Journal of Elementary Science Education, Vol. 20, No. 1 (Winter 2008), pp. 45-58.

Relationships Among Learner Characteristics and Preservice Elementary Teachers' Views of Nature of Science

Valarie L. Akerson, Indiana University
Lisa A. Donnelly, Kent State University

Abstract

The purpose of this study was to explore the relationship of learner characteristics and preservice teachers' views of nature of science (NOS) prior to formal instruction. Learner characteristics investigated included metacognitive awareness, self-efficacy, attitudes toward science teaching, Perry's intellectual and ethical developmental levels, concerns for teaching NOS, and cultural values. Findings indicated interesting relationships between NOS views and cultural values, self-efficacy, attitudes toward teaching science, metacognitive awareness, and Stages of Concern (SOC) for teaching NOS. Implications for preservice science teacher education include attending to cultural values related to science as a separate, but not better, way of knowing.

Introduction

An understanding of the nature of science (NOS) has been determined to be an important component of scientific literacy for all (AAAS, 1993; DeBoer, 1991). Considerable research has been conducted to improve preservice teachers' conceptions of NOS through elementary science methods courses (Abell & Smith, 1994; Barufaldi, Bethel, & Lamb, 1977; Shapiro, 1996). Many studies have found that using an explicit reflective approach helps teachers develop more accurate conceptions of NOS (Abd-El-Khalick & Akerson, 2004; Akerson & Abd-El-Khalick, 2003; Akerson, Abd-El-Khalick, & Lederman, 2000). Recent work indicates, however, that attainment and retention of NOS views is difficult for preservice teachers (Abd-El-Khalick & Akerson, 2004; Akerson, Morrison, & McDuffie, 2006). Reasons for this difficulty in attaining and retaining adequate views have been found to be related not only to methods course teaching strategies, but also to characteristics of the learner, or to a "conceptual ecology" for NOS learning. Southerland, Johnston, and Sowell (2006) related NOS views to teachers' affect, dispositions, and beliefs through explorations of NOS conceptual ecologies of inservice teachers. Our own work has found that there are relationships between ethical and intellectual developmental levels and cultural values related to teachers' NOS views (Akerson & Buzzelli, 2007). To plan for effective teaching of NOS, it is important for methods instructors to understand their preservice teachers. We believe that research on learner characteristics promises to be fruitful in describing influences on attainment and retention of informed NOS views. The purpose of this study, therefore, was to explore various learner characteristics to

determine relationships between these characteristics and preservice teachers' NOS views. From previous literature, the characteristics that we believed may have a relationship to our preservice teachers' NOS views were their (1) concerns for teaching NOS, (2) metacognitive awareness levels, (3) NOS self-efficacy, (4) ethical and intellectual developmental levels, (5) views of scientific inquiry, (6) attitudes toward science teaching, and (7) cultural values. Our specific research question is "What are the relationships of these various learner characteristics to preservice elementary teachers' views of NOS?"

Theoretical Framework

To frame our study, we drew upon the recent literature in NOS and in each of the areas of student characteristics we wished to explore. Each of these areas is reviewed below.

Nature of Science

NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). In their NOS position statement, the National Science Teachers Association (2000) recommends that science, along with its methods, explanations, and generalizations, must be the sole focus of instruction in science classes. Their position on what teachers and students should know includes that (1) scientific knowledge is both reliable (one can have confidence in scientific knowledge) and tentative (subject to change in light of new evidence or reconceptualization of prior evidence); (2) no single scientific method exists, but there are shared characteristics of scientific approaches to science such as scientific explanations being supported by empirical evidence, which are testable against the natural world; (3) creativity plays a role in the development of scientific knowledge; (4) there is a relationship between theories and laws; (5) there is a relationship between observations and inferences; (6) though science strives for objectivity, there is always an element of subjectivity in the development of scientific knowledge; and (7) social and cultural contexts also play a role in the development of scientific knowledge. We focused on preservice teacher views of these elements because these are the NOS ideas that they will be responsible for teaching.

Stages of Concern (SOC)

Abd-El-Khalick and Akerson (2004) investigated the factors influencing NOS conceptual change for preservice elementary teachers. They found that the effectiveness of the explicit reflective NOS intervention was mediated by motivational, cognitive, and worldview influences. Specifically, students who thought that NOS teaching and learning were important improved their NOS views more than their peers who did not hold this view. Students who related their NOS learning to their future teaching may be more successful at achieving adequate NOS understandings. In Alsop and Watts's (1997) expanded model of conceptual change, they outline a conative domain that entails how practically useful or "actionable" new knowledge is to the learner. In the context of preservice teachers' NOS learning, the conative domain may include the extent to which preservice teachers view NOS as relevant to their future science teaching. As such, preservice teachers may differ as to their degree of concern about incorporating

NOS instruction into their future science teaching. The current study will utilize valid and reliable instruments to measure the relationships between the kinds of concerns preservice teachers have about NOS and their views of NOS.

Metacognitive Awareness

Previous literature on NOS learning indicates the importance of metacognitive awareness. This metacognitive awareness may be related to the dispositions of individual learners. For example, Southerland et al. (2006) investigated the conceptual ecologies of five inservice science teachers. These authors suggest that NOS intelligibility is impacted by learning dispositions (i.e., reflection and need for cognition). Similarly, Abd-El-Khalick and Akerson (2004) found that preservice teachers who demonstrated a deep processing approach to learning about NOS also benefited more from the intervention than their peers who had a more surface-oriented approach. Prompts for metacognitive awareness built into NOS instruction may also facilitate NOS learning. For example, Schwartz, Lederman, and Crawford (2004) described how students' willingness and ability to reflect on their NOS learning during authentic science experiences was positively related to their NOS concept development. In this study, doing science was not enough; instead, students had to engage in reflection from the outside as they shifted their focus from the development of scientific content during their investigations to the epistemology of science in their reflections. Additionally, Tsai (2006) found that inservice and preservice teachers attributed gains in their NOS understandings to a conceptual change approach that made them aware of alternative NOS conceptions. The current study will enable us to note relationships among metacognitive awareness, NOS conceptions, and other learner characteristics that may influence NOS conceptions.

Self-Efficacy

Pintrich et al. (1993) argued that conceptual change is influenced by four motivational learner characteristics: (1) goals, (2) values, (3) self-efficacy, and (4) control beliefs. These are moderated by classroom contextual factors such as task, authority, evaluation structures, teacher modeling and scaffolding, and classroom management. In Alsop and Watts's (1997) expanded conceptual change model, they added a self-esteem component to the model. The authors argue that individuals' confidence about pursuing incomprehensible material and seeking out answers to scientific questions may be related to their science learning. In the context of preservice teachers' NOS conceptual ecologies, this self-esteem domain encompasses the teachers' perceptions of themselves as competent seekers of scientific information, a component of their self-efficacy. Hanson (2006) found that there was a relationship between self-efficacy and personal definitions of NOS, though the relationship was not linear. Therefore, more work needs to be done exploring the relationship of NOS views and self-efficacy.

Perry's Levels

William G. Perry (1999) devised a scheme of intellectual and ethical development that categorizes adults into epistemological levels such as *dualism*, *multiplicity*, *relativism*, and *dialetical*. Several studies of preservice teachers' NOS learning have addressed the relationships between students' developmental levels and their

NOS views. First, Abd-El-Khalick (2001) found that students understood that science was tentative but expressed an intolerance for ambiguity and uncertainty. Following instruction, the students adopted a naïve relativism perspective in which "anything goes." Abd-El-Khalick described how learning about NOS may be related to students' developmental level in that dualist, scientistic views may change to naïve, relativistic views when the desired instructional goal is probably more aligned with committed relativism. Akerson et al. (2006) also found that preservice teachers retention of NOS concepts was related to their developmental (Perry's) level. Similarly, in their investigation of preservice teachers' NOS learning ecologies, Southerland et al. (2006) determined that plausibility and fruitfulness is impacted by intolerance for ambiguity and need for external authority—dispositions related to developmental levels. Furthermore, Akerson and Buzzelli (2007) found that when preservice teachers of different Perry Positions held misconceptions of NOS views, the patterns of their views differed by developmental levels. The current study explores how these Perry Positions are not only related to patterns of NOS understandings but also to other characteristics of the learner that may be important in the acquisition of appropriate NOS content knowledge.

Views of Scientific Inquiry

In their investigation of preservice teachers' NOS conceptual ecologies, Southerland et al. (2006) described how fruitfulness was very much related to students' views of science as an enterprise. They found that considering science as a process, a product, or both was an important component of teachers' NOS conceptual ecologies.

Students' Attitudes Toward Science Teaching

Tsai (2002) investigated and found a relationship between Taiwanese secondary science teachers' NOS views, views of science learning, and views of science teaching. Thus, teachers who viewed science teaching as a traditional transmission of information also held more traditional positivist views of science. Similarly, teachers who ascribed to constructivist views of learning and teaching science were also more likely to hold more constructivist (consensus) views of science. This study suggests that teachers' ideas about science, learning, and teaching may be part of their NOS conceptual ecologies.

Cultural Values

Abd-El-Khalick and Akerson (2004) found that preservice teachers who viewed science and religion as distinct improved their NOS views more than their peers who maintained that science and religion are in opposition. Haidar (1999) described how teachers' views of NOS may be related to their religious views and their adherence to Western values associated with positivistic science. Furthermore, Aikenhead and Jegede (1999) suggest that science learning should be conceptualized as crossing borders between two cultures: (1) one's own family culture and (2) the culture of classroom science. They point out that each culture involves shared "norms, values, beliefs, expectations, and conventional actions" (p. 272). Accordingly, border crossings can be smooth, managed, hazardous, or impossible depending on the differences between students' own culture and school science culture. When students learn school science, they may engage in collateral

learning wherein they construct scientific conceptions alongside their indigenous explanations of phenomena. These two understandings exist simultaneously and may or may not interact. In the context of NOS learning, an examination of preservice teachers' cultural values warrants further exploration.

Method

We used a mixed methods approach (Creswell, 2003) to identify our preservice teachers' understandings of NOS and other learner characteristics that may be related to their NOS views. Our sample included 21 Master's-level elementary preservice teachers in a transition to teaching program. These preservice teachers were returning to college to become elementary teachers after a career in another field outside of education. The 18-month-long transition to teaching program leads to a Master's degree in elementary education, and the students take all classes as a cohort group. Of the 21 participants, only one was male. Ten students were under the age of 25, five were between 26 and 30, and six were between 31 and 40. While one student indicated she had taken no college science credits, eight indicated they had taken six or fewer science credits, six students had taken seven to nine college science credits, and only three students had taken ten or more credits. Three students did not indicate the number of college science credits they had taken. Data was collected at the beginning of the first semester of this cohort group's participation in the program. Specific research methods used to explore our question will be identified in the sections below.

Data Collection

A variety of instruments were used to discern preservice teachers' NOS views, conceptions of scientific inquiry, metacognitive awareness, intellectual development levels, SOC for teaching NOS, attitudes toward science teaching, self-efficacy, and cultural values. We will describe these instruments in the subsequent paragraphs. Lisa Donnelly, the second author, described the research study and obtained informed consent from the participants on the first day of class because Valarie Akerson, the first author, was the course instructor and remained blind to who was participating. The preservice teachers were not required to participate in the research portion, but all consented to do so. All instruments were distributed on the first day of class, and the preservice teachers were provided class time in which to respond to the items. It is estimated that filling out the instruments required one and a half hours of the three-hour session.

To measure the preservice teachers' NOS understandings, we used The Views of Nature of Science version B (VNOS-B) instrument (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). A subset of five students (approximately 25%) were randomly selected and interviewed to establish valid interpretation of the questionnaire responses to allow students to elaborate on their responses.

To determine the preservice teachers' views of scientific inquiry, we used The Views of Scientific Inquiry (VOSI-E) instrument (Lederman & Ko, 2004). A subset of five students (approximately 25%) were randomly selected and interviewed to establish valid interpretation of the questionnaire responses to allow students to elaborate on their responses.

We assessed metacognitive awareness using the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). Schraw and Dennison reported a Cronbach reliability of .90. The MAI is divided into the subscales of Knowledge of

Cognition (KoC) and Regulation of Cognition (RoC). KoC measures an awareness of one's strengths and weaknesses, knowledge of strategies, and when to use strategies. RoC measures knowledge about planning, implementing, monitoring, and evaluating strategy use.

We used the Learning Context Questionnaire (LCQ) (Kelton & Griffith, 1986) to measure the preservice teachers' ethical and intellectual developmental levels. This instrument was developed and validated for use with college students, and consists of 50 items (26 of which are scored) that are marked on a six-step scale from "strongly agree" to "strongly disagree." The authors report an alpha reliability of .77. The questionnaire sorts the student responses into the Perry Positions of dualism, multiplicity, contextual relativism, and dialectical commitment to relativism.

We used the Schwartz Values Inventory (SVI) (Schwartz, 1992) to describe participants' cultural values on ten subscales: (1) universalism, (2) benevolence, (3) tradition, (4) self-direction, (5) stimulation, (6) hedonism, (7) achievement, (8) power, (9) conformity, and (10) security. This quantitative Likert scale instrument has been validated and used with numerous students and teachers in at least 20 countries. Schwartz reported reliabilities ranging from .55 to .75 for the various SVI subscales.

We adapted the Stages of Concern (SOC) Questionnaire (Hord, Rutherford, Huling-Austin, & Hall, 1987) to measure preservice teachers' concerns related to teaching NOS. This instrument always requires modification because it is generic as to the type of concern that is being measured—that is, researchers need to add the terms that are of concern to the researcher. In our case, we modified it by adding the term "Nature of Science, or the ways that science differs from other ways of knowing." This model suggests that a learner progresses through a series of SOC about adopting a new intervention: awareness, information, personal, management, consequence, collaboration, and refocusing.

We used the Science Teaching Efficacy Belief Instrument (STEBI-A) (Enochs & Riggs, 1990) to assess self-efficacy. This scale is divided into the Science Teaching Outcome Expectancy (STOE) scale and the Personal Science Teaching Efficacy (PSTE) belief scale. The PSTE scale has an alpha reliability of .90. The STOE scale has an alpha reliability of .76.

We used the Science Attitude Scale (SAS) (Thompson & Shrigley, 1986) to measure attitudes toward teaching science. The SAS consists of four subscales: (1) comfort (teaching science), (2) need (for science teaching), (3) time (willingness to devote time to teach science), and (4) equipment (willingness to use equipment and do hands-on science). The alphas are as follows: .77 for the comfort scale, .63 for need, .79 for time, .64 for equipment, and .89 overall.

Data Analysis

Preservice teacher responses to the VNOS-B and VOSI surveys and interviews were tabulated, and then views were coded independently by each researcher as either *informed* (indicating a fully developed understanding of the NOS or inquiry aspect), *adequate* (indicating a developing view), or *inadequate* (indicating a misconception was held by the student). The interviews allowed us to elaborate on and clarify student responses. Additionally, the interviews allowed us to validate our interpretation of the written survey responses, enabling us to ascertain whether we were interpreting the written responses accurately. The researchers'

analyses were compared and discrepancies were resolved through discussion or consensus.

To develop the NOS SOC profiles, we followed the procedure described by Hord et al. (1987). For all other scales, the scores were totaled. Using NOS views as categories (*inadequate*, *adequate*, and *informed*), we compared scale scores using Analysis of Variances (ANOVAs) and *t*-tests. These two methods of statistical comparison rest on assumptions of normality and homogeneity of variance. To examine normality, histograms of responses for each variable were examined to see whether or not the variable was continuous and unimodal. Then, descriptive statistics were employed to ascertain the skewness and kurtosis for each variable (see Table 1). The Levene's Test was used to determine if the assumption of homogeneity of variance was met. Statistical comparisons for which these assumptions were not met were excluded from further analyses. In a similar fashion, we used ANOVAs to compare preservice teachers scale scores in different SOC categories. A null hypothesis of *no difference* was rejected when the *p*-value exceeded 0.05.

Results

We first present the results regarding NOS views in terms of their being either adequate or inadequate. No preservice teachers were found with informed views of any of the NOS aspects explored. We then present both descriptive results and statistical comparisons. See Table 1 for a list of descriptive statistics.

Views of NOS

Regarding the tentative nature of science, 17 preservice teachers held adequate views, with most of those views being that science will change with added information (i.e., having an "add-on" view of science). The other four preservice teachers held inadequate views of the tentative NOS, not acknowledging that science will change, but that it was certain knowledge.

All preservice teachers but one held the view that "seeing is believing" and therefore one has to see evidence in order to come to a scientific conclusion, indicating an inadequate view of the distinction between observation and inference. One preservice teacher indicated that scientists did not actually have to see data but did not know how scientists make claims if they do not actually view the data.

Regarding the distinction between theory and law, only one preservice teacher held an adequate view. Another preservice teacher believed that laws were facts and theories were not, indicating a view that laws were a better form of scientific evidence. The remaining preservice teachers held inadequate views with all but one stating that theories become laws with enough evidence.

Seventeen of the preservice teachers held inadequate views of the empirical NOS, generally believing that scientists collect their data through one single scientific method. Four preservice teachers held adequate views of the empirical NOS by acknowledging that scientists require evidence to make claims.

Eleven preservice teachers held adequate views of the role of creativity and imagination in scientific claims. These preservice teachers acknowledged that scientists need to be creative to interpret data and design investigations. Ten preservice teachers held inadequate views of the role of creativity and imagination, noting that if scientists used creativity and imagination then they would not come up with accurate results.

Regarding the subjective and sociocultural NOS, 12 preservice teachers held adequate views, describing that scientists interpret the data differently; however, they were not able to describe what influences scientists to interpret data differently. Nine preservice teachers held inadequate views of NOS, with most of these preservice teachers believing that if the scientists had more data, they would all agree on the interpretation of that data.

Table 1. Descriptive Results for Possible Components of Preservice Teachers' Learner Characteristics for NOS

Subscale	N	Range	Possible Range	Mean	Standard Deviation	Skewness	Kurtosis
SAS Total	21	34-79	22-110	49.1	10.3	1.07*	2.29*
SAS Comfort	21	17-42	9-45	25.0	6.1	1.37*	2.69*
SAS Need	21	5-14	5-25	7.7	2.3	1.20*	1.46
SAS Time	21	3-12	3-15	5.0	2.1	1.91*	5.36*
SAS Equipment	21	7-18	5-25	11.5	2.8	0.28	-0.25
STEBI-A	20	31-51	13-65	38.3	5.4	0.51	-0.05
STOES	20	18-40	12-60	30.6	5.6	0.01	0.09
Knowledge of Cognition	21	153-228	25-250	200.8	20.2	-0.85	0.03
Regulation of Cognition	21	92-175	19-190	138.5	21.5	-0.62	-0.20
LCQ	21	85-123	26-130	103.6	10.3	0.23	-0.58
Self-Direction	21	21-30	6-30	26.7	2.3	-0.84	0.49
Stimulation	20	8-13	3-15	11.0	1.3	-0.67	-0.29
Hedonism	21	5-10	2-10	8.5	1.0	-2.19*	6.40*
Achievement	21	19-24	5-25	21.7	1.6	-0.13	-1.04
Power	21	8-21	5-25	15.2	2.8	-0.45	1.68
Security	21	23-35	7-35	29.0	3.0	-0.36	-0.22
Conformity	21	13-19	4-20	16.4	1.5	-0.63	-0.04
Tradition	21	13-24	5-25	18.1	2.6	0.46	0.38
Spirituality	21	11-20	4-20	16.4	2.0	-0.70	1.30
Benevolence	20	27-35	7-35	31.8	2.4	-0.49	-0.71
Universalism	21	29-40	8-40	34.8	3.5	-0.16	-1.59

Note: The *skewness* and *kurtosis* values indicated with an asterix (*) are those that indicate a non-normal distribution according to the significance tests for skewness and kurtosis values described by Tabachnick and Fidell (1989).

Descriptive Results

These descriptive statistics can be useful for both characterizing this study's sample and for highlighting limitations for future statistical comparisons. With respect to the SAS scale, the preservice teachers showed a wide range of comfort with respect to science teaching, and most of the teachers were neither very comfortable nor very uncomfortable. The SAS need and time scales indicate that the vast majority of the preservice teachers in this sample appreciated the need to teach science and were willing to take time to teach and prepare to teach science. In regards to using science equipment, overall, the teachers felt anywhere from supportive to neutral towards using science equipment and conducting demonstrations. Unfortunately, the SAS scale *skewness* and *kurtosis* values suggest that these variables have a non-normal distribution and could not be used for further statistical analyses relying on the assumption of normality.

The self-efficacy STEBI-A and STOE scale scores suggest that the preservice teachers were mostly neutral with respect to their perceived self-efficacy and

outcome expectancy. The restricted range for the outcome expectancy measure, however, indicates that this sample did not contain participants that held particularly low outcome expectancies.

The MAI scales indicated that the sample scored quite high on knowledge of cognition. The knowledge of cognition range is restricted in that this sample did not contain any individuals with low knowledge of cognition scores. Similarly, the regulation of cognition scores suggest that this sample did not contain individuals with low regulation of cognition scores.

The LCQ scores indicate that this sample had very high intellectual development compared to previous studies (Akerson & Buzzelli, 2007; Akerson, Buzzelli, & Donnelly, 2007). In this sample, only one preservice teacher could be labeled as *dualistic*. Accordingly, eight preservice teachers could be categorized as *multiplicity*, nine preservice teachers as *relativism*, and three preservice teachers as *dialectic*.

The SVI results suggest that the preservice teachers maintain that many of the listed values are very important. For the most part, the preservice teachers valued self-direction, hedonism, achievement, security, conformity, spirituality, benevolence, and universalism very much. The only listed values that the participants did not find particularly important were power and tradition. Several of the SVI subscales, including self-direction, achievement, security, conformity, benevolence, and universalism, had a restricted range. For each of these subscales, this sample contained no individuals who did not find these values important. Only the hedonism subscale demonstrated skewness and kurtosis to such an extent that further statistical analyses relying on the assumption of normality could not be performed.

As one might expect, the preservice teachers' SOC for NOS results indicate that most preservice teachers could be categorized as nonusers of NOS intervention strategies. Nine preservice teachers had nonuser profiles that are characterized by not knowing much about NOS, wanting information, and concerned about how NOS instruction may impact them personally. Seven preservice teachers had SOC profiles that had two peaks—one for non-users and one for collaborative concerns. These individuals have the same concerns of other nonusers but are also concerned about how using NOS will fit within the context of what other teachers are doing. The remaining preservice teachers fit into four other categories of concerns: (1) nonusers concerned with management of NOS instruction, (2) nonusers concerned with the consequences of using NOS instruction, (3) nonusers wanting to refocus NOS instruction, and (4) individuals seeking more information about NOS instruction while concerned about management.

Comparisons of Learner Characteristics Related to NOS Views

Using *t*-tests and ANOVAs, the values, attitudes, self-efficacy, metacognitive awareness, and the developmental levels of preservice teachers classified as *adequate* and *inadequate* with respect to different aspects of NOS were compared. Preservice teachers with adequate and inadequate views differed on a number of subscales.

Students with different degrees of sophistication in their NOS views differed with respect to several of the SVI cultural values. Preservice teachers who have inadequate views of the tentative NOS value spirituality ($t_{(19)} = 3.73$, $p < 0.01$) and tradition ($t_{(19)} = 2.34$, $p < 0.05$) more than their adequate peers. Specifically, the 17 preservice teachers with inadequate views of the tentative NOS had a mean spirituality score of 17.0 while their four peers with adequate views of tentativeness

had a mean spirituality score of 13.8. Similarly, the 17 preservice teachers with inadequate views of tentativeness had a mean tradition score of 18.8 while their four peers with adequate views of tentativeness had a mean tradition score of 15.8. Furthermore, preservice teachers who have adequate views of the creative aspect of NOS value stimulation ($t_{(18)} = -2.11$, $p < 0.05$) and security ($t_{(19)} = -4.36$, $p < 0.001$) more than their inadequate peers. Specifically, the 13 preservice teachers with adequate views of scientific creativity had mean stimulation and security scores of 11.4 and 30.6 while their eight peers with inadequate views had mean stimulation and security scores of 10.3 and 26.4, respectively. Additionally, preservice teachers who have inadequate views of the cultural aspect of NOS value self-direction ($t_{(18)} = 2.11$, $p < 0.05$) more than their adequate peers. Specifically, the ten preservice teachers with inadequate views of the cultural NOS aspect had a mean self-direction value score of 27.7, while their 11 peers with adequate views had a mean self-direction score of 25. Finally, preservice teachers with inadequate views of the subjective NOS tended to value security ($t_{(19)} = 2.68$, $p < 0.05$) more than their adequate peers. In fact, the 11 preservice teachers with inadequate views of the subjective NOS had a mean security subscale score of 30.5 while the ten preservice teachers with adequate subjective-NOS scores had a mean security subscale score of 27.4. In summary, preservice teachers with differing NOS sophistication differed in the extent to which they valued spirituality, tradition, stimulation, security, and self-direction.

Preservice teachers' attitudes toward teaching science could not be compared according to their NOS conceptions because the SAS scale scores violated the assumption of normality. Preservice teachers' metacognitive awareness was also related to their views of NOS. Preservice teachers with inadequate views of the subjective NOS have higher knowledge of cognition (awareness of one's strengths and weaknesses) than their adequate peers ($t_{(19)} = 2.88$, $p < 0.05$). Specifically, the 11 preservice teachers with inadequate views of the subjective NOS aspect had a mean KoC value score of 211.2, while their ten peers with adequate views had a mean KoC score of 189.4. Preservice teachers' regulation of cognition was not found to be related to the sophistication of their NOS views.

Preservice teachers with varying degrees of NOS sophistication did not significantly differ with respect to their self efficacy, outcome expectancy, regulation of cognition, and developmental levels. The finding of a lack of significant difference may be related to the restricted range present in the outcome expectancy and developmental level—only one dualist—data.

Preservice teachers in the different categories of concern for teaching NOS were also compared with respect to the various subscales. None of the subscale scores differed for the different categories of preservice teachers' concerns about teaching NOS.

Discussion

We have found many interesting relationships among learner characteristics and preservice teachers' NOS views. We will discuss the statistically significant relationships identified in the "Results" section for the learner characteristics of cultural values and metacognitive awareness in the following paragraphs. These particular relationships could indicate important learner characteristics to attend to when planning NOS instruction and in developing NOS conceptual ecologies.

The relationships between NOS views and cultural values produced interesting patterns. First, preservice teachers who held inadequate views of the tentative

NOS value spirituality and tradition more than those who held adequate views. We might expect this relationship because those who believe that science does not change may value other ways of knowing that are not subject to change such as spirituality and cultural traditions. Additionally, in previous studies, we have found that preservice teachers with inadequate views of tentative NOS tend to be more dualistic (Akerson & Buzzelli, 2007). Next, preservice teachers with adequate views of the creative NOS valued stimulation. This makes sense in that preservice teachers who value creativity are more likely to recognize it in what scientists do. Preservice teachers who held adequate views of scientific creativity were also more likely to value security. This finding might be surprising in that it is not consistent with the "risk-taking" that one might associate with creativity, but it may also help preservice teachers feel secure that scientists are more similar to them rather than having an image of scientists as cold and distant people who hold special knowledge that is inaccessible to everyone else. Preservice teachers with inadequate views of the sociocultural NOS value self-direction more than those who hold adequate views. An explanation for this seemingly surprising result is that perhaps these preservice teachers value independence so highly that they do not recognize the socially embedded construction of knowledge. Finally, preservice teachers who held inadequate views of subjectivity valued security more than those who held adequate views of subjective NOS. This result can be explained by considering that those who do not recognize science as subjective seem to value a secure world in which results do not need to be interpreted but merely speak for themselves.

Regarding metacognitive awareness, preservice teachers who held inadequate views of the subjective NOS had higher KoC than those with adequate views of subjectivity. This group is very much aware of their own strengths and weaknesses and their strategies for learning. This group does not recognize that scientific evidence is interpreted through individual scientists' background knowledge, however. This result is surprising and requires more research to explore.

Despite results of this study that indicate there is no relationship between intellectual levels and NOS views, we still believe there are substantial relationships between those two constructs. For one thing, we had a small range of intellectual levels in this study, with most preservice teachers at the higher ends of the intellectual levels and only one at the dualist level, meaning we did not have much variance in our preservice teachers on this construct. Additionally, prior research has shown that most preservice teachers hold inadequate views of many NOS aspects; however, the qualitative flavor of these inadequate views differ as related to intellectual level (Akerson & Buzzelli, 2007). The current study did not explore the qualitative differences among NOS views by intellectual level and, therefore, this result may be embedded in the data.

Implications for Preservice Elementary Teacher Education

Preservice teachers come to the science methods classroom holding many cultural values. We are not advocating that science educators change these values but that they recognize their existence and develop strategies that ameliorate tensions that may exist for some students in attaining adequate NOS views for some elements. For instance, science educators need to recognize that many preservice teachers strongly value security, spirituality, and tradition. As such, we need to find teaching approaches for improving views of tentative, creative, and subjective NOS without threatening these ways of knowing that our preservice

teachers believe are not subject to change. Southerland et al. (2006) recommend adding a "bounded" NOS emphasis that may help categorize how science is a different, but not a better way of knowing than those that are not subject to change. Further exploration should be conducted to determine whether this "bounded" distinction can make a difference. In addition, for preservice teachers who strongly value self-direction, special emphasis may need to be placed on the social embeddedness of scientific knowledge.

One of the most important outcomes from a science methods class is for preservice teachers to envision themselves teaching science; therefore, we want to move them along the SOC for NOS instruction. In this study, most teachers were unaware but interested in NOS pedagogy and possibly concerned about how the use of such an innovation might affect them. Hord et al. (1987) recommend the following strategies for intervention managers to facilitate the adoption of an intervention: (1) develop supportive organizational arrangements (e.g., developing institutional plans for NOS instruction of preservice teachers, (2) training (e.g., modeling and observing NOS instruction), (3) consultation and reinforcement (e.g., coaching and providing practical assistance for NOS instruction), (4) monitoring (e.g., gathering information assessing usage and concerns about NOS instruction), (5) external communication (e.g., presenting NOS instruction at conferences), and (6) dissemination (e.g., making NOS instructional materials available). Given the number of preservice teachers in this study who held collaborate concerns (i.e., who were concerned about how NOS instruction might fit in with what other teachers were doing) indicates the *National Science Education Standards* for NOS instruction need to be emphasized, as well as providing role models of inservice teachers who are currently emphasizing NOS in their science instruction.

References

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but . . . . *Journal of Science Teacher Education, 12*, 215-233.

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education, 88*, 785-810.

Abell, S. K., & Smith, D. C. (1994). What is science? Preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education, 16,* 475-487.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*, 269-287.

Akerson, V. L., Abd-El-Khalick, F. S., & Lederman, N. G. (2000). The influence of a reflective activity-based approach on elementary teachers' conceptions of the nature of science. *Journal of Research in Science Teaching, 37,* 295-317.

Akerson, V. L., & Buzzelli, C. A. (2007). Relationships of preservice early childhood teachers' cultural values, ethical and cognitive developmental levels, and views of nature of science. *Journal of Elementary Science Education*, *19*(1), 15-24.

Akerson, V. L., Buzzelli, C. A., & Donnelly, L. A. (online version published December 2007). Early childhood teachers' views of nature of science: The influence of intellectual levels, cultural values, and explicit reflective teaching. *Journal of Research in Science Teaching.*

Akerson, V. L., Morrison, J. A., & McDuffie, A. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*, 194-213.

Alsop, S., & Watts, M. (1997). Sources from a Somerset Village: A model for informal learning about radiation and radioactivity. *Science Education, 81*, 633-650.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Barufaldi, J. P., Bethel, L. J., & Lamb, W. G. (1977). The effect of a science methods course on the philosophical view of science among elementary education majors. *Journal of Research in Science Teaching, 14*, 289-294.

Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*, 610-645.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice.* New York: Teachers College Press.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics, 90*, 694-706.

Haidar, A. H. (1999). Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education, 21*, 807-822.

Hanson, D. L. (2006). *Personal definitions of science and the self-efficacy and classroom practice of elementary school teachers.* Unpublished doctoral dissertation, Indiana University, Bloomington.

Hord, S. M., Rutherford, W. L., Huling-Austin, L., & Hall, G. E. (1987). *Taking charge of change.* Alexandria, VA: Association for Supervision and Curriculum Development.

Kelton, J., & Griffith, J. V. (1986). *The learning context questionnaire for assessing intellectual development.* Unpublished manuscript, Davidson College, Davidson, NC.

Lederman, J. S., & Ko, E. (2004). *Views of scientific inquiry, form E*. Unpublished paper, Illinois Institute of Technology, Chicago.

Lederman, N. G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching, 29,* 331-359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

National Science Teachers Association (NSTA). (2000). NSTA position statement: The nature of science. Retrieved January 29, 2008, from www.nsta.org/159&psid=22.

Perry, W. G. (1999). *Forms of ethical and intellectual development in the college years: A scheme.* San Francisco: Jossey-Bass.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*(2), 167-199.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19,* 460-475.

Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. *Advances in Experimental Social Psychology, 25,* 221-279.
Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88,* 610-645.
Shapiro, B. L. (1996). A case study of change in elementary student teacher thinking during an independent investigation in science: Learning about the "Face of science that does not yet know." *Science Education, 80,* 535-560.
Southerland, S. A., Johnston, A., & Sowell, S. (2006). Describing teachers' conceptual ecologies for the nature of science. *Science Education*, *90*(5), 874-906.
Tabachnick, B. G., & Fidell, L. S. (1989). *Using multivariate statistics* (2nd ed.). New York: Harper & Row Publishers.
Thompson, C. L., & Shrigley, R. L. (1986). What research says: Revising the *Science Attitude Scale. School Science and Mathematics, 86,* 331-343.
Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*, 771-783.
Tsai, C. (2006). Reinterpreting and reconstructing science: Teachers' view changes toward the nature of science by courses of science education. *Teaching and Teacher Education, 22*, 363-375.

Correspondence regarding this article should be directed to

Valarie L. Akerson
Associate Professor
Science Education
Indiana University
201 N. Rose Avenue
Bloomington, IN 47405
vakerson@indiana.edu
(812) 856-8140

Manuscript accepted December 11, 2006.