“Just Bare-Bones Facts”: STEM Career-Switchers’ Perceptions the Role of the Nature of Science in Science Education

Why Nature of Science?

Marjee Chmiel and Erin Peters-Burton

George Mason University

Abstract

This study investigates the Nature of Science (NOS) understanding of 17 pre-service teachers who are part of a career-switcher program. The study was conducted as an in-depth structured interview with the pre-service teachers shortly after they completed their science education methods course. This population was of special interest because these pre-service teachers all had careers in the sciences or engineering. All of the participants covered NOS as part of their science methods course of study. Analysis of the interview data revealed that pre-service teachers with a student-centered view of teaching discussed engaging students in data gathering and using evidence-based argumentations as being the primary vectors for NOS in the classroom. Pre-service teachers with a more teacher-centered view of their classrooms would focus on using giving lectures about the history of science to convey NOS to their students. Furthermore, we found that all teachers were far more likely to invoke their own experiences as science students when discussing their pedagogical approaches than to reflect on their professional experiences in science or engineering.

Keywords: pre-service teachers, teacher preparation, career switchers, nature of science, interview

Why Nature of Science?

Just as the needs for civic scientific literacy have increased, we find the general public growing increasingly alienated from scientific professionals.. This growing disconnect between the general public sphere and the scientific community can be seen in high profile controversies such as the teaching of evolution in public schools and concerns over global climate change (Jakobsson, Mäkitalo, & Säljö, 2009; Kohut, 2009). Bauer, Petkova & Boyadjieva (2000) argue that citizens who have a high degree of understanding of the nature of science knowledge (NOS) have a higher degree of trust in science as an institution. Unfortunately, the U.S. program of public science education has been found to offer very little in terms of NOS. Analyses performed by TIMSS and AAAS demonstrated that textbooks and teacher resources essentially amounted to a set of narrow, disjointed documents that neglected generative ideas and perpetuate oversimplified and incomplete “myths of science” (for example, the conflation of “theory” with opinion) (American Association for the Advancement of Science, 1993; National Research Council, 1996, Chinn & Malhotra 2002, McComas, 2004).

Presently, there is an effort among stakeholders in U.S science education to define a general underlying epistemology for science literacy lies in understanding the nature of science knowledge:, that is, the agreed upon methodologies, epistemologies, and assumptions that scientists share in order to construct knew knowledge (Lederman, 1992, 2007; Schwartz & Lederman, 2002) and leaders in the field of science education call for a more prominent role of the nature of science in curriculum (McComas, Almazroa, &

Clough, 1998). Calls for a more authentic education, one grounded in a robust understanding of NOS, “would more faithfully represent the processes by which science is conducted and its results are socially accepted” (Gilbert 2004, p. 116). Pedagogically speaking, the most accepted pathway toward scientific literacy in the science education community is to teach a greater understanding of the nature of science using inquiry as an instructional method (AAAS, 2009; Rudolf, 2005, Stewart & Rudolph 2001; Lehrer & Schauble 2004; Yager 2006). Inquiry can be used an instructional method that aims to teach content standards in tandem with NOS in order to engage students in activities cognitively modeled on the work done by scientists (NSES, 1996). By its nature, inquiry can be classified as a student-centered teaching method because it relies on a constructivist model of cognition. Given this pathway towards a greater understanding of NOS, many in the science education community have turned their attention towards in-service and pre-service teachers, their understanding of NOS, and their efforts towards inquiry driven instruction. Indeed, researchers in science education have found that robust, dedicated coursework in the philosophy of science, in tandem with pre-service science teaching methods courses, can elevate pre-service teachers’ discourse regarding the nature of science (Abd-El-Khalick, 2005). However, most pre-service programs do not have provisions for such coursework, and research suggests that the pre-service teachers’ college classroom discourse does not readily translate into professional practice.

NOS and Teacher Preparation

Research into NOS and teacher education has illuminated several barriers in preparing teachers for a NOS-informed curriculum.

For instance, most classroom teachers that come directly from teacher-training programs where their own science education provides little insight into scientific epistemology (Hogan & Maglienti, 2001), increasing the chances these teachers will revert to teaching science as a collection of facts. This means that many teachers who are otherwise very knowledgeable about science content lack the kind of scientific epistemology that is required to understand science at its frontiers (Duschl, 1990; vanDriel, Beijaard & Verloop, 2001). Research into the understanding of practicing and pre-service teachers’ understanding of NOS has been somewhat problematic as well. Teaching pre-service teachers NOS requires a curriculum designed with frequent and deliberate opportunities for metacognition (Abd-El-Khalick & Akerson, 2009; Peters& Kitsantas 2010). Preliminary research has also suggested that tacit epistemologies held by teachers on their way into teacher preparation programs will strongly influence their ability to understand and employ NOS as teachers (Yilmaz, & Topcu, 2007) . Another important consideration is that studies have shown that while teachers tend to have naïve conceptions about the NOS, their conceptions do not necessarily predict their pedagogical efficacy in this area (Hodson, 1993; Taylor & Dana 2003). Despite the fact that some teachers struggle with demonstrating NOS proficiency using pre-structured questions and prompts, their actual teaching practice reflects meaningful employment of NOS. The inverse is true, as well: teachers who can articulate an understanding of NOS that reflect recommendations from AAAS struggle to employ it in their teaching practice. While evidence suggesting that more extensive content knowledge in science influenced the participants’ understanding of NOS, this understanding of the nature of science was necessary but not sufficient in the ability to connect aspects of the nature of science into classroom lessons (Schwartz & Lederman, 2002). For instance, pre-service teachers could articulate a solid understanding of NOS components (such as scientific modeling), but struggle with how they could integrate such components into their curricular design (Windschil &Thompson, 2006).

Some researchers have suggested that providing pre-service science teachers with scientific research experiences can build a stronger scaffold in the NOS (McComas, 1998). However, research on practicing scientists’ understanding of NOS demonstrates that scientists themselves have a poor understanding of NOS outside of the lens of their own practice (Wong & Hodson, 2009). If scientists themselves have a hard time understanding NOS, why should we expect teachers to be able to grasp it? It is precisely because teachers are educating nonscientists that we need teachers to have and present a more omnipotent view of science. Ault (2009) talks about the role of teachers as “introducing science to novices as a culture—with distinctive patterns of discourse, methods of investigation, ion, and approaches.”

STEM Career Switchers

This brings us to an interesting question. With the extensive research documenting NOS understanding of in-service teachers, preservice teachers, and scientists, we know very little about what happens when the latter becomes the former. That is, what types of understandings of NOS do individuals hold who are leaving careers in STEM to become teachers? How do these people’s experiences in NOS throughout their STEM careers manifest themselves as they think about NOS in the classroom? The research presented in this study examines a novel population of educators that are at the intersection of two populations that have been the subject of professional understandings of NOS: scientists and teachers and expands upon previous work reported by (Peters & Kitsantas 2010). While there has been considerable interest in career switching in general there has been little focus on exploring this in science teaching. Early work examines particular challenges related to career switching teachers in general (Bullough & Knowles, 1990). Of particular interest, researchers have focused on transferable skills, looking at how career switchers already developed competencies might be leveraged into their developing teaching practices (Mayotte, 2003). Aside from a qualitative study of an individual 31-year-old scientists transition to classroom teaching (Powell, 1994), there is little work that has explored this transition in the sciences. Furthermore, there has been no exploration of the extent to which switching from science career to the science classroom affects teachers ideas about, or developing ideas about, the nature of science. These teachers already have identities as scientists, and have experience with doing science, it is critical to explore the extent to which these ideas transfer into their notions of teaching. This work is of critical importance because for the last twenty years career switching scientists have been explicitly targeted as a population who can help solve issues with staffing hard to staff science teacher positions. (Carey, Mittman, & Darling-Hammond, 1988; Clewell & Forcier, 2001)

In this study, we conduct structured interviews of 17 pre-service teachers who have completed a science education methods class as part of a career-switching program. These interviews examine and characterize participants’ understanding of the role of NOS and its role in science instruction in order to attempt to better understand this unique and increasingly important population of teachers.

Previous literature cited above demonstrates that pre-service teachers with no professional science experience often have a hard time understanding the NOS, as much of NOS is shaped by the professional scientific practice. On the other hand, professional scientists have been shown to have an understanding of NOS limited to their specific sub- discipline. The former scientist or engineer career-switching pre-service teacher stands between these two communities and therefore, in this study, we wanted to how such a cohort the perceived the relationship between NOS and science pedagogy. In this particular study, we took a “snapshot” of the pre-service teachers right after they completed their science education methods series. At this point, they were still not professional teachers, but they had been observing or apprenticing teachers, planning their own lessons, and spending some time learning about NOS in their methods class.

Research Design

The study involved a cohort of 17 (N=17) pre-service teachers in a post-baccalaureate teacher certification program at a large state university located in the Mid-Atlantic region of the United States. This program is geared toward career-switching professionals seeking to become certified to teach science after leaving a STEM-related career. As part of their certification program, the pre-service teachers are required to take science teaching methods course, which was taught by the second author of the current study and included two class periods focusing on the NOS and its relevance to K-12 science instruction in additional to revisiting NOS concepts in major assignments throughout the semester. Despite their previous careers as scientists, the science teaching methods course was their first introduction to NOS.

A variety of methods and instruments have been used to evaluate teacher understanding of NOS, however many of these studies have been unable to ascertain teachers’ views in situated, pedagogically relevant contexts (Guerra-Ramos, Ryder, & Leach, 2010 p. 283). Our intention in this study was to capture NOS understanding of the participants precisely as they transitioned between their STEM profession and teaching. This would allow a rare snapshot of the participants’ conceptualization of NOS as they prepare for their teaching career, but before shedding their prior professional identities in the STEM careers. For this reason, it must be understood that our participants do not have classrooms of their own, and have had limited opportunity to implement pedagogical strategies. However, participants have had the opportunity to develop curricular materials in a thoughtful, deliberate, and reflective environment. Therefore, to maximize our ability to examine these questions in pedagogically relevant context, the present study uses structured, face-to-face or Instant Message facilitated interviews that utilized pedagogically action-oriented questions to address NOS issues. The interview data was transcribed and analyzed by searching for patterned regularities emerging from the data (Wolcott, 1994).

Findings and Analysis

Several patterns emerged during the analysis of participants’ interviews. These themes were translated as domains of understanding, or common conceptions or misconceptions drawn out of the corpus of literature regarding K-12 science education and NOS. Two analysis agreed upon the domains of understanding found in the interviews and separately coded the interviews looking for evidence of these domains. Items that did not receive identical coding from both analysis were dismissed and not taken into consideration as this occurred with a four items.

For the coding of teacher-centered versus student-centered views of teaching, coders used the framework from the National Capital Language Research Center (2010) to identify language indicating: who initiates topics to be examined; who evaluates student work; who answers student questions, and other indicators of the participants’ vision of his or her classroom. To prevent bias, the teacher for this course was neither an interviewer nor a coder but rather used as a member check for the data analysis. The interviewers were not part of data coding or analysis, either. The domains of understanding are briefly summarized and illustrated in the following paragraphs and summarized in Table 1.

History of Science

The most prominent theme in participants’ discussions of the nature of science was incorporating the history of science. This theme emerged in 14 of the 17 participants discussions. In these cases, participants explicitly mentioned using stories garnered from the history of science as a way to introduce nature of science. These include statements from the participant that incorporate historical story telling as a way to demonstrate the NOS behind select content learning objectives. The following example is illustrative of some of the key themes that emerged from participants’ discussions of the history of science.

> you have to use examples and how did we get to this information. There is always a back story, and I think that part is interesting. How they discovered pulsars. You know some grad student somewhere put her instruments all together and she got a strange reading and she thought that birds were pooping in her instruments so it was the machines’ fault. That‘s how they found it and stuff like that. You know just by accident just by trial and error. (Interview, Teacher 2)

In this case, Teacher 2 presents the history of science as "back story." Just as with others in the class, she identified teaching NOS primarily through the history of science. After establishing the notion of this instruction as "back story", she goes on to tell one of those stories. In this case, the story involves a researcher's experience with error in an experiment and ends the story by telling us that the point of the story is to establish that scientific knowledge can be developed through accident and trial and error. In the end, she is touching on an important theme in discussions of the nature of science: that science is a human practice and that individuals are involved in the discovery and development of scientific knowledge. However, by adopting a notion of the history of science as story-telling, she has presented us with a teacher-centered view of incorporating NOS in the classroom. This idea of storytelling represented the majority of the participants' approaches. For example, Teacher 6 said she would accomplish teaching NOS "By explaining how known scientific knowledge was discovered." The verb choice is telling: she explains so that students absorb. Teacher 3 referred to this approach providing students with "historical factoids," even further demonstrating the way notions about teaching with the history of science can be confounded with a idea of history as discrete facts to be transmitted to students.

In many cases participants equivocated the history of science with the nature of science. For example,

> [Teaching NOS] is very easy in 8th grade science and Physical Science is it theories and…they changed and how they evolved and this is where we are now. We learned a lot about the scientists that allow us to be where we are today. (Interview, Teacher 1)

Teacher 1 seizes on the change of theories over time, a valuable concept related to the important notion that science develops.

In this case, the history of science represents a topic to be covered, and because history of science is used as a stand-in for NOS, NOS becomes something that can be covered in a few lessons.

More broadly, participants discussed this domain as a didactic practice; none of the participants explicitly discussed using historical data as part of a student-centered evidence and argumentation exercise (such as Chinn & DaCosta, 2005). While some of these responses drew a clear line from historical science to how scientists solve problems, other participants tended to conflate using the history of science for the purposes of NOS connections with using history of science as items of interest to engage students.

A few of the participants, specifically those that also focused on discussing data and evidence, did propose more robust ideas about NOS and the history of science. For example, teacher 11’s ideas about NOS,

> I think that you always have to talk about logic, about evidence, about creativity, about history of science, and a connection to perhaps the world that the kids can observe”. (Interview, Teacher 11)

In this example, the history of science is part of a broader definition of NOS. This exemplifies a greater pattern that emerged. When participants articulated multifaceted ideas about NOS, they were far more likely to also align themselves with student centered pedagogy. In contrast, weaker notions of the history of science were strongly associated with a broad idea that it would “engage” students or help them “relate”. For example,

> It really does help kids relate to science better. Bringing in some of the historical things. (Interview, Teacher 11)

The idea of helping students relate to, or helping students engage with content was frequently tangled in with ideas about teaching the history of science to get at NOS.

Hands on/ Discovery learning

Six of the participant responses conflated NOS as a type of progressive or “hands-on” pedagogical method, rather than an epistemology. Teacher 7’s definition of NOS offers a good example of this

> Like, you know I think its kind of like one of those new progressive ideas of student-based curriculum where students determine what they – I mean I think I want to learn to do it – like asking them what they want to learn specifically in that subject. (Teacher 7)

Teacher 7 sees NOS as a “new” idea in education, and conflates it with discovery learning. (To be clear, this was not the way NOS was presented during professional development.) What was somewhat surprising was that these participants, who all came from STEM careers, rarely drew from their professional experiences to discuss NOS. Participants were more likely to draw from their experiences as successful learners in science classes. For example, when Teacher 7 was asked to describe about how individuals learn scientific concepts he responded by drawing on his experiences as a learner as opposed to a STEM professional,

> A concept. Well the way I learned, I sat there and listened. I mean that’s – the lecture and the whatnot… I know that seems like a bad – not real- but it’s successful. It works. (Teacher 7)

Teacher 7, demonstrated rather robust and nuanced ideas about NOS, but when asked how one learns a scientific concept he returned to the way he learned. In other areas he repeatedly mentions that students learn concepts through repetition. This ultimately brings about important implications for what he thinks the value of NOS is. For him, the elements of NOS interchangeable with learning that is active or "hands on" and are primarily important for engaging students who he refers to as "Artisans or what not" who "are creative but they also represent 90 percent of high school dropouts." He attributes their dropping out to the fact that "they're so artistic and creative that the schoolbook learning and that sort of thing it doesn't give them their outlet to how their mind thinks." He suggests that having these "artisan" students work on posters and art projects might help motivate them to accomplish the kinds of "schoolbook learning" he succeed with, which he sees as the way individuals learn about scientific concepts. In this case, NOS, and other progressive ideas about inquiry and discovery learning are viewed as tactics to engage students to do the real science learning associated with lectures and memorization of concepts.

Interestingly, in one case, the same notion of NOS as discovery or inquiry learning led to nearly the opposite outcome. Teacher 4 represents an interesting outlier from the participants. He was the only one of the teachers who was openly hostile to the idea that NOS was a valuable part of learning science. The following represents his model of how one learns science as a spectrum,

> A scientist advances the envelope of scientific knowledge, or is it by… that's one end of the spectrum. The other end of the spectrum is some one is standing up there explaining it to them. This is how it works; this is how you work with the problem in it. After you show people enough of those problems, you build enough blocks that you can send them home with a problem… more advanced students an move out to the more inquiry based thing. I think the less advanced have to be politely scaffolded a little bit more and politely told what the answer is. (Teacher, 4)

Where Teacher 7 associated NOS as inquiry as a tactic for engaging students to accomplish more "schoolbook learning," Teacher 4 suggests inquiry is really only something for the most advanced students. While they each propose an opposite suggestion they are fundamentally operating from the same theory. In each case, they believe that one really learns science by assimilating scientific concepts. Teacher 4 dismisses the idea of inquiry as something for anything but the most advanced students because he associates it with the cutting edges of science.

Data, Evidence, and Argumentation

Nine participants talked explicitly and in depth about NOS as being linked to having students work to carefully construct laboratory reports, think “creatively” about how to collect and analyze data, and make arguments supporting their observations and conclusions. These participants were coded in this domain when they provided practical classroom applications that required students to work with data, design procedures and methods for analysis, propose explanatory models, and develop arguments. For instance, Teacher 14 does a nice job of discussing how he can involve students in developing and arguing for models while emphasizing the tentative nature of scientific knowledge:

> …they are actually getting involved in the show and say this is what we actually think happened, and this why we think it happened. But you have to say, “think,” you cannot say this is what absolutely, hands-down happened, so then you can say, “but you might have a reasonable idea, too”…answer to the best of your ability, give logical…what is the word…back yourself up. As long as you can back yourself up with the logical data, you might have an argument. (Interview, Teacher 14)

For Teacher 9, evidence and argumentation went hand-in-hand with making sure students developed metacognition around models they encounter is science textbooks

> I had this kid in one of the classes I observed that was like, “in the cell are all of the Golgi apparatus purple?” Because in the book they were purple. I think that is really important physically for science, because you use a lot of diagrams and models, but kids also have to realize it is a model, and every model has limits and it doesn’t necessarily match exactly what an atom looks like. It is just a tool to learn about the design. (Teacher 9)

Student Engagement

This code was applied to statements that explicitly talk about NOS as being valuable because it generates interest among students. This, of course, overlaps heavily with how some participants addressed NOS as the history of science as well as the participants who discuss NOS as discovery or hands on learning. However, some participants discussed student engagement more broadly, and more explicitly as being the inherent value of NOS:

> I really tried to incorporate a lot of the different aspects from nature of science into my lesson planning simply because they make a lots [sic] of sense. It really does help kids relate to science better. Bringing in some of the historical things. Bringing in other genres of study and really relating it to real world things not just…make sure they understanding…” (Interview, Teacher 3)

> [Responding to “How do you teach students how scientists think] I think brining real life examples of how they have been curious in their own lives. To show that scientists aren’t these brainy people that are nerdy out there. (Interview, Teacher 9)

Teacher 3 says that she is mindful to include items that she thinks will demonstrate NOS concepts (“historical things” “real world things”). However, she never discusses the epistemic value of NOS. Her statement, “It really does help kids relate to science better” indicates that she is confirming a belief (“it really does”) that was perhaps only tacitly held until she had the opportunity to express it during the course of the interview.

NOS as a Pervasive Element of Science

Eight of the participants spoke explicitly about NOS as being a unifying component of science and therefore science curriculum. Participants with this understanding of NOS also represent those participants who discussed lesson plans centered around data analysis, evidence, and argumentation. This is in contrast, for instance, to participants who perceived NOS to be highly topic dependant. These participants would discuss some content as being NOS independent. For instance, Teacher 12 begins to talk about photosynthesis as thought it might be NOS independent:

> There’s not like, a whole lot of new knowledge. It’s like it’s pretty – we know photosynthesis and cellular aspiration take place like this, this is what happens. We’re not gonna get specific enough examples to where they can – you know, you’re not getting down to the real, real fine molecular basis of it in like, a high school biology classroom. (Interview, Teacher 12)

Teacher 12 is saying that the frontiers of research into photosynthesis might not be appropriate for coverage in high school science. To him, this means the NOS integration in this lesson is not readily obvious. However, he does break this lesson planning apart to yield some age-appropriate, student centered ideas:

> …go out and collect their own samples of plants, and then look inside of it and actually find the chloroplasts and be like, this is what happens…my goal was to sort of get them to get to a point where I could tell them, “Here’s the information,” and then continue [to the] next step. (Interview, Teacher 12)

Contrast this with Teacher 7, who saw NOS as being highly specific to a select few topics:

> [Responding to the question of “how would you go about teaching something like force or cellular reproduction?”] I’m thinking just relatively like with these types of things that are just bare bones fact that need to be accomplished I think its kind of difficult about like how it – I could show them slides…{Interview, Teacher 7)

Teacher 7 had a difficult time talking about NOS outside of the topic of evolution. After a while, he finally offers the following example:

> A lot of people make health decisions like don’t smoke. Well why shouldn’t I smoke? Well here’s the evidence of why you shouldn’t smoke. So that’s even incorporated in the NOS –public and personal decisions. (Interview, Teacher 7)

His only other example included one surrounding personal health decisions and arguably falling outside of the standard secondary life science curriculum. Table 1 demonstrates that many of the participants who discussed NOS as a pervasive, unifying characteristic of science also talked about integrating lesson plans centered around data analysis and argumentation, and were more likely to evoke a student-centered pedagogy.

NOS as Teacher-Centered

These nine pre-service teachers that used lectures and other didactic methods in their descriptions for how they currently teach or plan to teach something. These participants were unlikely to discuss data collection, analysis, argumentation, and modeling as ways to incorporate NOS:

> …standing up there explaining it to them. This is how it works, this is how you work the problem in it. After you show enough of those problems, you build enough blocks that you can send them home with the problem. ..I think more advanced students can move out to the more inquiry based thing. I think less advanced [students] have to be politely scaffolded a little bit more and politely told what the answer is. (Interview, Teacher 4)

> [On how to teach a specific topic] I’m thinking just relatively like with these types of things that are just bare-bones facts that need to be accomplished…(Interview, Teacher 6)

NOS as Student Centered:

This code was applied to eleven se teachers who repeatedly emphasized their perceived importance of having students construct their own scientific understanding, but also mentioned that there was something inherent to the subject of science that made this type of learning especially possible or preferable. Participants who provided these types of responses were often the same participants who discussed the role of student work in data analysis and argumentation as being central to NOS. Note that because we looked individually at the statements participants made for teacher-centric or student-centric language, we did find three teachers who gave answers during different parts of the interview that placed them in both teacher and student centered camps. Below are sample responses given by participants who articulated student-centered science learning activities.

> Science is a nice field because they can do it, so I think the most important way to get students not only know it but to understand science is to actually perform the experiments or have them view real examples of the experiments.

(Interview, Teacher 14)

…letting them write procedures and their own data tables, which I hadn’t thought about before, and that allows them – it – well, it kind of forces them to be analytical and creative… (Interview, Teacher 13)

…always question their outcomes – why did something happen the way it did? It’s also important to get them into the routine of peer review, observing outcomes. (Interview, Teacher 10)

Table 1

	History of Science	Data, Evidence, Argumentation	Hands on/ Discovery Learning	Engage Students: “Make it real”	Teacher Centered	Student Centered	Pervasive
Teacher 1	X		X	X	X		
Teacher 2	X				X		
Teacher 3	X			X	X		
Teacher 4	X		X	X	X		
Teacher 5	X			X	X		
Teacher 6	X	X	X		X	X	
Teacher 7			X	X		X	X

Teacher 8	X	X			X	X	
Teacher 9	X			X	X		
Teacher 10	X	X				X	X
Teacher 11	X	X		X	X	X	X
Teacher 12		X	X			X	X
Teacher 13	X	X		X		X	X
Teacher 14		X	X			X	X
Teacher 15	X	X				X	X
Teacher 16		X				X	X
Teacher 17						X	

Discussion

At the onset of this research, we hoped to learn more about how pre-service teachers career-switching from the sciences or engineering would understand the role of NOS in science pedagogy. In this particular population, the participants’ general pedagogical outlook in terms of a student centered or teacher centered classroom, heavily influenced what he or she focused when discussing the role of NOS in teaching and learning. Participants were able to discuss NOS as both promoting teacher-centered and student-centered approaches to science instruction, as NOS was malleable within the context of the participants’ own developing teaching philosophy. Within this framework, participants saw NOS in the context of a variety of teaching strategies: as a hands-on approach, as way to engage all students, a way to challenge high-achieving students, even an approach for remediation. While the purpose of NOS as a teaching strategy varied greatly among participants, even the few who acknowledged that NOS was pervasive did not escape talking about it as a type of teaching strategy rather than a unifying epistemology that guides the discipline. For instance, participants who favored a teacher-centered classroom also favored the telling of historical stories as the primary vector of NOS. Participants who favored a more student-centered classroom spoke of evidence gathering, data analysis, and model building as way to make NOS pervasive throughout their teaching.

One of the most striking components of the participants’ responses in the interviews is the degree to which they express NOS through the filter of their perception of their profession. as a teacher. Many of the participants discussed their roles as clarifiers and explainers of science and NOS was seen as a way to aid explanation or clarification. Participants’ interaction with NOS during their previous scientific career was very rarely discussed by any of the participants. Very few of the participants discussed their careers as a source of NOS understanding. None discussed it at any meaningful length. One possible reason for this is that for many of these pre-service teachers, despite their previous careers as scientists, the science teaching methods course was their first introduction to NOS. Therefore, the participants were more likely to consider NOS in partnership with their anticipated professional roles as teachers, and not reflected enough on what their previous careers might have brought them in terms of helping their future students understand NOS. A potential implication here may be that instructors of all pre-service teachers need to be aware that by integrating NOS with their science teaching methods course, they may perpetuate such a misconception that NOS is a type of science pedagogy rather that a unifying epistemology of the scientific enterprise.. To be clear, we are not arguing against the integration of NOS in pre-service science teacher preparation. On the contrary, we would argue that it is absolutely essential and it must be explicitly discussed with pre-service teachers as a pervasive epistemology and clarify for pre-service teachers that this is not as a type of teaching strategy. Analysis of the discursive structures of some of the participants’ responses reveal that many of these misconceptions about NOS are tacitly held, and cannot be confronted unless participants have a chance to reflect upon their assumptions.

Participants talked in depth about NOS in the context of their perceived job roles: NOS is useful in explaining, gaining student attention, remediation students and, challenging students. In other words, these pre-service teachers saw NOS through the filter of the teaching profession. This is entirely consistent with Wong & Hodson’s (2009) findings that demonstrate professional scientists’ tendencies to view NOS through the filter of their own sub-discipline. Further work in this area could examine the career-switchers’ views of NOS prior to embarking upon their educational coursework and later, after they have spent some time in a teaching preparation program. This could provide comparative snapshots of the participants understanding of NOS fresh out of their science careers and later, as they prepare to be science educators. The key for educators in a science teacher preparation programs is to keep in mind that unlike scientists, current science education standards and benchmarks demand that teachers have a more global understanding of NOS. Here again, it is useful to prepare for the types of misconceptions that can arise about NOS unless pre-service teachers are able to confront such misconceptions.

In addition to confronting pre-service teachers’ misconceptions about NOS, our research demonstrates a strong link among an emphasis in curriculum that focuses on data analysis and argumentation, student centered pedagogy, and an understanding that NOS pervades and unifies the sciences. This suggests that a greater focus on teaching methods that privilege data analysis and argumentation can create a tighter scaffold into NOS and pedagogical practices. While some of the participants many have developed these linkages through their professional experiences in STEM careers, it cannot be taken for granted that such professionals have a deeper understanding of NOS as it relates to pedagogy. In fact, this population appears to be just as diverse in their ability to integrate NOS into their pedagogy as pre-service teachers without professional STEM experiences.

Conclusion

The current study examines NOS understanding as it relates to science pedagogy among a novel population: scientists’ career-switching into becoming professional K-12 educators. In addition to providing data about an under-theorized population of career-switching, pre-service teachers, this study provides generative data suggesting patterns of potential misconceptions among pre-service teachers that are preparing for careers as professional educators after spending some time in a professional science career. Data suggests that the pre-service teachers’ understanding of NOS is wholly situated in their perceived role as educators. If the pre-service teacher views education as teacher-centered, his or her understanding of NOS is couched in historical-story telling. If the pre-service teacher views education as being student centered, he or she is more likely to discuss NOS as student-initiated scientific model making, and consensus building. In better understanding the patterns of potential misconceptions, teacher educators can construct a deliberate curriculum to scaffold all pre-service teachers through a more robust understanding of the relationship between NOS and science education.

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