effectiveness of integrating explicit-and-reflective NOS instruction into the curriculum of a physical science content course for preservice elementary teachers. The course included a laboratory component, and thus efforts to integrate NOS into the course depended, in part, on the lab instructors' ability to effectively teach NOS to their students. As such, all laboratory instructors received professional development intended to address their NOS understandings and abilities to teach NOS (see Hanuscin, Phillipson-Mower, & Akerson, 2004). The purpose of this study was to assess the impact of explicit-and-reflective interventions undertaken in both the lecture and laboratory components of the course on preservice teachers' understandings of NOS. The specific research questions were:

1) What changes occur in preservice teachers' understandings of the nature of science over the course of the semester?
2) In what ways are these changes related to the course interventions undertaken in laboratory and lecture components of the course?

Method

<u>Context of the Study and Participants</u>

"Physical Science for Elementary Teachers" is the second-largest enrollment course offered by the department of physics at a large Midwestern university. The course serves as a prerequisite for the elementary science methods course, and consists of two 50-minute lectures each week, as well as a weekly 3-hour laboratory session. The first author served as the instructor of record for the course, and was responsible for the overall design of course, including the lectures and laboratory activities. All students enrolled in the course attended lecture as a single section, while enrollment in each of the laboratory sections was limited to 18 students. Each of the eleven laboratory sessions were taught by a different undergraduate teaching assistant (UTA). All UTAs received explicit-and-reflective NOS instruction during their training, to prepare them to lead NOS activities and discussions within their laboratory sessions. This training, and the impact on UTAs' views of NOS, is described elsewhere (Hanuscin, Phillipson-Mower, & Akerson, 2004).

In the semester this study was conducted, 183 students were enrolled in the course. These elementary education majors were mostly female (94%), mostly white (96%), and just beginning their professional preparation programs in the school of education. The majority (59%) were sophomores, while 32% were juniors, and 8% were seniors. Most students (54%) lacked any previous coursework in physics, while 44% indicated they had taken a high school physics course, and only 2% had any previous coursework in physics at the college level. These percentages are not particularly surprising, given it has been found elementary teachers generally do not have a solid understanding of science content, exhibiting misconceptions in physical science in particular (Lawrenz, 1986; Smith & Neale, 1989). With this information in mind, the course is designed to provide a conceptual foundation on a variety of topics commonly found in elementary science curricula (e.g. sound, light and color, electrical circuits, magnetism), while modeling inquiry-based pedagogy. The laboratory utilizes commonly found materials that would be expected to be available in an elementary classroom, rather than more expensive laboratory equipment, in the hopes that these activities would be viewed as conceivable for use with elementary students by the preservice teachers.

135 (73%) of the students enrolled in the course consented to participate in our study. Statistical analyses indicated this sample to be representative of the population in terms of academic performance and student background (see Table 1). Student academic performance was analyzed using eight sources of assessment that provided grades for the course: attendance, three exams, a project, homework average, laboratory grade and a final exam. The calculated z values for the averages in 6 of the 8 criteria show no significant statistical difference with the values of the population and those of the sample. Nevertheless a difference existed in terms of course attendance. This is reflected by the significant results for this criterion, where the grade was awarded in terms of presence in class ($z = 0.275$, $p = 0.001$). The other criterion where significant statistical difference between the sample and population was found was in the homework grades ($z = 0.254$, $p = 0.003$). In terms of student background, three general aspects were taken into consideration: previous physics coursework, year in university, and previous university science and education coursework. The χ^2 values obtained for the distributions showed no significant difference between sample and population, as illustrated in Table 2.

The Intervention

Aspects of NOS Emphasized

Because NOS remains such a highly contentious topic among scientists, historians, sociologists, and philosophers, the generalized and non-controversial aspects of NOS emphasized in the reforms were selected to avoid "paralysis of practical action" (Rudolph, 2000). Arguably, much of the debate within these communities is beyond the level of basic scientific literacy of concern in K12 classrooms (Matthews, 1998; Smith & Scharmann, 1999). As future K12 teachers, our students would be expected to teach the aspects of NOS emphasized by reforms to their students. These aspects include (a) scientific knowledge is both durable (one can have confidence in scientific knowledge) and tentative (subject to change); (b) no single, universal scientific method captures the complexity and diversity of scientific investigations; (c) creativity plays a role in the development of scientific knowledge; (d) there is a relationship between theories and laws; (e) there is a relationship between observations and inferences; (f) though science strives for objectivity, there is always an element of subjectivity in the development of scientific knowledge; and (g) social and cultural context also play a role in the development of scientific knowledge.

Integration of NOS into the Lecture

During lecture sessions, preservice teachers were introduced to the aforementioned aspects of NOS as a framework for reflecting upon the course material and laboratory activities. Students responded to a number of conceptual and reflective prompts and participated in small group discussions ("Think, Pair, Share"). For example, in one lecture session, students responded to the following:

> *Give an example of both a theory and a law that we have discussed in class. What kinds of information do laws provide? Theories?*

The instructor utilized students' written responses as starting points for subsequent class sessions, tailoring the discussion to address students' misconceptions. For example, selected responses would be posted for discussion and debate in the following class session:

> *Given the theories and laws you've examined, what do you make of the following statement? "Theories, once they are proven, become laws."*

Such student responses from lecture discussions were shared with lab instructors during weekly planning meetings, in order to assist them in effectively addressing these misconceptions within their sessions. By making them aware of the range of student ideas, UTAs were better able to anticipate points of difficulty students may have with specific laboratory activities, and to devise lines of questioning to pursue (see below).

Integration of NOS into the Laboratory

In order to integrate NOS instruction into the course, it was necessary that activities themselves accurately reflect NOS. Materials created by the previous instructor were adapted to be more inquiry-based, following the recommendations of Colburn (1997). Several of the more traditional verification or "cookbook" laboratory activities were revised to be more open-ended, providing the question for the investigation, but allowing the student to determine the necessary materials, procedures, and evidence necessary to answer the question.

Throughout the laboratory manuals, a series of "check-outs" were indicated at key points in the activities. These formative assessments provided instructors an opportunity to guide students in explaining their reasoning and reflecting on the activities they completed. As such, these also provided an opportunity to highlight specific NOS aspects. As a team, UTAs worked to develop lines of questioning for each specific "check-out" in the laboratory.

During some "check-outs", preservice elementary teachers were asked to respond to student scenarios which consisted of fictitious student dialogue related to an aspect of NOS, written by the course instructor. For example, after students completed several laboratory experiences related to light, reflection, and optical illusions, they were asked to respond to the following:

> Student #1: *Science is all about observations and facts. You shouldn't bring your personal bias into doing science. As a scientist, you have to be objective.*
>
> Student #2: *I disagree; even our observations are influenced by our perceptions and bias. There is no way to be completely objective.*
>
> ✓With which, if either, student do you agree? Discuss this as a group, and then contact your lab instructor for a check-out.

The discussion that followed this particular scenario was intended to elicit students' views of the subjective nature of scientific knowledge and to confront students' belief in objectivity and science as "truth."

In addition to student scenarios, open-ended questions were included at the end of each investigation to challenge students to defend their answers and explain their reasoning. These questions were intended to assist students in establishing a link between the targeted NOS ideas and the activities of the laboratory session, and were assessed by the UTAs as part of the laboratory report. For example, after investigating the law of reflection, students were asked to explain what a scientific law was, and to defend their ideas with examples.

Finally, several activities (e.g., “Tricky Tracks”, “Do you see the cow?”), were integrated into the laboratory. These content-generic activities were designed both to sensitize students to various NOS aspects and provide a basis for discussing and interpreting lab activities in the context of NOS, and have been used elsewhere with success (see McComas, 1998). Lab instructors themselves participated in these activities during weekly meetings, as the course instructor (first author) modeled and discussed ways to use these to engage students in the activities and facilitate small-group and whole-group discussions.

Sources of Data & Analysis

To answer the first research question, changes in preservice teachers’ NOS views were assessed through pre and post-semester administration of the *Views of Nature of Science Questionnaire* (VNOS-C) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Follow-up interviews were conducted 15% of the sample, following recommendations of Lederman and O’Malley (1990). The purpose of these interviews was to clarify ambiguities, assess meaning respondents ascribed to specific terms and phrases, and explore respondents’ lines of thinking.

VNOS data were analyzed using the aspects of NOS emphasized in the reforms and taught in the course as a general framework. Following a round of initial coding, views relevant to each of the targeted NOS aspects were categorized as being (1) *consistent* with reforms (across all items), (2) *transitional* (inconsistent across items or having elements both consistent and inconsistent with reforms), or (3) *inconsistent* with reforms. Definitions of each category and representative responses appear in Tables 3, 4, and 5. The researchers conducted independent analyses of the data, and met to compare analyses. Points of disagreement were resolved through further consultation of the data, consensus, and revision of the coding schema. The final coding schema was validated through comparison of separate analyses of participants’ questionnaire and interview data. A high degree of correspondence between the two analyses established the validity of inferences drawn from questionnaires, and provided a basis for analyzing the remaining questionnaire data, for which there were no associated interviews.

Next, each researcher conducted independent analyses of the remaining questionnaire data and inter-rater reliability was established by noting degree of correspondence. Analyses were used to generate profiles of each participant’s NOS views. Individuals’ pre- and post-semester profiles were compared to note shifts in views. The data were then aggregated to identify patterns of change in the entire sample. For example, given our categories, respondents’ views may have remained the same or changed in a number of ways either toward consistency with reforms or inconsistency with reforms. Such changes in views were compared using the Stewart-Maxwell statistic for dependent samples, where the change is considered in terms of the differences between rows and columns of a 3x3 contingency table. The χ^2 statistic calculated determines the significance of the change observed.

To answer the second research question, multiple data sources were sought. NOS interventions were documented through several means. The instructor kept artifacts (course materials, handouts, lecture notes, etc.) related to the planned interventions, and a reflective journal noting how she addressed NOS within lectures. Weekly meetings with UTAs, during which NOS aspects were introduced and discussed in the context of each lab, were audiotaped and transcribed for analysis. Laboratory sessions were observed by the researcher/instructor on four separate occasions during the semester. Two of these sessions featured content-generic NOS activities led by the instructors, while two did not feature these activities. The selection of sessions for observation was intentional, in order to determine whether and how NOS was being addressed outside of these pre-planned activities. Finally, interviews were held with each instructor to debrief the semester and reflect on their instruction.

Transcripts, field notes, and other artifacts were first analyzed using open coding. Next, codes were organized into categories and used to identify major themes and patterns across cases and among all data. This analysis served as a lens through which changes in preservice teachers' NOS views could be interpreted. Again, NOS aspects outlined in the reforms served as a framework throughout this process, given the goal of instruction was for students to understand these particular aspects of NOS.

Findings

Changes in Preservice Teachers' Views of NOS

Students' initial views of NOS, summarized in Table 6, varied in terms of consistency with the reforms. In the class as a whole, changes in respondents' views were observed post-semester in all the aspects of NOS investigated. The majority of changes were toward views of NOS consistent with the reforms, however cases were observed in which students views initially were consistent with reforms, but shifted towards inconsistency with reforms over the course of the semester. Changes from one categorization to another are summarized in Table 7, and discussed aspect by aspect in the sections that follow.

Regarding the tentative nature of science we observed a significant shift toward the notions presented in the reforms, with 24% of students changing in this direction (32% change of those not already in accordance with the reforms), with the largest change coming from the group of students whose views had been initially considered transitional. For example, a student in this group may have initially views scientific knowledge, with the exception of laws, as subject to change, but by the end of semester recognized that all scientific knowledge could potentially change with new evidence, including laws. 26 students made such changes in views over the semester ($\chi^2 = 30.73$, $p \ll 0.001$).

With respect to the creative nature of science, 50% of the students whose views were not initially in accordance with reforms changed their views, recognizing creativity and imagination as vital parts of science in their post-semester responses. It is worth noting that most of the students (64%) already presented views consistent with reforms ($\chi^2 = 14.7$, $p \ll 0.001$).

In the case of the socio-cultural aspect of NOS, post-semester responses represented shifts both towards views consistent with reforms and those inconsistent with them. 29% of respondents who initially viewed science as universal acknowledged the socio-cultural embeddedness of science in post-semester responses. However, a number of students (13%) changed their initial view of science as being reflective of socio-cultural norms to a view that science was universal. It is worth noting that the change in views in this aspect of NOS by students who initially held transitional views was almost evenly split in both directions (18% differing from reforms and 20% in agreement with reforms). When both those students who held transitional views and views inconsistent with reforms are considered, 38% of this group changed in a direction toward views consistent with reform characterizations of the socio-cultural embeddedness of science ($\chi^2 = 6.63$, $p = 0.036$).

Regarding their views on subjectivity in science, students who changed their initial position almost entirely moved in the direction of reforms with 44% of those initially holding views inconsistent with reform (viewing science as objective) recognizing subjectivity as inherent in the construction of scientific knowledge ($\chi^2 = 36.98$, $p \ll 0.001$).

When addressing their views on the definition and relationships between theory and law, students views of this aspect of NOS showed a significant shift towards consistency with the reforms with 48% (47% overall) of the students showing evidence of this change ($\chi^2 = 55.49$, $p \ll 0.001$). Many of these students initially believed in a hierarchal status of theory and law, but contradicted this idea in their post-semester responses.

Initially, only 12% of participants acknowledged that science relies on both direct evidence (observation) and indirect evidence (inference). Many held a view that "seeing is believing." In post-semester responses, 52% of the students that had, initially, presented views not consistent with reforms showed a positive change in this aspect ($\chi^2 = 53.75$, $p \ll 0.001$).

With respect to the empirical NOS, the majority of students (67%) initially showed evidence of views consistent with reforms. These students recognized that science relies on evidence that is testable against the natural world. In post semester responses, 36% of students whose views were not initially consistent with reforms were able to explicate the empirical nature of science ($\chi^2 = 16.00$, $p \ll 0.001$).

Finally when discussing the methods of science two observations are worth noting: most of the students (70%) held views inconsistent with reform and of these only 16% actually changed their views in a direction that could be considered consistent with reform ($\chi^2 = 12.26$, $p = 0.002$). The majority of students in the course viewed experiments as the sole means through which scientific knowledge advances. These students did not recognize that science relies on a variety of methods including observational studies and collection of specimens.

<u>Factors Influence Changes in Students' Views</u>

Overall, changes in preservice teachers' views of NOS were consistent with the relative emphasis given to each aspect of NOS in both lecture and laboratory components of the course. For example, the three aspects most heavily emphasized were the function and relation of theory and law, the subjective nature of science, and the reliance on observation and inference. The percent of students making positive shifts towards views of these aspects consistent with reforms was greater than that for other aspects.

Consistent with previous studies, the explicit-and-reflective attention to NOS promoted positive shifts toward views consistent with reforms. In post-semester responses to the VNOS-C, students directly attributed changes in their views to discussions in lecture and laboratory:

> *I feel I have a much better understanding about law and theory from in class lectures where we were given scenarios and asked to think about it.*

> *Initially I wasn't sure about the difference in [theory and law] but lecture has helped a lot to try to pinpoint what these two really mean.*

> *Discussions in lecture and in lab with [the lab instructor] were very helpful. Before this class, I believed that theories were one person (or group of peoples') opinion and was not necessarily supported with evidence, etc.*

> *My answer has tremendously changed because of different discussions we've had in lecture and lab.*

Similarly, students referred to the content-generic NOS activities used in the laboratory, such as the "Tricky Tracks," as helpful in changing their ideas:

> *In lab once we looked at a foot prints. That's what I thought; others thought the prints might have been ducks, dinosaurs, and many more. This is why we have different theories people have different perspectives in observations they've made, that is why we have so many different theories about one happening.*

> *I believe that theories can change through new scientific knowledge and data. The activity in lab where you had to make observations and inferences about the "tracks" on the overhead—This activity made you re-evaluate your initial thoughts, observations and inferences about the picture when more of the picture was revealed.*

Additionally, students related their own laboratory investigations to their NOS ideas, an indication that revisions intended to make activities more consistent with NOS were effective.

> *Yes [scientists use their creativity and imagination]. They have to create their experiments. They have to come up with ways to test their hypothesis. We had to do that a couple of times in lab. Each lab group came up with something different, but they were all effective ways of testing whatever it was that we were testing. They get to use their creativity in the planning and design and the conclusions.*

> *I believe that scientists use imagination and creativity when planning and designing an experiment, because they first need to think of how they can test or research their idea. Interpreting the experiment might require the scientist to think about what his observations mean, which may require some creativity. When conducting my own experiments in lab I used the same approach.*

Yet, while students such as those quoted above indicated such instruction was "helpful"; others were only "more confused" as a result of the explicit-and-reflective interventions:

> *As much as we have gone over this concept in lab and lecture it is still a difficult one and I don't always grasp the difference.*

> *We have talked about this topic a lot throughout the course and for some reason I still seemed to be a little confused by it.*

> *I think that there are things that are similar in theories and laws. Personally I'm more confused about the differences now then I was when I came to this class.*

Such statements provide evidence that course interventions produced cognitive dissonance, which is necessary for conceptual change to occur; however, they were not sufficient provide these students with a means to resolve their confusion. The importance of students' prior knowledge in this process, and indeed, their experiences in previous courses, may in part explain this difficulty:

> *There is a difference between a theory and a law. I am still a little confused though because each class that I have taken approaches it in a different way.*

Despite efforts of the instructors to provide explicit-and-reflective instruction about NOS, there is evidence that implicit messages about NOS were also of importance in shaping students' ideas, specifically with regard to the socio-cultural embeddedness of science. Students inferred from the presentation of science content that such content was universal, as demonstrated in the responses below:

> *It seems like in this class science is universal.*

> *I believe that science is universal. Take the law of reflection, this law is the same here as it is over in Europe or Asia.*

> *I believe that science is universal. A lot of science is based on not what you feel but what you actually observe and what you can see happen with your own two eyes. This is not going to be different from person to person. Everyone will see the same thing happen. For example, it is very easy to see what magnets will attract to one another and which ones will not attract. This not based on what you feel at all, it can simply be viewed by putting 2 magnets together.*

In this way, students' experiences learning science content were similar to their previous experiences in science courses:

> *I think science is more universal. It's the way I have always been taught about science that it's more a subject that is going to produce an end result like math. I always do science and math together. And especially after taking [this course], it really did not touch at all on anything but science being universal. It was more of a 'this is what happened this is the conclusion for this' and in lab we did things in lab on how to prove those things. To show how those things do occur. So didn't really touch on anything but science being a universal thing that all of us can see.*

> *I think that Science is universal. I can't think of anything I have studied in my years of science classes that I have felt was influenced by social and cultural values. In fact in middle school remember when we were studying the coming of the Earth there was a lot of controversy because my teacher was willing to explore all the different theories.*

Yet, there is evidence that at least one student was able to see beyond her experiences learning in class to consider the broader context of science:

> *I still would like to think that science would be universal but I don't think it always is. I think that science can still reflect social and cultural values, although I didn't see it in our class really. I really don't know how to explain but I do think that science is not always universal but instead reflects the people investigating it.*

Hogan (2000) differentiates between such NOS understandings as being *proximal* (related to students' school science experiences) and *distal* (relating to the context of science in society).

Changes in students' NOS views also appear to be reflective of the extent to which the course UTAs' held views of NOS consistent with the reforms. For example, as reported in Hanuscin et al. (2004), UTAs did not explicate views of the methods of science consistent with reforms. Instead, and much like the preservice teachers enrolled in the course, the majority viewed experiments as the sole means through which scientific knowledge could advance. It stands to reason that without accurate views of this aspect of NOS, UTAs would be unable to assist preservice teachers in understanding the multiple means through which scientists investigate their questions. Indeed, students' views of this particular aspect of NOS changed very little over the course of the semester. In contrast, all but one of the UTAs improved their views of the function and relation of theory and law through professional development (Hanuscin et al., 2004), explicating ideas more consistent with reforms. For this particular aspect of NOS, preservice teachers' views improved significantly. UTAs' views of the function and relation of theory and law could be considered a necessary, but not sufficient condition, for teaching NOS effectively to students. Indeed, there is some evidence not all UTAs were equally successful in promoting views of NOS consistent with the efforts of the course instructor:

> *Honestly, I know we studied this topic but I never felt that I totally understood the difference between [theory and law]. I feel this subject was approached but unclearly answered in [class]. I found myself especially confused in lab because it seemed that I was learning one definition in lecture and another in lab and no one had an exact answer for my questions.*

Observations of laboratory session revealed that laboratory instructors differed greatly in both the time and emphasis given to NOS. Instructors, in general, were observed to implement content-generic activities much as they were modeled by the course instructor during staff meetings, with several of the laboratory instructors who were physics majors drawing upon examples from history of science and their own research experiences to extend the discussion with their students. However, few lab instructors capitalized on opportunities to discuss NOS with students outside the context of these activities. Questions relating to NOS asked during check-out formative assessment points in the laboratory were limited to those explicitly provided by the course instructor in written handouts for each lab. Instructors who expressed a comfort level at leading class discussions were observed to engage students in extended discourse about NOS more readily than those who expressed anxiety about teaching. While preliminary analysis indicates that UTAs' views may play a significant role in the development of preservice teachers' views of NOS, further analysis of the data is needed to determine the degree to which these differences in instruction may be related to any differences between the improvements in NOS views occurring within each laboratory section.

Discussion and Implications

The results of this study demonstrate that explicit and reflective interventions, when undertaken in both lecture and lab components of the course, produce favorable changes in NOS views. These findings are consistent with studies examining the use of explicit and reflective instruction in other course contexts, such as science methods courses (e.g., Akerson, et al., 2000), and lend support to the effectiveness of such means in improving teachers' views of NOS. It would appear, however, that both implicit and explicit messages about NOS, however, are of important to the development of students views' of NOS, as evident in changes in students' views regarding beliefs of science being universal vs. influenced by socio-cultural norms. Despite explicitly-communicated NOS messages, students drew inferences about the universality of science based on the way in which they were taught and assessed on their understandings of science in terms of a common body of knowledge. With this in mind, future research should consider NOS messages communicated through both means, and their influence on student learning outcomes. Hogan's (2000) differentiation between proximal and distal understandings of NOS may provide a useful framework for assisting students in reconciling such differences between the context in which they learn science (school science) and the context in which professional scientists develop scientific knowledge (authentic science).

Despite the favorable changes produced within the constraints of the course structure the findings would imply, however, that efforts to improve teachers' views of NOS, are not simply a manner of the instructional approach. Course context and structure must also be taken into account. Unlike previous studies, in which smaller courses with a single instructor provided the context, this study utilized a large-enrollment course with different instructors for both lecture and laboratory components. Such courses pose a special challenge in promoting consistent NOS messages by multiple instructors, as evidenced by student comments regarding conflicting information presented in both lecture and lab. As emphasized in Hanuscin et al. (2000), the NOS views of all instructors must be taken into account. Furthermore, the large-group setting may limit the instructors' ability to address individual students' ideas and questions effectively- particularly those students holding transitional views attempting to resolve cognitive dissonance.

Finally, it should be emphasized that the focus of this study was limited to the context of a single course within preservice teachers' program of study. Further research is needed to assess the impact of this course in terms of retention of changes in students' NOS views. Additionally, studies should be conducted to examine the ways in which instruction in context of science courses influences students' NOS learning in their later teacher education coursework, including methods courses. Through this, the extent to which NOS instruction in the context of science content courses enhance the efforts of teacher education programs can be more accurately assessed.

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Table 1. Z-test of student academic variables related to the course

Criterion	Population		Sample		z
	Avg P.	StdDev	Avg S.	StdDev	
Attendance	115.11	20.25	119.23	14.98	0.275*
Exam 1	77.40	13.92	78.00	13.56	0.044
Exam 2	68.80	13.22	69.59	13.37	0.059
Exam 3	77.13	10.69	78.13	10.79	0.092
Final	78.49	12.70	79.42	12.02	0.077
Homework	87.41	10.86	89.37	7.74	0.254*
Lab	86.44	7.03	87.09	5.76	0.113
Mobile Project	89.35	10.60	90.31	7.93	0.121

* $p < 0.01$

Table 2. Chi-square analysis of student background variables

Year in College	Population	Sample
Freshman	1.09%	1.52%
Sophomore	60.66%	62.88%
Junior	32.24%	31.06%
Senior	6.01%	4.54%
$\chi 2$	0.645	

Previous Physics Courses	Population	Sample
None	31.68%	32.58%
Middle School	20.22%	19.70%
High School	43.17%	43.94%
Advanced Placement	0.55%	0.76%
College	2.19%	2.26%
No answer	2.19%	0.76%
$\chi 2$	1.067	

Required Science Education Courses	Population	Sample
Introduction to Inquiry	71.04%	72.72%
Biology for Teachers	0%	0%
Elementary Science Methods	0.55%	0.76%
Q200 and Q201	12.57%	12.88%
Q200 and E328	5.46%	4.55%
All	10.38%	9.09%
$\chi 2$	0.444	

Table 3. NOS Views Consistent with Reforms

View	**Major Elements**	**Representative Responses**
Durability and tentativeness	Recognizes that while it is durable, *all* scientific knowledge is subject to change with new evidence or the reinterpretation of existing evidence.	Science is a dynamic subject that deals with continuous observations, predictions and inferences. Science is different from religion and philosophy because it can have tangible data that can be used to observe or infer. Tangible data can still leave the initial question unanswered but this is somewhat expected in science.
Creativity & imagination	Considers creativity/imagination a vital part of all stages of scientific investigations (not only planning/interpretation). Recognize that ideas (theories, hypotheses) are created.	Scientists use their imagination and creativity to from hypotheses. Even though they are using imagination and creativity, the hypotheses are still educated guesses. So they have to use facts along with their creativity. During experiments, scientists use their creativity to help create inferences.
Socio-cultural context	Recognizes that science, as a human endeavor, both influences and is influenced by society and culture. May view science as a culture unto itself.	I believe that science reflects social and political values, philosophical assumptions, and intellectual norms of a culture. This is because people have certain ways of doing things because of the culture in which they are raised, so this will ultimately be reflected in their theories, inferences, and predictions.
Subjective/ theory-laden	Recognizes that human subjectivity is inherent in all scientific work. Recognizes that current theories serve as a lens through which we view data, and guides future work.	Everyone has their own ideas and interpret data in a different way. Background knowledge and the above mentioned differences often attribute to different theories to explain the same event.
Inferential	Recognizes that it is not possible to directly observe all phenomena; however, through indirect evidence it is possible to make logical inferences about these phenomena.	Scientists base this model of the atom off of indirect evidence. Although they are unable to directly observe the structure of the atom, it is fairly certain that this is how the atom is set up.
Theories and laws	Recognizes theories and laws as end product of science, and distinct from one another. Understands that laws are primarily descriptive of relationships between variables and that theories may explain or encompass laws.	Theories are developed to explain situations. For instance, Newton's law doesn't really explain anything about how or why gravity is on Earth, it just tells us what gravity does to objects. The Big Bang Theory gives an explanation on why the universe is as it is.
Empirical	Recognizes scientific claims must be based on empirical evidence (whether direct or indirect) and that they are limited to natural phenomena.	Science is the study of a being, process, or phenomenon that requires evidence or support to be stated as true. Science is different because it is supported by logical explanations or concrete evidence.
Use of multiple methods	Scientists use a variety of methods including experiments, observations, and collecting specimens. There is no single, universal, recipe-like “scientific method” that captures this diversity of methods.	Scientific knowledge does not require experimentation. Scientific knowledge can be inferred from observing something in its natural habitat. For example, scientific knowledge of the migration patterns of a herd may be inferred from observing the herds’ movements, where their food source is, and the climate best suited for them naturally.

Table 4. Transitional Views of NOS

View	**Major Elements**	**Representative Responses**
Durability and tentativeness	Recognizes that scientific knowledge can change; however may indicate, for example, that scientific laws are "set in stone" and cannot change.	I feel a law is something set in stone and a theory is an idea that is likely to change.
Creativity & imagination	Recognizes role of creativity and imagination in scientific investigation; however, may indicate that some aspects do not/ should not involve creativity/imagination (ex: data collection)	Scientists have to use imagination and creativity to develop ideas and come up with a hypothesis. This is useful in the early stages of investigation. However, the data collection and later stages of the experiment should purely be based on fact rather than include creativity because otherwise the data isn't 100% accurate since scientists could bend data around to apply to their original hypothesis.
Socio-cultural context	Recognizes either the influence of society/ culture on science or vice versa (but not both). May emphasize science as "universal" in ontological terms, as in describing a single reality.	I believe, especially when ideas are first developed, that they are strongly infused with social and cultural values, especially because of politics. However, I don't believe that everything would be affected by values. Science should be universal because for example, gravity works no differently in the US than it does in China.
Subjective/ theory-laden	Understands that subjectivity can play a role in the development of scientific knowledge; however this viewed as bias/ unethical conduct by scientists.	The nature of science lends itself to reflect social and cultural norms, because human beings are not perfect and have difficulty being objective as previously mentioned, however, I believe if the discipline of science wants to be respected, it should be universal. In other words, if something cannot be proven with facts that anyone can test and get the same result, then to me, it's only someone's opinion.
Inferential	Recognizes use of both observation and inference in science; however, may still focus on an ultimate need for direct observation as evidence.	Without experiments we would not be able to observe the result, therefore scientific knowledge would always be a guess at how and why things work. The specific evidence [scientists] used was probably from a series of observations, inferences, and predictions.
Theories and laws	Recognizes that theories and laws are fundamentally different (theories do not become laws) however, unable to articulate clear definitions, provide examples, etc.	A law is more like a principle while a theory is more of a synthesis of information. Laws are tested over and over again but theories are not necessarily tested, they are more of an idea.
Empirical	Refers to "data" and "testing," however, may not recognize this as distinguishing science from other disciplines of inquiry (e.g., religion). May focus on science as a democracy/ role of consensus.	Not everyone agrees with all the theories of science. For example the theory of evolution does not go along with everyone's social and cultural values…
Use of multiple methods	May confuse "experiment" with ANY form of scientific investigation. May view experimental designs are superior to other designs (e.g., observational studies)	I think that to an extent you do need to use experiments as a sort of proof that something will happen the way you say it will. However, I think that scientists can observe something happening and come to a conclusion (exp. an apple falling = gravity pulls toward the center of the earth). But I think after a scientists has observed a phenomena that testing other circumstances is just the next step.

Table 5. NOS Views Inconsistent with Reforms

View	**Major Elements**	**Representative Responses**
Durability and tentativeness	Views scientific knowledge as absolute, proven, and unchanging.	Science is a discipline in which answers are found through systematic research and tests. These answers are almost always facts, which means they are true.
Creativity & imagination	Views science as procedural, rather than creative.	Scientists can not use imagination; then their evidence would not be accurate.
Socio-cultural context	Views science as universal and/or separate from society/culture.	I believe that science is universal because I do not see any social influences in science. The basic laws of science are embedded in most peoples' lives, but I think that they are independent of what our social and cultural boundaries are. What I am trying to say is that science does not reflect values, it reflects fact.
Subjective/ theory-laden	Views science/scientists as objective and value-free. Differing interpretations occur because it can't be determined which is "right."	It is possible to have these two theories because no one really knows what happened, and both are theories that have a lot of evidence.
Inferential	Ascribes to the notion that "seeing is believing" and fails to recognize the role of indirect evidence in science.	Science is based more on what you can actually test and see instead of being based on things that have no physical evidence.
Theories and laws	Holds a hierarchal view of the function and relation of theory and law, in which theories (untested speculations) become laws (proven facts).	A scientific theory is something that can possibly change if something new is discovered and it contradicts the theory. A scientific law is something that is set in stone and cannot be changed because it is a fact. For example, a theory consists of beliefs about a particular subject. Also, there can be numerous theories on the same subject. Theories do not consist of proven facts.
Empirical	Fails to recognize reliance on evidence to support scientific claims. May emphasize individual beliefs and opinions over evidence.	I think of science as a series of ideas, some proven, some not, that we put our belief into to explain what we think is going on. I think that science is a part of a religion or philosophy because it backs up previous beliefs that there is a God in control of all things. Even things so small in detail but so important that people spend their whole lives devoted to God's plan and not even know it.
Use of multiple methods	Believes there is one, universal "scientific method" followed by all scientists in all field. Fails to recognize methods other than experimental designs (involving control and manipulation of variables).	Science disciplines differ from religion and philosophy because it is based on the scientific method, in which experimentation is a key component.

Table 6. Comparison of students' views of NOS with reforms

	Pre-semester			Post-semester		
	Consistent	Transitional	Inconsistent	Consistent	Transitional	Inconsistent
Tentative NOS	26%	66%	8%	49%	48%	3%
Creative NOS	64%	26%	10%	76%	22%	2%
Socio-cultural	23%	37%	40%	32%	40%	28%
Subjective NOS	28%	25%	46%	55%	20%	25%
Theory vs. Law	<1%	12%	87%	23%	32%	45%
Inferential NOS	12%	13%	75%	35%	30%	35%
Empirical NOS	67%	28%	5%	78%	19%	3%
Scientific methods	3%	15%	82%	11%	17%	72%

Table 7. Changes in preservice teachers' views of NOS

	Inconsistent with Reforms (Pre)			Transitional (Pre)			Consistent with Reforms (Pre)			
	Inconsistent (Post)	Transitional (Post)	Consistent (Post)	Inconsistent (Post)	Transitional (Post)	Consistent (Post)	Inconsistent (Post)	Transitional (Post)	Consistent (Post)	χ^2
Tentativeness	4	2	4	0	64	26	0	0	35	30.73*
Creativity	2	5	6	1	21	13	0	3	84	14.70*
Socio-Cultural	25	19	10	9	31	10	5	4	22	6.63*
Subjectivity	32	8	22	2	20	13	0	0	38	36.98*
Theory/Law	59	34	25	2	9	5	0	0	1	55.49*
Observation Inference	46	29	26	1	10	6	0	1	16	53.75*
Empirical	4	1	0	0	24	15	0	0	91	16.00*
Methods of Science	94	9	7	1	14	5	1	1	3	12.26*

* $p << 0.0$