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Middle School Science and Mathematics Teachers' Conceptions of the Nature of Science: A One-Year Study on the Effects of Explicit and Reflective Online Instruction

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Abstract

Science, Technology, Engineering, and Mathematics (STEM) education has become one of the main priorities in the United States. Science education communities and researchers advocate for integration of STEM disciplines throughout the teaching curriculum. This requires teacher knowledge in STEM disciplines, as well as competence in scientific literacy. Since nature of science (NOS) is a critical component of scientific literacy, this study examined teachers' conceptions NOS over a one-year period. Participants included 21 middle school science and mathematics teachers who integrated science and mathematics in their classrooms. We employed two NOS instruments to collect data on participants' NOS conceptions *before* and *after* a one-year online graduate program. This study examined changes in NOS understanding for the group as a whole, between science and mathematics teachers, and whether beginning and experienced teachers differed in their conceptions of NOS. Findings show that the teachers' conceptions of NOS improved significantly after two semesters of explicit, reflective NOS instruction. There was no significant difference between science and math teachers' conceptions of NOS. The notion that science teachers know just as much about NOS as mathematics teachers indicates that science teachers in the U.S. are just as unfamiliar with the nature of science as mathematics teachers. In addition, years of experience did not play a role in the participants' conceptions of NOS. Examination of teachers' conceptions of NOS will help researchers, teacher educators and teacher professional development providers gain insight on ways to develop STEM teachers' conceptions of NOS.

Key words: Nature of science; Science and mathematics integration; STEM; Middle school teachers

Introduction

Increasing scientific literacy has been a driving force behind science education reform (DeBoer, 2000). The National Research Council's (2012) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* highlighted the nation's need for scientifically literate citizens who understand the field of science and the scientific endeavor. The *Next Generation Science Standards* (NGSS) state that "One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge" (NGSS Lead States, 2013, Appendix H, p.2). One critical component of scientific literacy is knowledge on the nature of science (NOS) (Lederman, 2007). To understand the nature of scientific knowledge, and be scientifically literate, one must have accurate conceptions of NOS.

Although there is no singular definition for NOS, it has been described as, "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). It is also, "the intersection of issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and potentially impact science teaching and learning" (McComas, Clough, & Almazroa, 1998, p. 5). NOS is critical for teachers and learners of science since it authentically describes what science is, how it happens, and how scientific knowledge develops (AAAS, 1993; NSTA, 2000). McComas et al. (1998) argue that teachers must hold developed conceptions of NOS in order to teach science in authentic ways. Teachers must teach science in authentic ways so that students gain realistic conceptions of science and how it is practiced in real-world settings.

Teachers are integral negotiators of science content and curriculum in the classroom (Ramsey & Howe, 1969). It is imperative that teachers have an accurate view of NOS in order to include NOS in the science classroom and to lay the foundation for future learning and understanding of the disciplines of science, technology,

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engineering, and mathematics (STEM). Although teachers need developed conceptions of NOS, studies have consistently found that preservice and practicing teachers possess naive and incoherent understandings of NOS (Akerson, Morrison, & McDuffie, 2006; Dogan & Abd-El-Khalick, 2008; Firestone, Wong, Luft & Fay, 2012). This is exacerbated by the fact that science teaching practices and materials often do not specifically address NOS, and tend to emphasize science content over the processes and development of scientific knowledge (McComas et al., 1998). In addition, many studies have focused on science teachers' views of NOS in science settings. With the current call for integrated curriculum in the STEM fields (NGSS Lead States, 2013; National Research Council [NRC], 1996), further research is needed to explore the NOS understandings of teachers in other content areas, such as mathematics teachers, that integrate science in their classroom instruction.

Currently, there is a growing deficit in the STEM workforce in the U.S. (Gerlach, 2012). In order to remain competitive in the innovative world market, business, government and educators have called for integrated STEM education in U.S. classrooms (Bybee, 2010; Gerlach, 2012). Researchers have concurred that integrated curriculum can be beneficial for students learning of concepts (e.g., Czerniak, Weber, Sandmann & Ahern, 1999; Moscovici & Newton, 2006; Vars, 1991). Therefore, it is important for STEM teachers to have developed literacies in the different fields in order to effectively teach integrated STEM curriculum in the classroom. To gain insight into the knowledge base of teachers that integrate STEM in the classroom, and better learn how to support them, it is imperative that more is learned about what teachers know about the fields they are incorporating in their instruction. Specifically, it is important to assess how teachers' conceptions of NOS influence the integration of science with other content areas, such as mathematics. Teachers need access to professional and educational opportunities that emphasizes NOS in order to teach science in a way that authentically represents what science is and how it happens. These opportunities may be especially pertinent to non-science middle school teachers that integrate science with other content areas in the classroom.

This study explored how teachers who integrate science and mathematics in the classroom develop their conceptions of NOS. The research questions that guided this study were: (1) What were middle school science and mathematics teachers' conceptions of NOS before and after two semesters of online explicit and reflective NOS instruction? (2) How does science and mathematics teachers' NOS conceptions differ before and after two semesters of online explicit and reflective NOS instruction? (3) How do beginning and experienced teachers' NOS conceptions differ before and after two semesters of explicit and reflective NOS instruction?

Review of the Literature

Position statements over the past 40 years from the National Science Teachers Association (2003), Science for All Americans (American Association for the Advancement of Science [AAAS], 1990), and *Next Generation Science Standards* (NGSS Lead States, 2013) call for sophisticated conceptions of NOS to be added as important learning outcomes in science education. Scientists and science education researchers have embraced these documents and have worked towards helping students develop informed conceptions of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Duschl, 1990; Meichtry, 1993). Although there have been countless efforts to increase teacher conceptions of NOS, teachers continue to hold naïve conceptions of NOS (e.g., Abd-El-Khalick & Lederman, 2000; Akerson & Hanuscin, 2007; Duschl, 1990; Lederman, 1992; Ryan & Aikenhead, 1992).

Research on teacher development supports the need for teachers to have access to explicit educational and professional opportunities in order to develop more sophisticated views of NOS. Gess-Newsome (2002) found that preservice teachers in an elementary science methods course held more developed views of NOS after explicit NOS instruction. After a five-day professional development (PD) program, that explicitly taught NOS concepts integrated with language arts, Deniz and Akerson (2013) found that elementary teachers developed a better conceptions of NOS concepts and improved science teaching self-efficacy beliefs. Studies demonstrate that teachers need explicit NOS instruction in order to include aspects of NOS in lesson plans (Abell, Martini & George, 2001; Bell, Lederman & Abd-El-Khalick, 2000). This explicit instruction involves the planning and purposeful teaching of NOS concepts rather than expecting conceptions to occur as a byproduct of teaching strategies (Aikenhead, 1988 as cited by Lederman, 1999; Goeke, 2009).

However, explicit instruction alone is not enough. Research supports the need for teachers to engage in sustained NOS educational opportunities in order to develop and maintain more sophisticated conceptions of NOS (Akerson & Hanuscin, 2007; Akerson, et al., 2006). Akerson, et al., (2006), found that pre-service elementary teachers' views of NOS was improved after a one semester science methods course that incorporated explicit NOS instruction, but reverted back to their naïve views five months after the instruction concluded. Akerson and Hanuscin's (2007) study supported the need for sustained explicit NOS instruction for teachers by finding that a 3-year professional development program maintained improvement of elementary teachers' views of NOS and science pedagogy during the study period.

Characteristics of NOS

Lederman (2007) identified seven specific aspects of NOS that students should understand. First, students should recognize the difference between observations from inferences (Lederman, 2007). Second, students should recognize the delineation between a scientific law and scientific theory, and recognize that both types of scientific knowledge are valued in the field of science. Third, scientific knowledge relies on observations of phenomena, as well as human creativity and imagination. Fourth, scientific knowledge is influenced by beliefs, prior knowledge, preparation, experiences, and expectations. Scientific knowledge is also theory-laden and subjective to the individual. The fifth aspect of NOS students should know is that science is embedded within socio-cultural contexts where it is influenced by factors such as, "social fabric, power structures, politics, socioeconomic factors, philosophy, and religion" (Lederman, 2007, p. 833). Sixth, scientific knowledge is not absolute. Scientific theories, laws and facts are all subject to change as new evidence is discovered. Seventh, NOS is not synonymous with scientific inquiry or scientific processes (Lederman, 2007). It is critical that teachers develop sophisticated conceptions of these seven characteristics of NOS in order to foster students' conceptions of NOS and cultivate scientific literacy.

The Importance of Integration

Currently, there is a movement to integrate science and mathematics instruction in the STEM fields. The *Next Generation Science Standards* (NGSS) emphasize integration because science and mathematics are linked to engineering applications (NGSS Lead States, 2013). Similarly, the *National Science and Education Standards* (National Research Council [NRC], 1996) support integration because it can advance students' conceptions and applications of both subjects. The *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) also support integration because the "process and content of science can inspire an approach to solving problems that applies to the study of mathematics" (p. 66).

Numerous educational researchers have also advocated for an integrated curriculum (e.g., Bybee, 2010; Czerniak et al., 1999; Frykholm & Glasson, 2005; Kiray, 2012; Moscovici & Newton, 2006; Smith, Douglas, & Cox, 2009). Czerniak et al., (1999) found integration to be an authentic approach to education, while others found that integration improves student achievement (Beane, 1995; Vars, 1991). Integration has also been found to improve student engagement in the subject areas (Bragow, Gragow, & Smith, 1995; Greene, 1991; McComas & Wang, 1998). In middle school, integration can support learning when students are given opportunities to be actively engaged in challenging and authentic interdisciplinary problem-solving activities (Moscovici & Newton, 2006). An integration approach may also alleviate misconceptions regarding science and mathematics concepts (Moscovici & Newton, 2006).

It is imperative for both science and mathematics teachers who integrate science in their instruction to have a solid understanding of NOS. Science teachers often incorporate mathematics in their classes, as mathematics is used to teach scientific concepts, such as scientific laws and formulas. Mathematics teachers, in turn, use science examples to teach math because it provides a source of real-world examples of math in relatable contexts, and assist students to recognize math's role in other disciplines. Consequently, the integration of science into other content areas can lead to accurate conceptions of science, increased student achievement, and interest in science (Beane, 1995; McComas & Wang, 1998; Moscovici & Newton, 2006; Vars, 1991).

Currently, there is limited research on science and mathematics teachers' understanding of NOS. There is also limited research on middle school teachers' NOS conceptions, as most research focuses on preservice teachers, or teachers at the elementary level. Specifically, there is limited research on the NOS conceptions of science and mathematics teachers that integrate the two content areas in their classroom instruction. Therefore, this study will explore the NOS conceptions of middle school science and mathematics teachers that integrate the two subjects in their classroom instruction.

Theoretical Framework

This study was framed with a constructionist perspective, which presumes that individuals and groups interact within their environment, and that these interactive experiences generate meaning. Constructionism is, "the view that all knowledge, and therefore all meaningful reality, is contingent upon human practices, being constructed in and of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 1998, p. 42). Therefore, in this study, we viewed participants as interacting to find meaning and relevance, and designed the research methods and classroom activities to maximize the interaction between individuals, groups, and resources. This, in turn, elucidated participants' understanding of NOS over time.

Methods

This study utilized quantitative measures to understand participants' conceptions of NOS over a one-year period. Following is a description of the methods used to address the research questions.

Description of iSMART

Integrated Science Mathematics and Reflective Teaching (iSMART) is a two-year cohort-based online graduate program on the pedagogy and theoretical underpinnings of science and mathematics teaching, as well as integration of both content areas. Middle school science or mathematics teachers (grades 4-8) attended iSMART in Texas. The teacher participants initially met in person for a 1-week summer conference before their first semester. During this conference, participants engaged in activities that focused on topics relevant to science and mathematics education. Participants also learned about iSMART program expectations, as well as how to use technology tools pertinent to the program such as the online platform in which classes took place. They also began projects as part of their first semester courses.

Throughout the academic year, students participated in online courses. All science and mathematics methods iSMART courses took place via Blackboard Collaborate, an online platform that allowed for interactions in real time. The classes were synchronous, so that everyone in the course was online simultaneously and able to interact via the platform. This allowed for the participants and the instructor to engage in activities, discussions, group work, and presentations together. The platform was housed in Blackboard that provided avenues for students to access course readings, assignments, and discussion boards asynchronously.

In the fall semester, the teachers engaged in a science education methods course and a mathematics education course. In the spring semester, they participated in an additional science education course as well as a mathematics education course. All iSMART participants engaged in explicit and direct NOS instruction and activities during science education courses, which occurred during both semesters. After the first academic year, students returned to campus for a second week-long summer conference. Participants again engaged in activities on science and mathematics education, technology tools, and program expectations. For a complete description of iSMART, please see Lee, Chauvot, Vowell, Culpepper, & Plankis (2013).

Research Participants

The participants of this study (N=21) consisted of a cohort of 12 science and 9 mathematics middle school teachers enrolled in the iSMART program. Nineteen of the teachers were female and two were male. Of the participants, 18 were white, two were Hispanic, and one was African-American. Teachers had from 3 to 26 years of classroom experience at the start of the study. Of the participants, 18 worked in public schools, and three worked in private schools. Twelve teachers were traditionally certified, and 9 were alternatively certified. All teachers in the cohort gave consent to participate in this study.

Explicit and Reflective NOS Instruction

During the one-year period, participants engaged in activities during two online science methods courses that explicitly addressed the aspects of NOS described by Lederman (2007). The first author taught the first middle school science methods course (3 credit hours) during the fall semester. Another science education instructor taught a second middle school science education course (3 credit hours) during the spring semester that also addressed NOS. These classes were held every other week for three hours each. In total, the fall and spring science education classes met 7 times per semester.

The fall science methods course focused on helping the in-service teachers develop: (1) Inquiry-based instruction in the middle school classroom, (2) integration of science and mathematics content in the middle school classroom, (3) deeper science content knowledge, and (4) more sophisticated conceptions of NOS, as outlined by Lederman (2007). The course included inquiry-based activities and course discussions that explicitly addressed NOS concepts, including a) the tentative nature of science, b) the importance of examining new and existing evidence, c) the difference between observations and inferences, d) the distinction between scientific laws and theories, e) scientific knowledge is developed via multiple methods, f) science is subjective to prior knowledge, beliefs, and values, and g) creativity is required throughout the entire scientific endeavor.

The course included opportunities for students to reflect explicitly on NOS, such as discussion board prompts. These prompts were housed on Blackboard and included individual reflections on the topics as well as responses to other students' posts. The following is an example of reflective responses to a prompt regarding a reading related to NOS:

> Prompt: What is the nature of science? After reading Lederman's seven aspects about NOS all students should know, did any of them surprise you, or conflict with what you understood about NOS prior to reading? If so, explain. What do you now know about NOS that you didn't know prior to class and the readings?

> Student 1: There were several aspects of NOS that surprised me or conflicted with my beliefs and understandings. First, I was surprised that creativity, invention and imagination were considered part of the nature of science. I thought that science was more orderly and rational.

> Student 2: After reading your discussion . . . it made me think about how we teach science. Most of the time we teach it in a very orderly and rationally fashion, maybe that is why we didn't think of science as creative. Most of the time there is not much inquiry involved in teaching science. We are usually on a set scope and sequence and making sure we teach what is required for the next test. This does not lend itself to a lot of inquiry, creativeness, or imagination in learning about science. In my perfect science world, I would be Ms. Frizzle, and every lesson would allow for creativity and imagination.

During the course, NOS concepts that were explicitly addressed were reinforced during subsequent class sessions so that students reviewed previously introduced NOS concepts over time. This was done so that students could build their understanding of NOS as they proceeded through the science methods course during the semester. Repeated opportunities to reflect on NOS were provided through class discussions and discussion board prompts. NOS was also integrated in course assignments. For example, NOS was a required component for written lesson plans and the teachers' analyses of their own classroom practices. This resulted in NOS ideas being cumulative, reviewed, and reflected upon throughout the semester.

The spring science methods course focused on (1) Constructivism and student learning, (2) scientific evidence vs. pseudoscience, (3) greater understanding of NOS, and (4) the difference between NOS and Nature of Mathematics (NOM). Concepts regarding NOS continued to be explicitly and reflectively addressed throughout the course via inquiry-based activities, readings, and course discussions. Specifically, this course addressed what constituted scientific evidence, as well as the role of social cultural context, beliefs, and values on the development of scientific knowledge.

Data Collection

Studies that use only paper and pencil short-answer or multiple choice tests have been criticized because they provide a limited level of detail about participants' NOS understanding. Interviews, on the other hand, can provide additional detail and insights into participants' NOS understanding. Therefore, using both a paper and pencil test and a semi-structured interview may provide multiple angles to view participant's conceptions of NOS. This studied included both forms of data collection to emphasize outcomes by allowing researchers to implement methods that best address the research questions (Creswell, 2013). In this study, participants completed the paper and pencil VNOS-C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) and the Modified VNOS-C Interview (Brown, Luft, Roehrig, & Fletcher, 2006).

The VNOS-C instrument is an open-response questionnaire with 10 prompts. A corresponding guide for scoring the responses to each prompt categorized responses as naïve or informed, or on two-point scale. For complete details on VNOS-C, see Lederman et al. (2002). Participants individually completed the VNOS-C before the start of the iSMART program (T0), and one year later after two semesters in the iSMART program (T1). Each participant was provided an electronic version of the instrument with only the prompts, and asked to type their responses on the electronic document. For both data collection points, participants were specifically asked to answer to the best of their ability without referencing any resources. Participants were allotted as much time as they needed to complete the instrument. Two researchers independently coded the blinded responses before collaborating on a final score based on the associated VNOS-C guide. The following is an example of responses for the prompt, "Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example."

Table 1. Coding example for responses on the VNOS-C question "Is there a difference between a scientific theory and scientific law? Illustrate your answer with an example?"

Response	Category	Explanation for categorization
I think that there is a fine line in the difference between scientific theory and scientific law. Theory is a "best guess" based on information that is already known and how that information has appeared to work together. Scientific law is theory that has been tested over and over again and has proven to be true. The Law of Gravity probably started out as a theory about what influenced objects staying "glued" to the ground. After lots of experiments and exploring, the idea and proving the theory true, it became the law of gravity.	Naïve	This respondent's statement contained misconceptions about scientific theories and laws. For example, the responses indicated that theories are not as certain as laws. It also indicated that there is a hierarchal relationship between theories and laws in that theories turn into laws after repeated testing.
Theories are explanations for events that happened. Laws are descriptions. The law of gravity describes what happens when an object is dropped or falls from an elevated surface. The theory of evolution is an explanation for something that happened and appears to keep happening. Theories do not turn into laws.	Informed	This response was categorized as informed because the response indicated that theories provide explanations for events, while laws describe them. This response also acknowledges that theories do not turn into laws over time through repeated testing.

The Modified VNOS-C Interview (Brown et al., 2006) is a semi-structured interview protocol based on VNOS-C. The interview was designed to include semi-structured prompts to allow for researchers to modify follow-up questions for clarification, detail, or insight on participant's views (Fylan, 2005). The instrument was also designed to develop a more nuanced view of participants' understanding of NOS by categorizing responses into three categories instead of two. Categorizing responses into three categories helps to elucidate the participants' level of NOS understanding.

The Modified VNOS-C Interview consists of probes on: 1) the discipline of science, 2) the scientific method, 3) advancement in science, 4) the role of experimentation, 5) the role of scientific theories and laws, and 6) science as a socially constructed entity. Rubrics were used to categorize responses as product, process, or situated. Product responses represented undeveloped NOS understandings. Process responses were more developed then product, but less developed than situated responses. Situated responses were sophisticated in NOS understanding. (For complete details on VNOS-C, please see Brown et al., 2006).

The first interviews occurred after the initial summer conference, prior to the first academic year (T0). The second interviews occurred after the second summer conferences, prior to the second academic year (T1). For both T0 and T1, participants were given the Modified VNOS-C Interview via phone, and their responses were audio-recorded for later analysis. After data collection, two independent researchers listened to the responses and coded responses using a rubric. The rubric categorized responses on a three point scale: product, process, and situated. Coding of responses followed the consensus model in which the two independent researchers collaborated to reach unanimous agreement and resolution (Herrera, Herrera-Viedma, & Verdegay, 1996) .

Table 2 illustrates how responses were coded for the Modified VNOS-C Interview the prompt, "What are the roles of theories and laws in science?" For statistical analyses, the scores were quantitized (Teddlie & Tashakkori, 2006) in which product was coded as "1", process was coded as "2", and situated was coded as a "3". Paired t-tests were conducted with the Modified VNOS-C Interview to explore whether participants' conceptions regarding NOS were represented in greater detail. Statistical analyses of the Modified VNOS-C Interviews also provided a means to compare responses from each participant on the VNOS-C and Modified VNOS-C Interview to check for consistency of participants' responses in regards to their conceptions of NOS.

Table 2. Coding example for Modified VNOS-C Interview question "What are the roles of theories and laws in science?"

Response	3-point	Explanation
Theory is just a very dressed up way of saying hypothesis. Means the same things, but theory is a more sophisticated vocabulary terms. A law is basically theories that people have embraced as law. So much evidence once a theory as x amount of evidence, so now it is a law. They are proven. Happens every time.	Product	Response indicated that scientific laws are absolute and proven.
Theory is explanation of observable phenomenon. Laws are descriptions. It's what scientists do to develop theories and laws. Natural human curiosity asks questions about the natural world. Why it works and way it is. Why patterns repeated. Have the laws to say, like law of gravity, every time we drop something it drops down. That is an observation of pattern in nature you see. Theory is why this does that. Have to have the questions, tentative explanation, but until you can replicate it, or show that it is something done over and over and observed over and over it won't become a theory.	Process	Response indicated that theories and laws are the result, or goal of science.
A theory is something that is explaining an observed phenomenon. It is based on best experimentation, and the best technology. It's the truth that we have at this point. It doesn't turn into a law like I used to think. Law is more of something that can be observed that happens every time. They are different. It's not linear situation. When I was in school, you have the hypothesis that leads to conclusion that leads to theory, and if it proves for period of time, it becomes a law. It's not law is something more graduated than a theory. Different thing than a theory. Scientists think about them when they plan experiment and interpret [the data].	Situated	Participant indicated understanding that theories and laws impact the processes of science.

Paired t-tests were used to compare the T0 and T1 scores of the participants on both the VNOS-C and the Modified VNOS-C Interview. A series of independent t-tests were conducted on both the VNOS-C and the Modified VNOS-C Interview to assess whether the science teachers' NOS scores and mathematics teachers' NOS scores were statistically significantly different from one another. Independent t-tests were then conducted to determine if years of experience (0-5 vs. 6 or more) played a factor in NOS conceptions on both instruments. The reason for choosing the dividing line for experience in teaching at 0-5 versus 6 or more is that teachers with less than 6 years of teaching experience are considered 'beginning teachers' (Luft et al., 2011). Teachers in this phase of their career are still acclimating to their new role as science and mathematics teachers and are more moldable in their practices when compared to their more experienced peers (Henry, Fortner, & Bastian, 2012; Luft, 2001).

Results

A set of paired-samples *t* tests was conducted to evaluate whether there was a significant difference between the participants' conceptions of NOS at T0 and T1 on both the original, written VNOS-C and the modified oral interview VNOS-C. Results from the written VNOS-C indicated that the mean conceptions of NOS at T1 (M = 1.64, SD = .26) was significantly greater than the mean conceptions at T0 (M = 1.08, SD = .09), $t(20) = -10.1$, $p < .01$. Results from the modified VNOS-C oral interview indicated that the mean understanding of NOS at T1 (M = 1.65, SD = .26) was significantly greater than the mean understanding at T0 (M = 1.3, SD = .17), $t(20) = -5.75$, $p < .01$ (see figure 1).

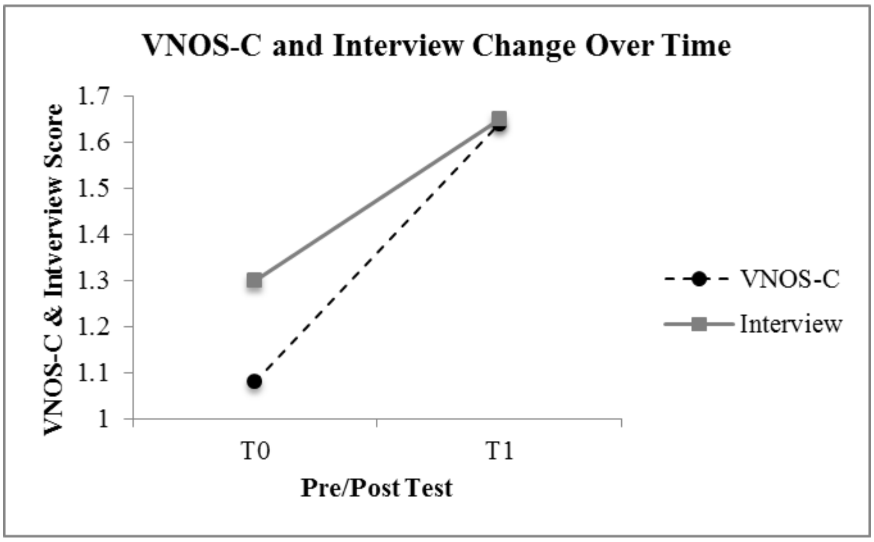

Figure 1. Change of VNOS-C and Modified VNOS-C Interview scores for all participants on both Pre/Post assessments

Several independent sample *t* tests were conducted to evaluate whether there was a significant difference between science teachers' and mathematics teachers' conceptions of NOS on the VNOS-C at T0 and T1. Additional independent sample *t* tests were also conducted to explore whether there was a significant difference between novice and experienced teachers on the VNOS-C at T0 and T1. Overall, there was no significant difference between science teachers (M = 1.09, SD = .089) and mathematics teachers (M = 1.05, SD = .074) on the VNOS-C at T0, $t(19) = -.918$, $p = .370$, $d = -.42$. At the end of the study, there was also no statistical difference between science teachers (M = 1.66, SD = .2) and mathematics teachers (M = 1.6, SD = .34) at T1, $t(19) = -.523$, $p = .607$, $d = -.24$ (see figure 2).

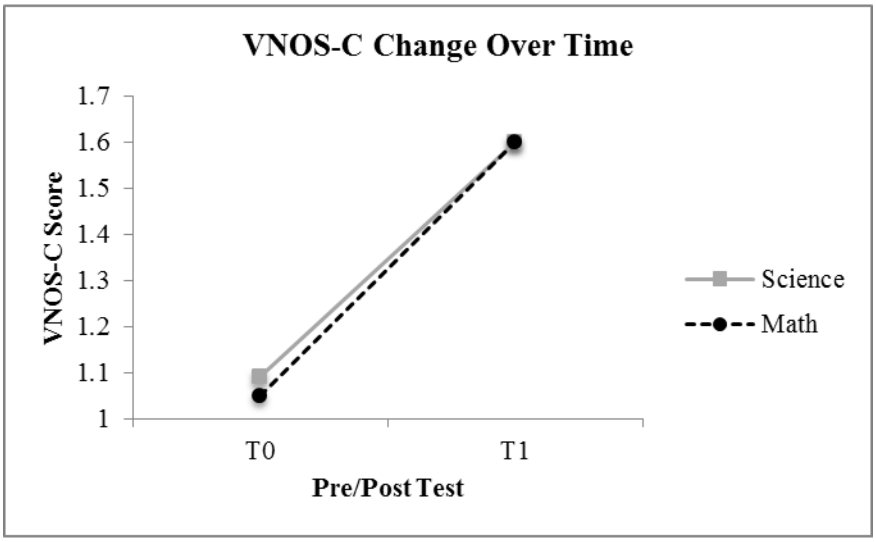

Figure 2. Change of VNOS-C scores for Science versus Mathematics participants on both Pre/Post assessments

In terms of years of teaching, there was no significant difference between novice teachers (*M* = 1.05, *SD* = .07) and experienced teachers (*M* = 1.05, *SD* = .09) on the VNOS-C at T0, *t*(19) = -1.327, *p* = .2, *d* = .61. Nor was there any difference between novice teachers (*M* = 1.59, *SD* = .26) and experienced teachers (*M* = 1.67, *SD* = .25) at T1, *t*(19) = -.749, *p* = .463, *d* = -.34 (see figure 3).

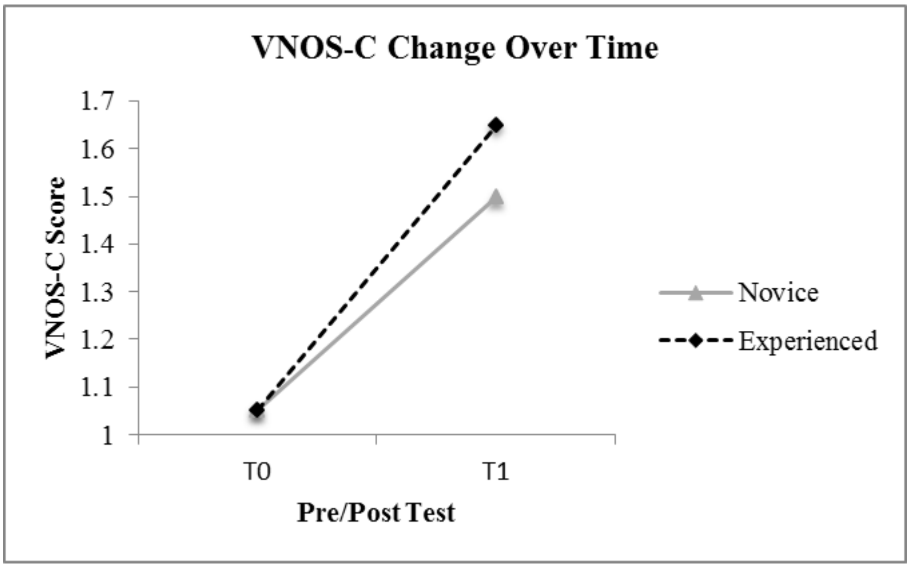

Figure 3. Change of VNOS-C scores for Novice versus Experienced participants on both Pre/Post assessments

Independent sample *t* tests were conducted to investigate whether there was a significant difference between science teachers' and mathematics teachers' conceptions of NOS on the Modified VNOS-C Interview at T0 and T1. Independent sample *t* tests were also conducted to ascertain whether there was a significant difference between science teachers' and mathematics teachers' conceptions of NOS on the Modified VNOS-C Interview at T0 and T1. Results revealed that there was also no significant difference between science teachers (*M* = 1.29, *SD* = .21) and mathematics teachers (*M* = 1.32, *SD* = .11) at T0, *t* (19) = .326, *p* = .75, *d* = .15. There was also no statistical difference between science teachers (*M* = 1.65, *SD* = .29) and mathematics teachers (*M* = 1.65, *SD* = .26) at T1, *t*(19) =-.067 , *p* = .948, *d* = -.03 (see figure 4).

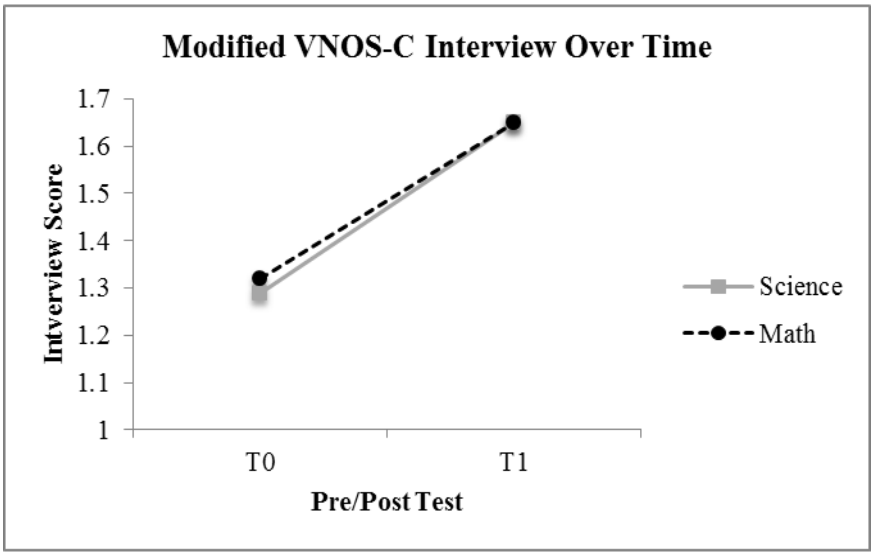

Figure 4. Change of Modified VNOS-C Interview scores for Science versus Mathematics participants on both Pre/Post assessments

In terms of years of teaching, there was no significant difference between novice teachers (*M* = 1.3, *SD* = .07) and experienced teachers (*M* = 1.33, *SD* = .22) on the Modified VNOS-C Interview at T0, *t*(19) = -.189, *p* = .85, *d* = -.09. Nor any difference between novice teachers (*M* = 1.65, *SD* = .19) and experienced teachers (*M* = 1.65, *SD* = .31) at T1, *t*(19) = -.039, *p* = .97, *d* = .02 (see Figure 5).

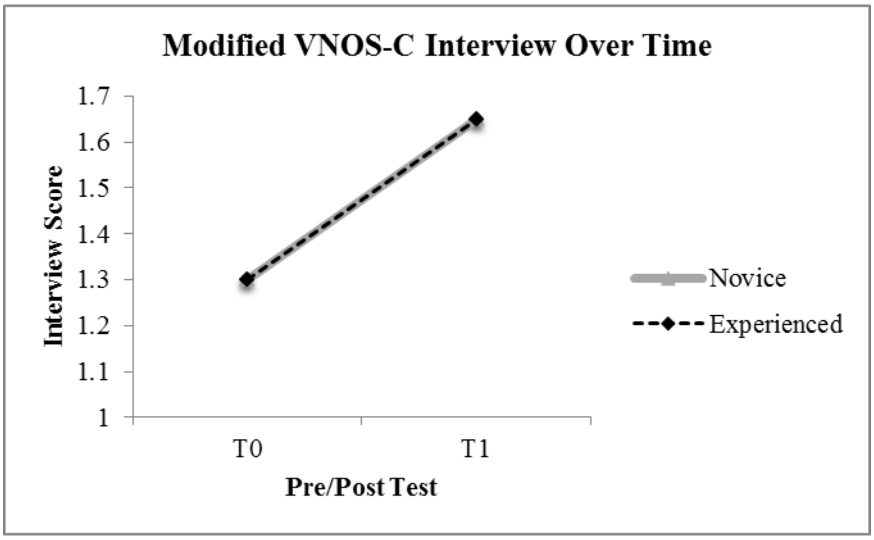

Figure 5. Change of Modified VNOS-C Interview scores for Novice versus Experienced participants on both Pre/Post assessments

Conclusions

Institutes of higher education have integrated online instruction as a way to provide continuing education opportunities. In the southern U.S., about half of higher education institutions that offer face-to-face Master's degrees also offer Master's degrees through online programs (Allen & Seaman, 2013). The development of iSMART allows teachers to take all of their continuing education courses in an online format. Although the online format is a component to the context of this study, the focus was to explore the development of science and mathematics teachers' conceptions of NOS over the course of 1-year in the iSMART program. Results of this study revealed middle school science and mathematics teachers' conceptions of NOS as they engaged in an online master's program that focused on integrating science and mathematics in the classroom. Below, we pair results with each research question that guided this study. Finally, we discuss implications for explicit and reflective instruction for teachers that integrate science and mathematics in the classroom.

What were middle school science and mathematics teachers' conceptions of NOS before and after two semesters of explicit and reflective NOS instruction? Statistical analysis of the VNOS-C and the Modified VNOS-C interview revealed that the participants improved their level of conceptions of NOS during the study period on both instruments. Of note is that the participants did not achieve the highest possible scores on many items of the Modified VNOS-C Interview. Although the participants did not develop the most sophisticated level of NOS conceptions, the findings support existing research that has strongly advocated for the teaching of NOS in explicit and reflective ways (Deniz & Akerson, 2013; Lederman, 2007). The explicit and reflective NOS instruction conducted through the iSMART master's program during the study period seems to correlate with the participants' increased development of NOS conceptions.

How does science and mathematics teachers' NOS conceptions differ before and after two semesters of online explicit and reflective NOS instruction? Both the science teachers and the mathematics teachers were found to have statistically significantly improved their level of NOS conceptions over time. However, there was no statistically significant difference between these two groups at the beginning or the end of the study. This result was surprising since we hypothesized that mathematics teachers would have a less developed concept of NOS at the start of the study than the science teachers. We also hypothesized that science teachers would have a more developed concept of NOS than the mathematics teachers by the end of the two semesters.

How do beginning and experienced teachers' NOS conceptions differ before and after two semesters of explicit and reflective NOS instruction? Results show that teachers with up to 5 years of experience at the start of the program, and those that had six years or more statistically improved in their NOS conceptions. However, as in the case of science vs. mathematics teachers, when the two groups were compared at the beginning and at the end of the study, they were indistinguishable. This was also surprising, since we anticipated that novice teachers would show greater change in their NOS conceptions due to being more malleable in their understandings (Luft, 2001). However, there was no significant difference in the rate of change between beginning and experience teachers. In other words, beginning and experienced teachers both increased their NOS understanding, and neither increased more than the other.

Discussion

The results of this study align with research that advocates for explicit and reflective instruction of NOS to develop teachers' NOS conceptions (e.g.; Akerson & Hanuscin, 2007; Akerson et al., 2006; Deniz & Akerson, 2013; Gess-Newsome, 2002). This study also found that both science and mathematics teachers improved their conceptions of NOS when they experienced the same treatment. Therefore, teachers who teach science, or integrate science in some way, may improve their conceptions of NOS when provided opportunities to do so.

When separated by their years of experience, the teachers did not show a statistically significant difference in their conceptions of NOS at the start of the study. Initially, we did expect that experienced teachers' conceptions would be more developed, since they had more time to gain experience and knowledge than their less experienced counterparts. Previous studies show that beginning teachers improve n their instruction and knowledge over time (Henry, Fortner, & Bastian, 2012). Yet, the lack of professional development on NOS for practicing teachers may explain why there was virtually no difference in conceptions of NOS between the novice teachers and the experienced teachers. This aligns with the work of academics in the field that have found preservice and in-service teachers both hold naive views of NOS (e.g.; Akerson, et al., 2006; Dogan & Abd-El-Khalick, 2008; Pomeroy, 1993).

It is surprising that the level of NOS conceptions was indistinguishable between science and mathematics teachers on both the pre and post assessments. We hypothesized that science teachers would have a more developed conceptions of NOS at the start of the study than their mathematics counterparts due to their teacher preparation in science teaching, knowledge about the science fields, and experiences in science teaching. We also expected that science teachers would have higher scores than mathematics teachers at the end of the study, since science teachers would have acquired more sophisticated conceptions of NOS due to their familiarity with science and science teaching. However, it was somewhat troubling that science teachers

First, the notion that science teachers know just as much about NOS as mathematics teachers indicates that science teachers in the U.S. are just as unfamiliar with the nature of science as mathematics teachers, even though they teach and represent the field of science in their daily instruction. While this supports the idea that science teachers hold naive conceptions of NOS (e.g., Akerson & Hanuscin, 2007; Abd-El-Khalick & Lederman, 2000; Duschl, 1990; Lederman, 1992; Ryan & Aikenhead, 1992), it also indicates that science teachers know just as little about NOS as teachers of other content areas.

Second, we found that science and mathematics teachers improved their conceptions of NOS only to a limited extent. The use of the Modified VNOS-C Interview had the potential to result in higher scores than those gathered from paper and pencil tests. However, neither science nor mathematics teachers achieved the highest scores, indicating that both groups of teachers did not increase their conceptions of NOS to their full potential. This reveals that teachers trained in science or science pedagogy are not necessarily more receptive to improving their NOS concepts than non-science teachers. The finding that science teachers did not surpass their mathematical counterparts in improving NOS conceptions is supported by the finding that experienced teachers are less likely to change their beliefs than their novice counterparts (Luft, 2001).

One explanation is that science teachers gained experience during preservice and in the classroom, and repeatedly taught science in a certain way (e.g., one scientific method, science is objective and absolute), so that their naive beliefs about NOS were reinforced. This may have made it more challenging to shift from naive conceptions of NOS to the most developed conceptions of NOS, as measured by the instruments. Therefore, while we expected that science teachers would improve their scores the most due to their understanding of science and their science teaching experiences, it may actually be the contrary. Science teachers' long-held, naive conceptions of NOS may have hindered their ability to improve their conceptions of NOS over the one-year study period.

Implications

The implications of this study support established arguments on the necessity to explicitly and reflectively instruct science teachers about NOS (e.g.; Akerson & Hanuscin, 2007; Akerson, et al., 2006; Bell, et al., 2000;

Deniz & Akerson, 2013; Gess-Newsome, 2002). Findings indicate that NOS should be included explicitly and reflectively in science teacher preparation programs and PD for in-service science teachers, in order to support teachers' and students' development of scientific literacy (Akerson & Hanuscin, 2007; Akerson, et al., 2006). Since NOS is critical for scientific literacy, this study adds to the literature on NOS by advocating for opportunities to learn about NOS in explicit and reflective ways. It also calls for non-science teachers that integrate science in their instruction, such as those that teach mathematics, to learn about NOS in explicit and reflective ways.

As the U.S. pushes for students to be STEM-literate, this requires that our teachers are STEM-literate as well. The current push for STEM education in the U.S. has resulted in the need for all teachers to develop more sophisticated conceptions of NOS. In light of the current STEM movement, and Lederman's description of NOS, this study highlights the importance for STEM curriculum developers, teachers, and stakeholders to develop understanding of the epistemology of science, mathematics, engineering, and technology as individual content areas, as well as how they interplay when integrated together. This study illuminates the importance for STEM teachers and researchers to develop an understanding of how science, technology, engineering, and mathematics are each distinct ways of knowing.

Fundamentally, science teachers need to understand NOS because it is a critical component of scientific literacy. If teachers themselves do not hold sophisticated conceptions of NOS, then they cannot help their students' develop a well-rounded and sophisticated view of science and scientific knowledge. Teachers who integrate science and math must hold accurate conceptions of NOS in order to cultivate students' conceptions of NOS and foster scientific literacy. For STEM education to succeed, teachers who include science in their instruction must hold solid conceptions of NOS, which is critical to foster scientific literacy and promote science and the STEM fields for students.

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