Virginia Initiative in Science Teaching and Achievement (VISTA): Developing Effective Elementary Science Teachers, Year Two

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Abstract

This paper discusses results in year two of implementation of the *Virginia Initiative for Science Teaching and Achievement* (VISTA), a U.S. Department of Education (USED) science teaching reform effort. VISTA is a partnership among 67 Virginia public school districts, six universities, and the Virginia Department of Education to build an infrastructure to provide sustained, intensive science teacher professional development to increase student performance. Funded by USED (Investing in Innovation Fund – i3), the goal of VISTA is to improve science teaching and student learning throughout Virginia especially in high-need (high-poverty, high minority) schools and for limited English proficient students, rural students, and students with disabilities through a validation study as it is being extended across multiple school districts. VISTA has been designed to build leadership and shape state and local practice through four intensive professional development programs for elementary teachers, secondary teachers, school district science coordinators, and university science education faculty. This paper focuses on the elementary teacher component of the professional development programs and its associated preliminary research findings from year two of the project. The paper specifically reports the results for elementary teachers' understanding of and confidence in implementing nature of science instruction.

This paper shares the challenges being encountered in the initial stages as the *Virginia Initiative for Science Teaching and Achievement* (VISTA) is ratcheted up statewide. The policies and strategies particularly with nature of science (NOS) instruction that have helped or hindered this implementation are the focus of this paper. VISTA is a partnership among 67 school districts, six universities, and the Virginia Department of Education to build an infrastructure to provide sustained, intensive science teacher professional development to increase student performance. This paper specifically reports on the elementary institute focused on grades 4-6. VISTA continues research on this model as it is validated and adapted for wider distribution in Virginia via state- and local-level implementation efforts.

Elementary science teaching continues to be hindered by two fundamental, unmet needs: elementary faculty very often have teaching degrees but lack a solid grounding in science content knowledge (Fulp, 2002), as well as the nature of science and how to teach it (Akerson & Abd-El-Khalick, 2003; NRC, 2007; NCMSTTC, 2000). These distinctly different problems in teaching lead to a common result: Student achievement in science suffers. Well-prepared teachers have the greatest impact on increasing student achievement (Darling-Hammond, 2000, 2003). The National Council for Accreditation of Teacher Education found in its study *What Makes a Teacher Effective* that "effective teachers—those who know the knowledge base on teaching and learning and are able to apply it—help raise student achievement" (NCATE, 2012).

In elementary school, as a result of the increased focus on language arts and mathematics, there is a lack of science teaching and in particular, inquiry-based teaching, as called for in the Virginia *Science Standards of Learning* (2010) and *National Science Education Standards* (1996). VISTA provides intensive support and effective interventions to help teachers learn science content and develop the experience and confidence in teaching problem-based learning

(PBL), inquiry-based science, and the nature of science. Of these three strategies, this paper focuses on NOS instruction.

Research in each of these areas indicates that these strategies, practices, and knowledge bases are not without challenges. For elementary students to become successful in building their science knowledge, Duschl, Schweingruber, and Shouse (2007) suggest that elementary students must have the opportunity to engage in authentic inquiry-based experiences that engage them in constructing arguments, and organizing and articulating evidence through reasoning. These skills are new to many, if not most, elementary teachers. Further, even though explicit instruction in the nature of science has emerged as the linchpin of effective nature of science (NOS) instruction, difficulties persist in translating the construct of "explicitness" into classroom practice (Bell, Blair, Crawford, & Lederman, 2003). Maeng and Bell (2012) reported that elementary teachers in year one of the VISTA intensive summer and academic year training program showed only moderate gains in confidence in implementing NOS instruction in their classrooms.

Theoretical Background

An informed understanding of the nature of science is considered a key component of scientific literacy, as reflected in the foundational documents for science education developed by the American Association for the Advancement of Science (Benchmarks for Science Literacy, 1993) and the National Research Council (National Science Education Standards, 1996). Local science education organizations have further developed recommendations for teaching the nature of science in their states and communities. In 2010, a task force appointed by the Virginia Mathematics and Science Coalition (VMSC) developed a white paper, *Scientific Inquiry and the Nature of Science*, that defined the nature of science as a key component of scientific literacy, one that “depicts science as an important way to understand and explain what we experience in the natural world, and acknowledges the values and beliefs inherent to the development of scientific knowledge.” This task force developed a list of seven aspects deemed appropriate for science instruction in the K-12 setting:

1. Scientific knowledge is empirically based.
2. Scientific knowledge is both reliable and tentative.
3. Scientific knowledge is the product of observation and inference.
4. Scientific knowledge is the product of creative thinking.
5. Scientific laws and theories are different kinds of knowledge.
6. Scientists use many methods to develop knowledge.
7. Scientific knowledge is subjective, to a degree.

During the development of the VMSC white paper, the Virginia science standards of learning were revised. Consequently, the aspects of the nature of science published in the VMSC white paper appeared, with variations, in the Curriculum Framework that accompanied the 2010 standards of learning for science. The sixth grade Curriculum Framework (2011) contains the following section:

> The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts
>
> a) the natural world is understandable;
>
> b) science is based on evidence, both observational and experimental;
>
> c) science is a blend of logic and innovation;
>
> d) scientific ideas are durable yet subject to change as new data are collected;

e) science is a complex social endeavor; and

f) scientists try to remain objective and engage in peer review to help avoid bias.

The aspects found in the Curriculum Framework became the foundation for nature of science instruction for the VISTA elementary science institute (ESI).

Though it would seem that teaching science well would also mean one teaches the nature of science, in fact the body of research on the teaching of the nature of science (NOS) provides compelling evidence that merely participating in science lessons is not sufficient for gaining understanding of NOS (Abd-El-Khalick, Bell, & Lederman , 1998). Prior to science education research that targeted NOS understanding as a goal of K-12 science instruction, teachers employed an implicit or historical approach to teaching students about NOS. An implicit approach involved the assumption that doing authentic science investigations would lead to informed understandings of NOS; the historical approach used episodes from the history of science that illustrated various aspects of NOS. Bell, Matkins, and Gansneder. (2010) found that even a rich context such as instruction in global climate change, coupled with interactions with climate scientists, yielded informed understandings of the nature of science only when accompanied by explicit instruction in the nature of science. Researchers (Akerson & Hanuscin, 2007; Khisfe, 2008; Scharmann, Smith, James, & Jensen, 2005) reached the conclusion that explicit instruction in the nature of science was more consistently effective than either the historical or the implicit. “Explicit” was described by Akindehin (1988) as “planned for, instead of being anticipated as a side effect or secondary product”. In the explicit approach, students’ attention is intentionally drawn to targeted aspects of NOS, in the context of discussion and science activities and investigations. The use of the word “explicit” was not intended to lead to didactic instruction, instead, it was meant to support instruction that left “no room for confusion or doubt”, the definition of explicit (Oxford Dictionaries, 2013).

Over the last 20 years, research on K-12 nature of science instruction has consistently shown that (1) teachers themselves lack key understandings of the nature of science and (2) having an informed understanding of the nature of science does not necessarily lead to student understanding of the nature of science. Indeed, in projects where teachers were successful in teaching NOS to students (Akerson & Hanuscin, 2007; Akerson, Cullen, & Hanson, 2009), the teachers had experienced support and professional development in developing instructional strategies specific to teaching the nature of science. Also, recent research has shown that early elementary children (kindergarten through third grade) were able to express, in language appropriate for their developmental levels, understandings of the evidentiary nature of science, creativity in science, the durable yet tentative aspect of NOS, and the distinction between observation and inference (Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011).

The Study Context

VISTA is a statewide initiative for science teacher professional development to increase student performance in science. With the nature of science being a new extended focus in science in Virginia and now open for assessment on statewide science testing for students, a renewed focus is on NOS instruction. For many science teachers’, especially elementary teachers, this is the first time they have been exposed to the nature of science. Therefore, making professional development instruction as effective as possible is a form of continuous improvement at which we are specifically looking.

In the *Year Two Research and Evaluation Annual Report* (2012), VISTA’s external evaluator reported that the first cohort of participants in the Elementary Science Institute demonstrated some increased understanding of NOS; however, very few participants reach the "fully aligned" level by the end of their participation in the study.

Table 1
ESI Cohort 1 Teachers' understandings of NOS instruction.

	Pre-Instruction (n=49, 100% responding)			Post-Instruction (n =49, 100% responding)			Year End (n =47, 94% responding)		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
NOS understandings	46 (93.9%)	3 (6.1%)	0 (0%)	23 (46.9%)	22 (44.9%)	4 (8.2%)	23 (48.9%)	20 (42.6%)	4 (8.5%)

Therefore, it appears that we are heading in the correct direction, but need to do more for teachers to achieve NOS understanding. This aligns with the research literature on NOS being difficult for teachers to understand and include in their instruction (Abd-El-Khalick, et al, 1998; Akerson & Hanuscin, 2007; Bell, Matkins, & Gansneder, 2010; Khisfe, 2008; Scharmann, Smith, James, & Jensen, 2005). Time and practice are required for teachers to become confident and proficient at teaching NOS and for students to demonstrate NOS understanding.

Research Questions

How did participating in the Elementary Science Institute impact teachers' understanding of NOS?

How did participating in the Elementary Science Institute impact teachers' incorporation of NOS into their camp and classroom teaching?

Methods

Participants

During year two, 123 upper elementary teacher participants (grades 4-6) attended a four-week summer institute offered at three regional sites. Cumulatively, teacher participants in the institute were 22 males and 101 females from 29 elementary schools in 28 districts.

Design of Professional Development

During week one, teachers receive professional development in scientific, problem-based learning where students solve real science problems in a way similar to a scientist (Delisle, 1997; Hmelo-Silver, 2004; Krynock & Robb, 1999; Shack, 1993; Stepien & Gallagher, 1993) as well as student-centered inquiry and the nature of science. During weeks two and three, teachers collaboratively taught inquiry-based science to high-needs students from 24 school districts in a PBL summer camp setting. The camp is designed so that the teachers work in teams as they *learn* about problem-based learning and receive *feedback* as they *try* inquiry-based science teaching. In week 4, teachers reflected on their summer teaching experience and planned implementation of a problem-based teaching and learning unit in their school. Follow-up professional development and coaching support during the academic year helps them *implement* science-based approaches in their classroom settings.

The nature of science is an important component of the VISTA team's work with elementary teachers. As noted, the external evaluator reported that the participants NOS understanding increased for cohort one and our efforts were paying off. The VISTA implementation team felt several additions and modifications to the professional development work could have significant impact and move more teachers forward in their thinking. To provide insight into how the team taught NOS in year one and changed their instruction in year two a description of both years follows.

During the first ESI, the participants' professional development on NOS involved eight components spread across the four week institute, school year coaching sessions, and fall follow up sessions. In Table 2, a summary of the components for year 1 and 2 are displayed. On the second day of the institute, the participants received an introduction to the NOS tenets. Each site introduced NOS by sharing the story of a group of students from New Country Day School in Minnesota. These students encountered frogs with mutations during a field trip. This field-trip evolved into an extended study for those students and for the Minnesota Pollution Control Agency and California Agency scientists (Youth, 2011). At the end of the story, the participants discussed with the facilitator the aspects of NOS that they heard in the story. The participants were then provided with their own opportunity to explore frogs that engaged them in various tenets of the nature of science. These tenets were discussed and developed with the participants as their investigation evolved. This led to an introduction of the aspects of NOS in the VA Science Standards of Learning and the importance of being explicit with students. During the planning of the science camp, the teachers were reminded and assisted with the inclusion of NOS in their lesson plans.

As the participants planned for the PBL camp on days three through five, their lesson plan template had them incorporate the aspects of NOS they wanted to address in their lesson. During the planning process, numerous opportunities for discussion and revisiting the NOS tenets occurred. The participants shared and reviewed each other’s lessons, they received feedback from the facilitators, and they presented their lessons to the group before camp. NOS was one of the foci for discussion in each of these sessions.

During the two week camp for students, each teacher taught their lesson to the students. At the end of each day, teachers serving as peer observers highlighted where in the lesson they saw the teacher being implicit and explicit and possible places for inclusion in the future. During these two weeks, the teachers also had a field experience in a scientist’s lab for two days. Everyone had the opportunity to spend two days in a lab with a scientist. Scientists were brought on board to discuss their work, how they got to their position, and how their work links to the aspects of NOS that we had been working with. The scientists also engaged the participants in their research or activities similar to their research during the two days. At the end of the two days, one of the facilitators met with the teachers to discuss their experience and its relationship to NOS and how they can be more explicit with the students.

During the last week of the institute, the participants work in teams to develop a PBL for implementation during the school year. As the teams prepared their units, they were reminded to include the nature of science aspects in their lessons and to describe how they would be explicit with the students. During the sharing of their units with other teams, they were asked about how they were going to help the students understand NOS.

After the summer institute during the fall, the participants attended six hours of follow up, either as a single day or two half-day sessions. During the follow up session the participants shared their successes and struggles with implementing their unit. One of the areas of discussion was NOS.

Each teacher receives the equivalent of three school days with a VISTA coach. The coaches observe lessons when the teachers are teaching their PBL unit to provide support and suggestions. They also visit and help the teachers improve their use of inquiry and NOS throughout the school year. During their observations and visits, the coaches use a rubric to gauge their level of explicitness with NOS and discuss their observations afterwards with the teachers. The rubric in year one asked had coaches identify one to three tenets that were implicit or explicit by the students and to evaluate the level of understanding of the students with respect to that tenet on a scale of one to three.

Table 2

Elementary Science NOS Professional Development Components

	Year 1	**Year 2**
ESI Week 1	*Day 2:* Frog Scenario from Minnesota (1), Frog Exploration (2), VA NOS tenets and teaching explicitly *Days 3- 5 (3):* Planning of Camp by participants with NOS included in the lesson plans	*Day 2:* NOS Card Sort (9), Frog Scenario from Minnesota (1), Organism Exploration (2), VA NOS tenets and teaching explicitly, NOS Card Sort (9) *Day 3:* NOS Card Sort (9), Seeing Like an Astronomer Activity (10), NOS Card Sort debrief (9) *Days 3- 6(3):* Planning of Camp by participants with NOS included in the lesson plans
ESI Week 2 and 3	*Teaching and Observation of Peers Teaching (4):* Identification of NOS implicitly and explicitly taught by teacher *Working with Scientists and Debrief (5):* Scientists engaged them in their labs for two days, discussed how they approached their field of study, and discussed how their work embedded the NOS aspects, debrief with VISTA staff on the use of NOS by the scientists	*Teaching and Observation of Peers Teaching (4):* Identification of NOS implicitly and explicitly taught by teacher *Working with Scientists and Debrief (5):* Scientists engaged them in their labs for two days, discussed how they approached their field of study, and discussed how their work embedded the NOS aspects, debrief with VISTA staff on the use of NOS by the scientists
ESI Week 4	*Planning Classroom Units (6):* embedding NOS in lesson plans, feedback from peers and VISTA team	*Planning Classroom Units (6):* embedding NOS in lesson plans, feedback from peers and VISTA team
Coaches Sessions	*Rubric and Lesson Debrief (7):* Use of simple NOS rubric to identify implicit and explicit teaching by the teachers, and explicit use by the students.	*Rubric and Lesson Debrief (11):* Use of expanded NOS rubric to identify implicit and explicit teaching by the teachers, and explicit use by the students.
Fall Follow Up Session	Revisiting NOS in Units (8)	*Revisiting NOS in Units (8)* *Revisiting NOS through activities*, such as fossil footprints, burning cheese candle, water drop (12)

To improve the delivery of the NOS component in year two, the team developed a 12 component strategy to highlight NOS during the four week institute, school year coaching sessions, and fall follow up sessions. We included the components from year one and added several new components designed to reinforce and highlight the NOS tenets (#9 through 12) (Table 2).

On the second day of the summer institute, we began with a card sort that included a set of cards with statements that were and were not true about how scientists work and the nature of science (NOS). These statements came from the work of Bell, Maeng, and Peters (2010), Cobern and Loving (1998), Lederman, Abd-El-Khalick, Bell, and Schwartz (2002), Liang, Chen , Chen, Kaya, Adams, Macklin, and Ebenezer (2008), and Schwartz, Lederman, and Crawford (2004). We asked the participants to sort the cards into three piles based on whether they agreed, disagreed, or were not sure if the statement was correct. The participants then shared one they agreed with and one they disagreed with their table group. After sharing they put their sorted cards away to be revisited later in the session. The next component of this session was the sharing of the story about the students from New Country Day School in Minnesota. Just as in year one, at the end of the story, the participants discussed with the facilitator the aspects of NOS that they heard in the story. The participants were then provided with their own opportunity to explore an organism (frog or pill bug, depending on the site) that engaged them in various aspects of the nature of science. These aspects were discussed and developed with the participants as their investigation evolved. This led to an introduction of the tenets of NOS in the VA Science Standards of Learning and the importance of being explicit with students. This session concluded with the participants revisiting their cards and reorganizing them based on their new knowledge.

On the third day of the institute, the participants were asked to review the aspects of NOS shared the day before. The team led an investigation into observations made by astronomers by leading a simulation using various observation tools. They discussed the various aspects of NOS in the simulation and how the facilitator was explicit about various aspects of the nature of science in their delivery of the simulation. This simulation was adapted from an activity titled "Seeing Like an Astronomer" found on the American Museum of Natural History website (AMNH, 2003). Like the activity, the facilitators also discussed the different tools astronomers use to see objects in space and the benefits of each tool. The participants revisited their card sort and discussed how their understanding of the aspects of NOS had changed. This session ended with the participants examining lesson plans to discuss opportunities for discussion by the teacher and students of NOS.

As the participants planned for the PBL camp on days three through six (one additional day in year two), their lesson plan template had them incorporate the aspects of NOS they wanted to address in their lesson. As in year one, there were numerous opportunities for discussion and revisiting the NOS tenets.

During the two week camp for students, as in year one, each teacher taught their lesson to the students, peer observers recorded the implicit or explicit teaching of NOS, and the teachers participated in daily debrief sessions. Again in year two, the teachers had a field experience in a scientists' lab for two days. At the end of the two days, one of the facilitators met with the teachers to discuss their experience and its relationship to NOS and how they can be more explicit with the students.

During the fourth week of the institute, the participants developed a PBL unit with NOS embedded for implementation during the school year.

During the fall, the participants attended six hours of follow up, either as a single day or two half-day sessions. The participants shared their work and status of teaching their PBL unit. In these discussions, each site had participants discuss how they were incorporating the NOS tenets in the PBL unit and other science lessons. In addition, activities, such as the fossil footprint, the burning cheese candle (Bell, 2008) and the water drop activity (Rezba, Sprague, McDonnough, & Matkins, 2007) were conducted to review the various tenets of NOS.

As described for year one, the coaches observe lessons when the teachers are teaching their PBL unit to provide support and suggestions. During their observations, the coaches use a rubric to gauge the teachers and students level of explicitness with NOS and debrief their observations afterwards with the teachers.

Research Design

This mixed methods case study collected qualitative and quantitative data concurrently from teachers as the program was being extended and adapted across a state. The study highlights the issues the teachers encountered and how the teachers grappled with implementing the new program based on previous programs that had a record of success. Qualitative data were analyzed using a constant comparative process of grounded theory (Glaser, 1978; Glaser & Strauss, 1967; Strauss & Corbin, 1998) and cross-case synthesis (Yin, 2003) and quantitative data were analyzed using descriptive statistics.

Measures

Perceptions surveys. Perceptions data collected both years consisted of participants' responses to perceptions surveys administered pre-/post the VISTA professional development and interviews. The perceptions surveys were designed to elicit participants' perceptions of the effectiveness of the VISTA professional development and their understanding of the key objectives of the VISTA professional development (PBL, NOS instruction, and inquiry instruction). These surveys contained a combination of Likert-scale and open-ended items. Face and content validity for each survey was supported by the review and suggestion of revisions by a panel of experts with backgrounds in science education and research evaluation. Additionally, participants in the ESI were asked to define and describe inquiry, nature of science, and problem-based learning instruction and indicate the frequency and confidence with which they implement these into their science instruction. Common to post-perceptions surveys were additional Likert-scale and open-ended questions designed to elicit participants' perceptions of the strengths and weaknesses of the VISTA professional development, the quality of the VISTA professional development relative to other professional development experiences, and how participants intended to use what they learned during the professional development during the upcoming academic year.

Retrospective survey. Participants were asked to rate their understanding of NOS prior to instruction, on day three after two instructional blocks, and after the summer science camp. A retrospective approach was used on the midpoint collection to allow participants to reflect and re-gauge their original understanding against their current understanding. The teachers were asked to comment on "how and why it was changing" and "how they planned to incorporate the tenets into their classroom instruction." Results were analyzed to learn whether patterns existed in how their thinking had changed for one site.

Exit slips. Teachers responded to an open-ended prompt, "After the NOS training today, how can you incorporate the tenets of the nature of science in your classroom?", administered at the conclusion of day three after the two instructional blocks. These responses were analyzed to learn whether the participants understood the need to deliver instruction on NOS explicitly and whether they could envision having their students explicitly talking about the nature of science in their lessons.

Camp teaching observation forms. Additional results were obtained by analyzing teacher observations of science teaching in the context of the summer camp that accompanied the summer training.

Field experience reflections. Teachers reflected on their experience and NOS at the end of their two day experience in a practicing scientists lab. These reflections were analyzed for one site to determine whether the participants were able to identify tenets of NOS from their experience.

Coach observation forms. During coach observations of classroom teaching, they have several rubrics to collect data with and to use in their debrief session with a teacher. One rubric assesses the implicit and explicit delivery of the tenets of NOS for teachers and students. These forms were analyzed to determine the frequency of coach observation of each tenet for a sampling of lessons.

Findings

This paper reports on the results of assessments of elementary teachers' understanding of and confidence in implementing the nature of science (NOS) to support learning.

Perceptions survey

In the *Year Two Research and Evaluation Annual Report* (2012), VISTA's external evaluator reported that the second cohort of participants in the Elementary Science Institute demonstrated increased confidence for incorporating explicit NOS instruction.

Table 3
ESI Cohort 2 Participants' Confidence in Incorporating Explicit NOS Instruction, M (SD)

Overall		Site 1		Site 2		Site 3	
Pre (n=94)	Post (n = 92)	Pre (n=32)	Post (n=31)	Pre (n=36)	Post (n=35)	Pre (n=26)	Post (n=26)
2.1 (1.0)	3.8 (.90)	2.2 (1.1)	3.9 (.81)	2.1 (1.1)	3.8 (.91)	2.1 (.95)	3.5 (.91)

It is hoped that this increase in confidence will translate into more cohort 2 teachers having "fully aligned" understandings of NOS at the end of their participation in the study and reporting more explicit instruction regarding NOS in their classrooms.

Retrospective survey

On the first day of the Elementary Science Institute, before receiving any instruction (pre), teachers were asked to rate their understanding of NOS (1 = "I have very little understanding," 3 = "I have moderate understanding," 5 = "I am an expert"). After approximately half of the instruction related to NOS had been completed, teachers reassessed their initial rating (retromid) and then rated their understanding at the current time point (mid). Finally, at the end of the institute, after all NOS instruction had been completed (post), teachers again rated their current understanding. Table 4 provides descriptive statistics for these four data points across the three implementation sites as well as for all sites combined.

Table 4
Teachers' Ratings of Their Understanding of the Nature of Science – Descriptive Statistics

	Pre		**Retromid**		**Mid**		**Post**	
	M	SD	M	SD	M	SD	M	SD
Site 1 (n = 34) VCU	2.26	.96	2.91	1.07	3.82	.59	4.20	.58
Site 2 (n = 38) WM	2.05	1.09	2.36	1.18	3.25	.73	4.12	.65
Site 3 (n = 25) Mason	1.92	.91	1.68	.90	3.12	.53	3.76	.52
Combined (n = 97)	2.09	1.00	2.30	1.16	3.36	.69	4.03	.61

A Chi-square analysis was run to determine whether the ratings of understandings were evenly distributed across the three sites. The analysis revealed uneven distribution of responses among the three sites for each data collection point except pre (see Table 5).

Table 5
Chi-square Analysis of Rating Distributions among Sites

	Pre	Retromid	Mid	Post
χ^2	.46	.04	.02	.03

Paired samples t-tests showed that each site, as well as the entire combined sample, had significant gains in understanding of NOS between all data collection points except between pre and retromid (see Table 6). This analysis of participant understanding indicates that the participants increased their understanding with each opportunity to learn and apply their learning about NOS. Although it was not significant, it is of interest to note that participants' ratings of their understanding of NOS at two sites increased from pre- to retromid-test, while participants at the third site reported decreased understanding of NOS in the same time period. These results indicate that participants, upon reflection, felt their initial rating of understanding was at the correct level of understanding. However, several participants expressed confusion regarding how to complete the retrospective rating, which may have resulted in inaccurate data for that collection point.

Table 6
Understanding of NOS Paired Sample t-Tests

	Pre-Retromid			**Pre-Mid**			**Pre-Post**			**Retromid-Mid**			**Retromid-Post**			**Mid-Post**		
	t	df	*p*	*t*	df	*p*	*t*	df	*p*	*t*	df	*p*	*t*	df	*p*	*t*	df	*p*
Site 1	2.05	21	.05	6.84	21	.00	8.07	24	.00	4.63	21	.00	4.31	19	.00	2.99	19	.01
Site 2	1.57	35	.12	6.17	35	.00	10.16	25	.00	4.58	35	.00	7.19	25	.00	6.34	25	.00
Site 3	-1.66	24	.11	7.86	24	.00	10.82	24	.00	8.77	24	.00	12.06	24	.00	6.53	24	.00
Combined	1.61	82	.11	11.51	82	.00	16.26	75	.00	9.39	82	.00	12.62	70	.00	8.71	70	.00

At the midpoint, participants were asked to explain "how and why their" thinking had changed. Participants at Site 1 shared the following insights:

- I love the specific explicit language I have been given for the NOS.
- I knew very little about NOS on June 26th. Now I feel comfortable explaining and identifying NOS aspects. It feels really good to have learned so much in so little time. My confidence has increased.
- It changed due to my learning about what each one actually is. Before I rated myself upon my assumptions.
- I feel much more competent in NOS because of what we have been doing. Relating what we are talking about with the sort.
- It is becoming clearer everyday!
- I still need a more cognitive understanding of the "durable."
- I'm feeling a little more confident. I need to review notes and change previous thinking.

The participant ratings and comments indicate that at the mid-point (Day 3 of the Institute) they are growing in their understanding of NOS.

At the end of camp (day 17), in addition to the retrospective questions the participants were asked to comment on “how and why their” understanding had changed. A sampling of insights shared include:

- I don't believe I am an expert but I do believe that I have learned quite a bit on all of these.
- Initially, I felt that I knew more about hands-on, inquiry, and NOS but after the camp experience I have found that my understanding is/was not as complete as it needed to be. The experience helped me to learn the specifics and to recognize the true elements of each.

- The hands-on experiences made the difference! I learned so much about the NOS and its tenets.
- I have gained a wealth of knowledge and experience in this area. I have a better understanding of hands-on, inquiry, and NOS based on what I learned and experienced in the lessons taught. I am more aware of what is required and am very confident to incorporate them in my lessons daily.
- With the repeated discussions about NOS, my comfort with using NOS in my classroom has grown. Using inquiry with the students in camp has also helped. This inspires me to use more inquiry and hands-on in my classroom this year.

The participant ratings and comments at the end of camp (day 17) indicate that they continue to grow in their understanding of NOS and how to teach NOS explicitly in the classroom.

Exit Slips

After the NOS session on day three, the participants were also asked "how they could incorporate the tenets of NOS into their classroom." Table 7 provides the analysis for each site with an exemplar for implicit inclusion in lessons, explicit inclusion by teacher, explicit use by students, and a combination of both explicit by teacher and students. Analysis of participant responses indicates that some of the participants continue to not use language that specifically indicates explicit teaching of NOS and thus it remains implicit, while others use language that involve the explicit teaching of NOS, and in some cases the students explicitly use NOS language.

Table 7
Incorporation of NOS tenets in classroom by level of explicitness

	Implicit in Classroom	Explicit by Teacher	Explicit by Students	Explicit by Teacher and Students	Not Applicable/ Incorrect

Site 1 (n= 24 comment)	4 (number of responses)	3	9	5	3
Site 1 Exemplar	Have students show evidence, have students share thoughts and information in a social way, explain and provide examples of bias towards different things.	Post NOS poster in room, develop lesson plans to explicitly teach each aspect of NOS, relate content units to NOS.	By constantly referring back to each of these tenets each time I do an activity. I would like to post the tenets on the wall and use them each time I do a lesson by asking the kids which part of NOS it fit in on.	I can incorporate the aspects of NOS in my classroom by displaying the NOS poster we will receive, creating an image to go along with each aspect and an activity to go along with each aspect so they can learn them well. Then, I can provide the kids authentic experiences and constantly point out the NOS aspects/have them identify the NOS aspects as we complete them.	I feel that this institute has helped me to realize the NOS clearer and to understand the importance of consistently implementing the principles. I see that the tenets can now be incorporated throughout the day in my lesson planning.
Site 2 (n= 34 comments)	17 (number of responses)	8	1	2	6

Site 2 Exemplar	I will incorporate it daily mainly with the direction of my questioning. I will be putting in much more thought to the depth of my questions. I would like to incorporate even more opportunities for investigations prior to developing the concepts – I want them to have their own "a-ha" moments rather than teaching a lesson and then doing a demo or setting up an experiment to prove what we think should happen.	I need to explain to kids before the lesson what the nature of science is, and afterwards focus on the key points of NOS that were covered in the lesson.	Scientific knowledge is empirically based is easy to incorporate through experiments and observations. Reliable and tentative students need to understand that although reliable science is not definite, it can change. Example would be that Pluto is no longer a planet. Students can and have learned this when studying the planets. I can also pose problems where they have to think and be creative.	Making sure to use the vocabulary of observations, evidence, social and durable so the students understand and even use them.	Many of the math standards and skills could be used in teaching science. Students also usually enjoy working together to create things using their imagination.
Site 3 (n=17 comments)	12 (number of responses)	3	0	1	1
Site 3	One key in	I have been		As we work	The NOS

Exemplar	incorporating the nature of science is including activities that cause kids to question what they think they know. This sets the framework for your science instruction and helps kids understand that their ideas will change, they need to use evidence, the different between observation/inferen ce, etc.	explicitly teaching observatio n and inference, but I have taught that inference does not have a place. I need to adjust my teaching on this. I will keep the poster up and refer to it after each lesson.		through experiments, refer back to the tenets of NOS to make connection explicit.	correlates very well with math standards and lessons. I can use these by allowing and encouraging creativity, differentiation , group work, etc.

Camp observations

During the teaching of camp, participants were either involved in teaching or observing their peers. When observing their peers, the teachers were asked to document how the various components of the institute, including NOS, were being incorporated into the lessons. These documents were used in a daily debrief. These documents were kept at two sites and provide insight into whether the observing teachers identified NOS tenets taught implicitly or explicitly in the lesson. At both sites, the teachers identified the use of explicit NOS teaching strategies more frequently than implicit teaching of NOS. At both sites, “science is a social activity” was identified most frequently (see Table 8). Other tenets frequently identified at Site 1 were “science demands evidence” and “science uses a blend of logic and imagination.” At Site 2, “scientific knowledge is the product of observation and inference” and “scientists use many methods to develop knowledge” were more frequently identified. At both sites, “scientific laws and theories are different kinds of scientific knowledge" was identified least frequently (see Table 8). The low frequency of teaching of this tenet may be due to teachers' lack of experience in talking about these ideas and their inclusion in the Virginia middle and high school Standards of Learning and not in the elementary Standards of Learning. At Site 2, "scientists avoid bias" was also a tenet least frequently identified. At Site 1, this tenet was identified more frequently, while "scientific knowledge is the product of observation and inference" was identified less frequently.

Table 8

Frequency of Implicit and Explicit Teaching of NOS in Science Camp Lessons

NOS Tenet		IMPLICIT FREQUENCY	EXPLICIT FREQUENCY	FREQUENCY (Implicit and Explicit)	RELATIVE FREQUENCY	PERCENT OBSERVED
Science demands evidence.	Site 1	9	8	17	17/75	23
	Site 2	9	23	32	32/244	13
Scientific ideas are durable yet subject to change.	Site 1	5	4	9	9/75	12
	Site 2	10	17	27	27/244	11
Science uses a blend of logic and imagination.	Site 1	4	10	14	14/75	19
	Site 2	5	23	28	28/244	11
Science is a social activity.	Site 1	15	10	25	25/75	37
	Site 2	8	38	46	46/244	19

Scientists attempt to avoid bias.	Site 1	1	4	5	5/75	7
	Site 2	2	15	17	17/244	7
Scientific knowledge is the product of observation and inference.	Site 1	0	2	2	2/75	3
	Site 2	10	30	40	40/244	16
Scientific laws and theories are different kinds of scientific knowledge.	Site 1	0	0	0	0/75	0
	Site 2	2	15	17	17/244	7
Scientists use many methods to develop scientific knowledge.	Site 1	0	3	3	3/75	4
	Site 2	3	34	37	37/244	15

Field experience debrief

During the two weeks of science camp, each of the participants spent two days with a practicing scientist. This opportunity allowed the participants to learn about the scientist's work and how the various aspects of NOS are embedded in the real life work of a scientist. Participants provided reflections at the end of the two days during a debrief session. Analysis of these reflections at site one, Table 9, finds that the participants were able to identify different components of the two days that demonstrated each of the VA NOS tenets. In three of the reflections, the participants indicated that all tenets of NOS were addressed by the scientist.

Table 9

Debrief and Reflection After Working in a Scientists' Lab from Site 1

Virginia NOS Tenets (K-5)	**Number of Individuals identifying**	**Exemplar**
The natural world is understandable.	7	This experience has helped me to see that science is understandable and a social activity as I provide opportunities for my student to participate in hands-on lab experiences. It will also help them to develop their methods of inquiry as they began to share in discourse sessions why certain phenomena occur, or sometimes not occur.
Science demands evidence, both observable and experimental.	12	Science demands evidence and we did many experiments that reflected on what was taught. Evidence was clear when we did our experiments with plants and the microscopes.
Science uses a blend of logic and imagination.	7	I loved the connections to the food revolution which shows how some science ideas have changed. Scientists need to look at evidence and there is cool evidence to show how plants have adapted over the past billion years. We saw how logic and experiments have taught us about plants.
Scientific knowledge is durable yet subject to change.	10	That is science is durable yet it changes as new data is introduced. Thus the progression of the greening of Earth, the mutations of weeds into domestic plants that are used as our food supply.
Science is a complex social activity.	8	The questions come about through the imagination and "what if" ideas to answer the new questions. The scientists share and communicate ideas that lead to other questions peer review. The activities in the lab encouraged our socialization and discussion to help understand scientific knowledge.
Scientists attempt to avoid bias.	7	A lot of research and experiments are done to accept certain ideas; try to stay free of bias.
Scientific knowledge is the product of observation and inference.	2	Science is based on evidence, both observational and experimental.
Scientific laws and theories are different	0	

kinds of scientific knowledge.		
Scientists use many methods to develop scientific knowledge.	4	I learned that science is innovative and creative. The different ways she exposed the class to collecting samples and creating simple experiments using limited resources.

The participants also shared other features of the two days that contributed to their understanding of NOS. These include:

- Using real plants and materials, relating to real life
- Evidence for questions leads to new questions (11 similar ideas)
- She posed questions and then provided evidence
- Seeing a real scientist
- It is extremely important to read peer-reviewed work that other scientists have already done.
- Nothing really new but strengthened (2 similar reflections)

These reflections indicate that the participants learned about NOS from this experience, deepened their understanding of NOS, and learned beyond the tenets being explicitly taught in the Institute.

Coach observations

The teachers returned to their classrooms to teach during the 2012-2013 school year. VISTA provided instructional coaches to support and provide guidance to the teachers after the ESI. The coaches conduct classroom observations using a variety of rubrics. The rubrics provide a debrief tool when the coach meets with the teachers. The NOS rubric allowed them to record the frequency of NOS tenets taught just as the teachers had during the science camp. For site two, we analyzed the rubrics submitted to VISTA by the coaches to determine how frequently each tenet was observed. From Table 11, the coaches observed more explicit NOS tenets as compared to implicit NOS tenets. Of interest is whether patterns from teachers during the summer were similar to or different to those of the coaches during the school year. A comparison of frequencies, in Table 10, for Site 2 matches the results of the teachers in Table 8. However, the coaches observed more implicit examples of NOS in their classroom than the teachers identified in the summer camp teaching. Coaches also indicated that the most common aspect of NOS observed was "science demands evidence" followed by "science is a social activity". The least frequent aspects of NOS observed were "scientific laws and theories are different kinds of scientific knowledge" and "scientists avoid bias", which matched the frequency of teacher observations for site two.

Table 10

Frequency of NOS Aspects in ESI Teachers' Classrooms Observed by Coaches post-ESI for site 2

NOS Tenet	**IMPLICIT FREQUENCY**	**EXPLICIT FREQUENCY**	**FREQUENCY**	**RELATIVE FREQUENCY**	**PERCENT OBSERVED**
Science demands evidence.	72	18	90	90/282	32
Scientific ideas are durable yet subject to change.	9	19	28	28/282	10
Science uses a blend of logic and imagination.	12	25	37	37/282	13
Science is a social activity.	2	56	58	58/282	21
Scientists attempt to avoid bias.	8	4	12	12/282	4
Scientific knowledge is	2	34	36	36/282	13

the product of observation and inference.					
Scientific laws and theories are different kinds of scientific knowledge.	1	0	1	1/282	0
Scientists use many methods to develop scientific knowledge	5	15	20	20/282	7

Anecdotal data

During the fourth week of the institute, the teachers at all sites developed problem-based learning units to take back and implement during the 2012-2013 school year. All units were to include NOS in the teaching. Anecdotal data shared by teachers indicates that the posters with the NOS tenets have been very useful. At one school, the team has a NOS song to help the students learn the various tenets of NOS. One teacher shared this about her unit,

> The challenge that the children had to solve was, how they could protect plants and animals in their habitats from the effects of climate change.
>
> The engagement level was huge. It was fascinating to hear from parents that dinner time conversation was now about climate change. That children were guiding their parents into making wise decisions because of climate change. And to see how they took what they had learned about extreme weather about habitat and the environment and really connected it to their reality.
>
> Their work on this unit was especially exciting because they truly felt empowered and felt that they could make a difference in something that affects people all around. It was relevant.

> They acted like scientists. They did the work of scientists. Each day as we wrapped up a lesson, we would say, What work did we do today that real scientists do? So they totally understood that the work going on in the classroom was the kind of work that real scientists do.
>
> And from that, I have a level of excitement about science in my classroom that I've never had. My kids every day are telling me how much they love science. And so many of them now are looking forward to a career that involves science. It's been a really thrilling experience.

We are still collecting examples from teachers to show the impact of the ESI on the teaching of science.

Discussion

The results of this study have the potential to inform professional development that supports educators' implementation of NOS instruction by in-service elementary science teachers. The VISTA model of professional development for elementary teachers of having a camp with students can be used to improve science instruction and provide an authentic framework to teach NOS. Using a science camp eliminates teacher concerns about students passing state tests. Thus teachers can focus on their teaching and implementing new strategies. This framework can be used by educational planners to design effective teacher training modules for understanding PBL using inquiry-based and NOS instruction.

As programs are expanded to new audiences, they face new challenges. This paper describes the growth of one program and shares the challenges being encountered in one state when science professional development programs are extended statewide. Improving teacher effectiveness is an intermediate but very important variable strongly related with improving student outcomes.

Teaching the nature of science has been a long-standing goal of the science education community. This goal has become more focused by research findings about the importance of explicit instruction. This paper provides encouraging results when (1) the construct of "explicitness" was addressed overtly with elementary teachers, (2) multiple opportunities to experience NOS instruction were provided over time, and (3) supervision and immediate feedback were provided to teachers.

Teachers perceived positive changes from participating in VISTA and that VISTA was effective in supporting improvement in confidence and proficiency in implementing nature of science instruction. This study confirmed the literature that it is difficult for teachers, especially elementary teachers, to understand and teach NOS. After participating in the Elementary Science Institute, there was an increase in the teachers' understanding of NOS. The participants in cohort one moved from 94% not understanding NOS to 43% partially understanding NOS to 8% fully understanding NOS.

Cohort two participants' confidence in incorporating explicit NOS instruction increased overall and at all sites. In addition, over time self-report ratings of their understanding of the nature of science significantly increased at all three sites. There was a shift from implicit to more explicit instruction. The participants appreciated revisiting NOS over the year while in the treatment group. Initial classroom data suggests that we need to implement more in-classroom study of NOS.

One strategy that may help further support teachers' implementation in camp and back in their schools is a further refinement of the lesson plan template. This change would better support the teachers' implementation of NOS, and also provide additional data and insights into how teachers move from implicit to explicit NOS instructional activities for students.

This study has two main limitations, the first is most data are self-report and the second is data collection for some parts of the study is inconsistent across sites. This study is based on data from years one and two and will be more robust after the five years of the study. As more data is collected and analyzed across the years, the accuracy of the data should be higher and the strategies used for teaching and learning more robust as continuous improvement takes place. A further question is: Will teachers continue to improve over time?

The VISTA efforts to build capacity among participants to establish a collaborative community of science teachers and science teacher educators may serve as a model for other regions. The impact of implementation of system wide reform such as VISTA is an area where little research has been conducted. We must consider the whole system and the role of all related personnel, if we are to understand the variables that impact science instruction and student learning.

Each component of the VISTA professional development has the potential to be of interest to members of the education community. Educators who deliver professional development for teachers may be interested in using the VISTA ESI professional development framework and materials to involve other school districts in developing their own PBL professional development using an inquiry-based approach to teaching the nature of science.

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