Elementary Teachers' Views on the Nature of Scientific Knowledge: A Comparison of Inservice and Preservice Teachers Approach

Minsuk K. Shim
University of Rhode Island

Betty J. Young
University of Rhode Island

Judith Paolucci
Yarmouth School District, Yarmouth, Maine

Abstract

Nature of science (NOS) refers to the epistemology of science including values and beliefs inherent in science and its development through scientific inquiry. This study examined the differential views on NOS between 348 inservice and 110 preservice elementary teachers, measured by a survey instrument, adopted from the Student Understanding of Science and Scientific Inquiry instrument. Four distinctive scales showed reasonable reliability. It also examined whether preservice teachers' views of NOS change after a science methods class that focuses on inquiry-based science instruction. Preservice teachers before the class did not have different NOS views from inservice teachers. However, after the class, preservice teachers showed significant changes in their views on NOS and their views were significantly different from those of inservice teachers. Inservice teachers' NOS views were not influenced by their preference of teaching science or their experience teaching science using science kits.

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Introduction

Since the 1990s the renewed push for reform in K-12 science teaching has included the development of student understanding of the nature of science (NOS) (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996). NOS refers to the epistemology of science including values and beliefs inherent in science and its development through scientific inquiry (Lederman, 1992). As documented in national science reform initiatives, NOS is a critical element in scientific literacy of teachers and their students (e.g., AAAS, 1993; NRC, 1996; NSTA, 2000). Science educators and researchers continue to advocate for approaches that help preservice and inservice teachers develop more accurate conceptions of how science research is conducted or how scientific knowledge develops. Given more informed understandings of science, along with specific instructional strategies, these teachers can guide elementary students, through the design of lessons that focus directly on the nature of scientific knowledge, to understand science and the processes of knowing science as more than a set of facts developed by experts using one approach: “The Scientific Method.”

The purpose of the present study is to examine the differential views on the nature of scientific knowledge between 348 inservice and 110 preservice elementary teachers who may have developed more informed views of NOS while learning to teach science using inquiry methodologies. The preservice teachers are participants in a 5-year longitudinal study in which their beliefs and practices are tracked from their entrance into the teacher preparation program, through the methods year, the student teaching year, and into their first three years of teaching. Their NOS views are being followed along with their beliefs of efficacy, disposition toward teaching inquiry science, science content knowledge, and application of inquiry-based pedagogy as they plan and teach in elementary classrooms. This study addresses the following three questions:

1. Do preservice teachers have different views of the nature of science from inservice teachers?
2. Do preservice teachers’ nature of science views change after a class on inquiry-based science instruction?
3. Do inservice elementary teachers have different views of the nature of science based on their preference of teaching science and/or experiences with kit-based science?

Nature of Scientific Knowledge

The study of NOS conceptions and the development of measures to assess these notions has been a strand of science education research since the 1970s (Abd-El-Khalick & Lederman, 2000). Researchers have suggested that teachers’ conceptions of NOS are important because they may influence decisions made in the classroom and because teachers having “naïve understandings” of NOS are not prepared to enlighten their pupils. In studies of interventions aimed at helping teachers to develop more informed views of NOS, researchers have found that the teachers’ understanding of NOS is independent from many other teacher characteristics such as science content knowledge (Billeh & Hasan, 1975; Scharman, 1988a, 1988b), locus of control (Scharmann, 1988b), gender (Wood, 1972), level of science taught (Wood, 1972), field-based teaching experiences (Scharmann, 1988b), and logical thinking ability or quantitative or verbal aptitude (Scharmann, 1988a, 1988b).

While research connecting teachers’ NOS views to classroom practice has been far from conclusive, some studies have found that teachers’ promotion of open-ended scientific inquiry in the classroom relates to their perceptions on NOS (Bencze & Bowen, 2006). Teachers with more coherent understandings of NOS are more likely to plan explicit instructional sequences to teach about NOS (Abd-El-Khalick, 2005). Additionally, teachers holding positivist-aligned epistemological views allocate more instructional time on lectures while teachers holding more constructivist-oriented epistemological views allocated more time for inquiry (Tsai, 2006a).

Some studies have found the most effective move toward developing contemporary NOS views involves explicit instruction on NOS, science history, and philosophy of science (Abd-El-Khalick & Lederman, 2000) or the inclusion of explicit NOS instruction combined with the inquiry approach (Akerson & Volrich, 2006). Abd-El-Khalick & Lederman (2000) suggested two of the factors mediating the disconnection between teacher NOS and its appearance in teaching practice: implicit versus explicit approach in teachers' lessons as well as the NOS assessments used. Further, the instruction in the nature of scientific knowledge seems to greatly benefit from explicit approaches (Abd-El-Khalick & Lederman, 2000; Akerson & Volrich, 2006). Moreover, Jones and Carter (2007) found that teacher attitudes and beliefs influenced many aspects of their practice, including both instruction and interactions with students, yet efforts to change such attitudes and beliefs were difficult. While all may not agree that holding more contemporary beliefs on NOS may in itself affect teacher practice, such beliefs are prerequisites to having teachers realize the importance of explicit instruction of NOS as called for in the science reform movement.

Prior to investigating teacher conceptions, the first task of this study was to choose an effective way to measure the key elements of scientific knowledge in order to reliably assess and track changes in NOS beliefs of teachers. The types of NOS assessment methods include fixed-response surveys (Billeh & Hasan, 1975; Ogunniyi, 1983), dual-response instruments (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2008), semi-structured interviews (Aikenhead & Ryan, 1992), and fixed-response/interview approaches (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2001; Shapiro, 1996). These assessments vary in terms of advantages and disadvantages mainly based on the trade-off between intensive interviews that yield depth over generalization and fixed-response methods that can be used with larger numbers, but do not allow participants to express views in their own words or elaborate on reasons and examples of their choices.

Method

Data and Procedure

Inservice teacher participants. Data for the study were collected from 348 inservice elementary teachers from 37 schools in a northeastern state. Within this group, two-thirds of the teachers (N = 230) were located in schools using kit-based science materials supported by professional development, and one-third of the sample were based in schools using other means such as textbooks. The years of experience did not differ between these groups with 64 percent of the total sample reporting 10 years or more in the field. Table 1 describes the participants and presents the breakdown of the preference ranking for teaching in relation to other elementary subjects (i.e., reading, mathematics and social studies). Thirteen percent of the inservice teachers ranked science as their favorite subject and 15 percent indicated it was their least favorite area of instruction.

Preservice teacher participants. The study included 110 elementary preservice teachers who participated in the pre-administration of the survey, 89 of whom completed the post-survey. These students were newly enrolled in the state university teacher preparation program. They took their elementary science methods course in the second semester in the program. The science methods course was specifically designed to model science as something they did instead of something they just read about and repeated accurately. The course activities were geared to change negative and inaccurate views of science by emphasizing the creativity and multiple approaches to investigating research questions as opposed to one rigid 'Scientific Method.' Students were engaged in activities that peaked their curiosity about how things work and then were encouraged to be creative in exploring phenomena. While students did background reading in a regular science methods text, the classes were intended to demonstrate the ideas and allow direct experience of the topics in the text. This format was a great departure from many university courses and a refreshing change for our students.

The activities of the course included a number of activities adapted from the Institute for Inquiry at the Exploratorium (e.g., "Process Circus" that helps students to identify different aspects of science investigations, "Three Kinds of Hands-On" that guides them to see that not all hands-on involves high levels of critical thinking, and "Formative Assessment" that examines the relative usefulness of different types of feedback). Additionally, the students did in-class investigations, based on FOSS and STC kits while the instructors model guiding questions and effective closure of lessons to help children make meaning and connect evidence to claims.

In the structure of the course, the active engagement in the in-class science activities as well as the practice of using more open-ended approaches involving inquiry through in-class micro-teaching and videotaped science lessons in an elementary classroom assisted the preservice teachers in applying knowledge and skills into realistic instructional settings. Their efforts were carefully examined through the observation directly made in the university classroom, the instructors' feedback on the videotaped lesson and the students' reflections that analyzed their teaching and indicated what was effective and what they would do differently the next time. The course instructors explored the beliefs and knowledge about science that these preservice teachers held before and after the course to track the progress because of the important connection between NOS beliefs and the teachers' approaches to teaching science. While there was no explicit instruction connected to contemporary NOS views, many of the activities provided examples of more contemporary views of nature of science and the text had readings in this area.

When asked to rank elementary subjects of science, math, social studies and reading in terms of their teaching preferences, only 7 percent of the preservice teachers indicated science as their favorite subject to teach before completing the science methods course, while 8 percent of the sample listed science as most preferred subject after the methods course. However, bigger changes occurred in the proportion of preservice teachers who ranked science as their least favorite subject. Those ranking science as their least favorite subject to teach changed from 14 percent before taking science methods to only 7 percent after completing the course.

Table 1
Descriptions of Participants

	Preservice Teachers		Inservice Teachers		
	Pretest	Posttest	Kit-based Schools	Non Kit-based Schools	Total
Total	110	89	230 (66%)	118 (34%)	348
Teaching Preference					
Prefer Science Most	8 (7%)	7 (8%)	23 (10%)	19 (17%)	42 (13%)
Prefer Science Neither most or least	87 (79%)	76 (85%)	168 (76%)	76 (67%)	244 (73%)
Prefer Science Least	15 (14%)	6 (7%)	31 (14%)	19 (17%)	50 (15%)
Teaching Experience					
1 – 4 Years			26 (12%)	21 (18%)	47 (14%)
5 – 9 Years			42 (19%)	33 (29%)	75 (22%)
10 – 14 Years			56 (25%)	18 (16%)	74 (22%)
15 – 19 Years			31 (14%)	19 (16%)	50 (15%)
20 + Years			68 (31%)	24 (21%)	92 (27%)

Instrumentation

As a part of a larger research effort on inquiry-based science instruction for elementary teachers, inservice and preservice elementary teachers completed a suite of surveys that included background information (e.g., experience and preferences for teaching subjects), frequency of employing various science teaching practices, readiness to engage in reform practices, efficacy in teaching science, and beliefs about the nature of science. Additionally, the preservice teachers wrote in-class essays on "What is science?" at the beginning and the completion of their science methods course.

Nature of Science. The research team incorporated the fixed-response items on the nature of scientific knowledge of the Student Understanding of Science and Scientific Inquiry (SUSSI) (Liang et al., 2006). Based on the NOS views that have been widely discussed in the literature, SUSSI (version 2) incorporates six aspects of NOS. However, two scales in the pilot study (i.e., Change of Scientific Theories, and Scientific Laws vs. Theories) showed low reliability (Cronbach's $\alpha < .3$) (Liang et. al., 2006). As a result, the team decided to use the four scales with higher reliability. These scales included:

- Observations and Inferences: Observation and inferences are the basis of scientific knowledge and multiple perspectives of science and scientist lead to multiple interpretations that are valid,

- Social and Cultural Influences on Science: Scientific knowledge is shaped by and from concepts that are a product of society and culture,

- Imagination and Creativity in Scientific Investigation: Scientific knowledge involves creative imagination, and

- Methodology of Scientific Investigation: Scientific method is not a rigid step-by-step process; it is developed and interpreted in various ways.

First, we examined the validity and the reliability of the adapted instrument used to measure NOS with the sample. As we adopted the items from the original survey, it became necessary to establish the underlying dimensions and their reliabilities with our data. The quality of measurement improves if similar items measuring an underlying construct are combined together as one indicator for the construct. Mayer (1999) recommended the use of composite scales that combine items measuring the same latent construct rather than individual item. We generated reliability analyses to see the internal consistency of the scales. Negatively-worded items were recoded so that they had the same directionality as the other items. Table 2 shows the sample item and the psychometric information of each scale. For our sample, Cronbach's alphas ranged from .42 to .86. Except Scientific Method, NOS scales show reasonable internal reliability. In addition, a total score based on all 15 items was also reliable (α = .75).

Table 2
Reliabilities of the Nature of Science Scales

NOS	Sample question	No. of items	α
Observation and Inferences	Scientists' observation of the same event may be different because scientists' prior knowledge may affect their observation	4	.67
Social and Cultural Influences	Cultural values and expectations determine WHAT science is conducted and accepted.	4	.64
Imagination and Creativity	Scientists use their imagination and creativity when they analyze and interpret data.	4	.86
Scientific Method	Scientists follow the same step-by-step scientific method.	3	.42
Total		15	.75

We then employed exploratory factor analyses to identify the underlying dimensions of NOS within the data and used the results to develop composite scales (Mayer, 1999). Factor analysis is a statistical technique to uncover the underlying structure within a set of observed variables and is often used in surveys to see how groupings of questions measure the same concept (Dillon & Goldstein, 1984). It is commonly used to identify a parsimonious model with a smaller set of variables that accounts for most of the variances in the data. Among various methods of factor extraction and rotation, we used principal components analysis (PCA) with the varimax rotation, the most commonly used technique in exploratory factor analysis. PCA on the 15 NOS items extracted four factors. The varimax solution revealed a simple structure in the data that was easily interpretable. Table 3 shows the factor loadings of NOS scales. The factor loadings on their respective factors are highlighted in bold. All items had high loadings on their respective factors (average factor loadings = .695) and weak loadings on all other factors (absolute average factor loadings = .110). This clear pattern of loadings supported the underlying four factor model as theoretically valid and empirically distinct. The four factor model explained 57% of the total variances.

Table 3
Factor Loadings of NOS Scales

Scale	Item	Factor1	Factor2	Factor3	Factor4
Imagination and Creativity	1	**.888**	.073	.044	.125
	2	**.876**	.036	.112	.080
	3	**.833**	.037	.012	.031
	4	**.692**	.023	.047	.186
Observation and Inferences	1	.117	**.776**	.067	.004
	2	-.011	**.664**	-.017	.338
	3	.094	**.663**	.176	-.188
	4	-.070	**.633**	.036	.364
Social and Cultural Influences	1	.075	-.030	**.851**	-.118
	2	.099	.059	**.789**	-.125
	3	-.041	.148	**.599**	.380
	4	.059	.215	**.486**	.363
Scientific Method	1	.183	-.029	.011	**.678**
	2	.075	.085	-.094	**.653**
	3	.151	.152	.182	**.339**

"What Is Science?" Essays. One of the activities in the methods course had students complete an in-class "quick-write" on "What is science?" as a time capsule at the beginning of the semester and again at the end of the course. One of the prompts asked students to explain the nature of science.

The samples of the typical preservice teachers' pre- and post-methods responses to the "What is science?" prompt presented more in-depth information on the changes in their knowledge and views of the nature of science.

Results

Differences in NOS Views between Preservice and Inservice Teachers

The first question of the study calls for a series of Multivariate Analysis of Variance (MANOVA) to see whether preservice teachers hold different NOS views from inservice teachers. As the pretest and posttest data of preservice teachers are not independent, it is not plausible to examine the differences among three groups (inservice, preservice pretest, and preservice posttest) simultaneously.

First, we compared pretest data of preservice teachers (N = 110) with inservice teachers' data. The overall MANOVA statistics showed that there were no significant differences between preservice and inservice teachers across all four NOS scales and a total (Hotelling's Trace = .018, $p>.05$), supporting our assumption that preservice teachers before their methods course held similar views of NOS as inservice teachers. Second, we compared posttest results of preservice teachers (N = 89) with those of inservice teachers to see whether preservice teachers after a semester of methods course emphasizing inquiry-based science teaching held different views of NOS from inservice teachers. There were significant differences between preservice and inservice teachers on all NOS scales (Hotelling's Trace = .082, $p<.01$).

Table 4
NOS differences between Preservice (Posttest) and Inservice Teachers

	Preservice		Inservice			
Scale	M	SD	M	SD	F(1,425)	η^2
Observation and Inferences	3.895	.584	3.662	.577	11.307**	.026
Observation of the same event will be different as prior knowledge affect observations	3.966	.769	3.806	.792	2.801	.007
Observation of the same event will be the same as scientists are objective	2.448	.912	2.647	.847	3.635	.009
Observation of the same event will be the same as observations are facts	2.207	.929	2.575	.954	10.299**	.025
Different interpretations on the same observations	4.230	.742	4.053	.582	5.566*	.014
Social and Cultural Influences	3.551	.553	3.368	.613	6.513*	.015

Scientific research is not influenced by society and culture	2.253	.955	2.534	.845	7.173**	.017
Cultural values determine what science is conducted and accepted	3.299	.891	3.247	.863	.245	.001
Cultural values determine why science is conducted and accepted	3.333	.911	3.175	.864	2.244	.006
All cultures conduct scientific research the same way	2.172	.865	2.406	.866	4.989*	.012
Imagination and Creativity	3.145	.900	2.850	.881	7.752**	.018
Use imagination and creativity when collecting data	3.126	1.108	2.722	1.074	9.569**	.023
Use imagination and creativity when analyzing and interpreting data	3.103	1.012	2.797	1.059	5.840*	.014
Do not use imagination and creativity because these conflict with logical reasoning	2.793	1.058	3.038	1.029	3.814	.009
Do not use imagination and creativity because these interfere with objectivity	2.885	1.083	3.094	1.003	2.859	.007
Scientific Methods	3.568	.636	3.169	.648	26.687**	.059
Use different types of methods to conduct scientific investigation	4.138	.824	3.822	.904	8.670**	.021
Follow the same step-by-step scientific method	2.747	1.059	3.128	.992	9.804**	.024
When use the scientific method correctly, the results are true and accurate	2.736	.869	3.178	.880	17.399**	.041
Total	3.537	.400	3.270	.436	27.202**	.060

* $p<.05$, ** $p<.01$

1 'Strongly Disagree' 2 'Disagree' 3 'Uncertain' 4 'Agree' 5 'Strongly Agree'

Table 4 shows that preservice teachers held more flexible and informed NOS views than inservice teachers. When each item was examined, preservice teachers agreed more strongly on the statements such as 'scientists use imagination and creativity when collecting data,' 'scientists use different types of methods to conduct scientific investigations.' On the contrary, inservice teachers agreed more strongly on the statements such as 'when scientists use the scientific methods correctly, their results are true and accurate,' 'scientists' observations of the same event will be the same because observations are facts,' 'scientific research is not influenced by society and culture,' and 'scientists follow the same step-by-step scientific method.'

Changes in NOS Views of Preservice Teachers

Multivariate Repeated Measure design was used to examine changes in the NOS views of preservice teachers. We examined the data from the eighty nine preservice teachers who completed both pretest and posttest administrations of the instrument in order to see whether they made significant changes from the beginning to the end of the class (Table 5). There were significant differences between pretest and posttest of pre-service teachers (Hotelling's Trace = .261 $p<.01$) on Imagination/Creativity, Scientific Method and Total Nature of Science Scores. Preservice teachers showed more informed NOS views after a semester of methods course focusing inquiry-based science instruction. A closer look at the differences showed that preservice teachers became more favorable in posttest that 'scientists use their imagination and creativity when whey analyze and interpret data.' They also became more skeptical about the statements such as 'scientists do not use their imagination and creativity because these conflicts with their logical reasoning,' 'scientists do not use their imagination and creativity because these conflicts with objectivity' and 'scientists follow the same step-by-step scientific method.'

Table 5
NOS changes of Preservice Teachers

	Pretest		posttest			
Scale	M	SD	M	SD	F(1,85)	η^2
Observation and Inferences	3.867	.469	3.895	.591	.214	.003
Social and Cultural Influences	3.509	.621	3.538	.552	.230	.003
Imagination and Creativity	2.855	.796	3.137	.906	8.860**	.094
Use imagination and creativity when collecting data	2.953	.999	3.118	1.117	1.674	.020
Use imagination and creativity when analyzing and interpreting data	2.847	1.018	3.094	1.019	4.281*	.048
Do not use imagination and creativity because these conflict with logical reasoning	3.200	.973	2.800	1.067	9.038**	.097
Do not use imagination and creativity because these interfere with objectivity	3.235	.972	2.894	1.091	7.617**	.083

Scientific Methods	3.314	.499	3.566	.641	12.507**	.128
Use different types of methods to conduct scientific investigation	4.082	.775	4.141	.833	.314	.004
Follow the same step-by-step scientific method	3.388	.901	2.765	1.065	19.555**	.189
When use the scientific method correctly, the results are true and accurate	2.776	.822	2.729	.864	.233	.003
Total	3.391	.357	3.531	.403	11.129**	.116

* p<.05, ** p<.01

1 'Strongly Disagree' 2 'Disagree' 3 'Uncertain' 4 'Agree' 5 'Strongly Agree'

We examined the question whether the changes in preservice teachers NOS views resulted in the changes in their report of plans to use more of reform approaches to science teaching. In another part of the overall project survey, preservice teachers were asked to indicate the likelihood of the classroom practices they would use in teaching science. After the science methods course, preservice teachers indicated plans to use significantly fewer traditional approaches of using science textbook, worksheets and multiple choice/short answer tests. Preservice teachers indicated that they would use significantly more of hands-on investigations, hypotheses testing, real life applications and open-ended questions after a semester of methods course (Hotelling's Trace = .788, p<.01). It demonstrates the effectiveness of methods course in changing preservice teachers NOS views and subsequently teaching approaches to more informed, inquiry-based.

Changes in Preservice Teachers' Description of Science

Another indication of this change in their views of science can be seen in the responses to the "What is science?" writing assignment. At the beginning of the science methods course, most students recited the branches of science: biology, geology, chemistry, and physics when asked to write a short essay on "What is Science?" By the end of the science methods course, students reported changes in their negative perceptions of science, and their ideas about nature of science had expanded in some important ways (Table 6).

Table 6
Responses on "What is Science" essay

At the beginning of the methods course	At the end of the methods course
• When I think of science I think of the weather and the way clouds, rain, snow, etc. are formed. • Nature of science to find the answers to facts that can be proven. • The nature of science is generally more formulaic, like math, in which there are certain things which are absolute. • I think of the scientific method and lab reports. • I don't know how to answer what the nature of science is	• I think science tests and instruction do have right and wrong answers, but science itself doesn't have to be that way. • I thought of science as being formulaic, like math, however, since I have been in this class, I have come to think of science as more of a means of discovery as to why/how things happen. • The importance of science is discovery because it is ever-changing. • Science is not about finding meaning through a textbook or following explicit instructions—it is hands-on learning. It involves curiosity and excitement. • Science thrives on curiosity.

Different NOS Views among Inservice Teachers

The third question addresses the differences in NOS views among the inservice teachers. Since there were schools that used kit-based science curriculum as part of another science initiative, we examined the difference between inservice teachers who were in kit-based schools and those who were not. Teachers in the kit-based schools had professional development in the use and science content of science kits (e.g., Full Option Science Systems and Science and Technology for Children) as well as an introduction to inquiry-based teaching of the kits by increasing the critical thinking of students. Generally, a teacher would have received 12 hours of professional development in each of three kits. This professional development occurred in 6-hour sessions over the first 2-3 years of kit use. While the kits and the professional development provide opportunities to change teachers' view of the nature of science, presenters did not make explicit connections in these sessions.

All inservice teachers were surveyed to determine those who felt more comfortable teaching science and who did not. To estimate the comfort level, teachers were asked to rank the subjects they preferred to teach (i.e., reading, math, science, social studies). Teachers were classified into three groups, those who indicated science as their favorite subject, those who indicated science as their least preferred subject, and those for whom science was neither the least nor the most favored topic. In these analyses, there were no significant differences in preference for teaching science between teachers in kit-based schools (32 %) versus in non-kit schools (34%) ($\chi^2 = .711$, df = 2). Thus, using kit-based science did not improve teachers' enjoyment in teaching this subject in relation to other elementary disciplines.

For the question of possible differences in NOS beliefs of teachers in kit-based schools, we employed a MANOVA examining the group differences over multiple dependent variables. Hotelling's Trace shows that there were no significant differences in the NOS views among inservice teachers with different preference for teaching science or experience using science kits (.027 for preference and .004 for kit-based school experience). None of the group differences reached the significance level of .05.

Because the professional development activities in kit-based initiative focused more on science teaching practices rather than explicit NOS beliefs, we examined whether inservice teachers in kit-based schools had different approaches to teaching science. Although teachers in kit-based schools did not show different NOS beliefs, they indicated that they used significantly more of reform approaches such as hands-on investigation and introducing real-life connections to science topics than traditional textbook and worksheet approach (Hotelling's Trace = .667, $p<.01$).

Discussion and Conclusions

National Science Education Standards (1996) identify the development of more contemporary views of scientific knowledge and the work of scientists as critical elements of scientific literacy for all learners. Scientific inquiry is, "far more flexible than the rigid sequence of steps commonly depicted as the scientific method….More imagination and inventiveness are involved in scientific inquiry" (AAAS, p.9). In this study, we measured the views on the nature of science of preservice and inservice teachers with the modified SUSSI. Exploratory factor analyses empirically supported the theoretically-driven four dimensions. All NOS scales showed high to medium reliability. The omission of open-response sections is one of the limitations of this study, a trade-off in order to examine this construct with greater numbers of preservice and inservice teachers than those who have typically been studied in the literature.

The present study also examined the differential NOS views of preservice and inservice teachers. Preservice teachers did not have different views of NOS from inservice teachers before their science methods course. However, their views had significantly changed into more flexible contemporary views after a semester of methods course where students had first-hand experiences of inquiry-based science instruction. They held more flexible ideas about scientific inquiry. The findings provide support for the assertion that the methods course facilitates change to more informed conceptions of NOS, particularly by engaging preservice teachers in open-ended inquiries and allowing them to design investigations using a variety of means. This outcome is particularly interesting in relation to the absence of explicit teaching of the nature of science components in the science methods course.

In the longitudinal study of a subset of preservice teachers from this sample, the ability to sustain these more contemporary NOS beliefs will be examined as they student teach in the following year and enter the teaching profession. The novice teachers appear to be more receptive to these new ideas, an assertion that is consistent with an earlier study (Luft, 2001). It showed that following training, experienced teachers demonstrated more change in their practices than their beliefs. Likewise, following science education courses that focused on the philosophy of science and contemporary learning theories, teachers' views toward the nature of science were affected (Tsai, 2006b).

The finding that inservice teachers, even those using kit-based instruction, retain very traditional NOS views appears to demonstrate the persistence of limited views of the nature of scientific knowledge and how it is developed. Tsai (2006) found that inservice teachers have more established beliefs about science that were more difficult to change than those of preservice teachers. This factor suggests the need for more explicit information and reflection on NOS within the professional development sessions for the inservice teachers.

In the present study, the differences between inservice and preservice teachers' change in beliefs may be explained by the fact that the preservice teachers have a more sustained exposure to a different view of science and have many more opportunities to reflect on their teaching and attitudes toward science under the careful coaching of instructors as compared to the inservice teachers. For the inservice teachers, science professional development sessions are distributed over several years and do not include the level of reflection and coaching that one would see in preservice preparation. Inquiry-based science pedagogy often times is quite different from the way both preservice and inservice teachers learned science and requires a lot of planning and preparation. The alteration of these views requires a series of experiences that illustrate the more informed view of the work and ethos of scientific endeavors. The kit-based teachers all had some exposure to the more contemporary NOS views, but they require more intensive professional development experiences in this inquiry-based science if we expect them to view science in a new way. This goal is critical, as the way teachers understand the nature of science is reflected in their instruction.

This study contributes to the NOS dialogue in several ways. First, the numbers of inservice and preservice teachers are substantially larger than those in many previous studies thus providing greater generalizability. A number of recently published studies have less than 40 participants (e.g., Lord & Peard, 1995; Tsai, 2002; Abd-El-Khalick & Akerson, 2004; Akerson & Volrich, 2006; Hanuscin, Akerson, & Phillpson-Mower, 2006) while only a few published studies have sample sizes over 100 (e.g., Liang et al., 2008; Bauer, Petkova & Boyadjieva, 2000). While these differences are a function of the measurement approaches, given that interviews are more time-intensive than surveys or survey/open-response formats, the generalizability of findings is greatly enhanced with more robust sample sizes. Second, teachers' settings, teaching preferences, and reported practices are known so that the comparisons can include disaggregation based on attitudes, teaching methods, and curricular approaches of practice. Finally, this work provides a large comparison group as the longitudinal study progresses, following the preservice teachers into student teacher and the first years of induction. This information will provide better understanding of how this new appreciation of inquiry-based science instruction of preservice teachers is transferred as inservice teachers later. Large scale, longitudinal study examining multiple aspects of knowledge transfer such as mentoring will be beneficial to inform science teaching.

In the continuing study of a subgroup of preservice teachers, the research team is continuing to sample the view of scientific knowledge and how it is developed. We will also explore the teachers' views in more depth by collecting and analyzing teachers' statements justifying their responses on the SUSSI and conducting a more thorough content analysis of the elementary science methods pre/post essay assignment in which student teachers write their concepts in response to "What is science?" Finally, a future direction would be to examine the ways the informed view of NOS is taught implicitly compared with more direct teaching contrasting traditional views with more informed ideas in this area.

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