Outcomes of the Virginia Initiative for Science Teaching and Achievement (VISTA) Professional Development

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Abstract

This paper builds upon the previous papers in the set by reporting the results of assessments of VISTA participants' understanding of and confidence in implementing problem-based learning (PBL), nature of science (NOS), and inquiry instruction. The context for the assessments is three key VISTA components: the Elementary Science Institute (ESI), New Science Coordinator Academy (NSCA), and Science Education Faculty Academy (SEFA). Participants in the NSCA were 3 males and 10 females from 12 different school districts. Participants in the SEFA were 4 males and 4 females from 7 different universities and colleges. Participants in the ESI were 9 males and 43 females from 17 different elementary schools in 11 different districts. Data in this mixed-methods study consisted of responses to pre-/post Perceptions surveys and interviews designed to elicit participants' understandings and intentions to implement PBL, NOS, and inquiry instruction. Analysis of the Perceptions surveys suggested that participants in the three professional development academies perceived positive changes with respect to key program objectives. Participants in all three groups experienced substantive improvements in their understanding of and proficiency in implementing PBL, NOS, and inquiry instruction in their respective contexts. Additional results reflect participants' perceptions of positive and negative aspects of their respective professional development experiences.

Introduction

The *National Science Education Standards, Benchmarks for Scientific Literacy*, and recently released *Framework for K-12 Science Education*, identify scientific literacy a principal goal of science education (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC] 1996, 2011). Scientific literacy addresses the need for students to use scientific knowledge to draw evidence-based conclusions about science-related issues, understand the characteristics of science as knowledge and inquiry, understand how science and technology shape the material, intellectual, and cultural environments, and to engage in science-related issues as a reflective citizen (Hazen & Trefil, 1992; Kolstoe, 2000; Roberts, 2007). Achieving scientific literacy requires four areas of science in which students should be proficient:

1) knowing, using, and interpreting scientific explanations of the natural world,
2) generating and evaluating evidence,
3) understanding the nature of and how scientific knowledge is developed, and
4) participating productively in scientific practice and discourse.

These interrelated strands represent the scientific knowledge, methods of science, and nature of scientific knowledge that K-12 science students need in order to develop scientific literacy and actively participate as educated citizens in society (Bell, Maeng, Peters, & Sterling, 2010; Bybee, 1997; NRC, 2007; Posnanski, 2010). Scientific knowledge includes the scientific concepts, laws, and theories most often associated with science instruction. The varied process skills used by scientists to generate scientific knowledge are the methods of science. The most abstract and least familiar of the components of scientific literacy is the nature of science, which addresses the characteristics of scientific knowledge itself. The nature of science acknowledges the values and beliefs inherent to the development of scientific knowledge and depicts science as an important way to understand and explain the natural world (Lederman, 2007).

Reform-based Science Instruction

Science education reform documents indicate students develop proficiency in science through student-centered instruction that facilitates understanding of all three aspects of science (scientific knowledge, processes of science, and nature of science). Effective science instruction should promote students' conceptual understanding and use of science concepts, provide students opportunities to learn about and practice science inquiry and the process skills necessary to conduct inquiry, and include explicit instruction about the nature of scientific knowledge (AAAS, 1993; Bell, Blair, Crawford, & Lederman, 2003; Donovan & Bransford, 2005; Khishfe & Abd-El-Khalick, 2002; Kolstoe, 2000; Lederman, 2007; NRC, 1996). This type of instruction places the teacher in the role of facilitator of learning and provides students opportunities for collaboration, scientific discussion, and debate (NRC 1996).

Problem-based learning (PBL) is one instructional model that provides a context for reform-based science instruction. PBL incorporates an authentic context, problems with multiple or divergent solutions, inquiry experiences, and collaboration among students. Additionally, it facilitates students' real-world application of science knowledge and methods through student-centered instruction (Chin & Chia, 2004). PBL also has the potential to provide teachers opportunities to explicitly address the nature of science in instruction.

Such reform-based approaches to science instruction represent dramatic shifts from traditional instruction and have proven difficult to implement in classrooms for a number of reasons (Loucks-Horsley & Matsumoto, 1999). Many of the barriers contributing to some teachers' reluctance to implement reform-based science instruction are institutional and technical. These include emphasis on standardized testing by administrators and teachers, a perceived disconnect between students' exploration of concepts through investigations and district-mandated content objectives, and a lack of resources (Arora, Kean, & Anthony, 2000; Bauer & Kenton, 2005; Blumenfeld, Krajcik, Marx, & Soloway, 1994; Johnson, 2006, 2007; Keys & Bryan, 2001; Keys & Kennedy, 1999; Yerrick, Parke, & Nugent, 1997).

Other barriers relate to teachers' knowledge of science content, understandings of the nature of science, and/or familiarity of pedagogical approaches that support reform-based instruction (e.g. Johnson, 2006, 2007; Lederman, 2007; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Supovitz & Turner, 2000.) Effective nature of science and inquiry instruction does not come naturally for most teachers (e.g. Lederman, Lederman, Kim, & Ko, 2012). Teachers' understandings of science inquiry and the nature of science are typically not aligned with those promoted by science education reforms (Lederman, 2007; Lederman, Lederman, Kim, & Ko, 2012). For example, some teachers conflate inquiry instruction with hands-on instruction and teaching the nature of science with inquiry and process skills (Abd-El-Khalick, Bell, & Lederman, 2007; Crawford, 2000, NRC, 2000). Others do not consider the nature of science to be an important aspect of scientific literacy (Bell, Lederman, & Abd-El-Khalick, 2000; Lantz & Kass, 1987). Still others do not recognize that nature of science instruction must explicitly address targeted nature of science conceptions through reflection and discussion to be effective (e.g. Bell, Blair, Crawford, & Lederman, 2003; Bell, Mulvey, & Maeng, 2012; Hanuscin, Akerson, & Phillipson-Mower, 2006; Khishfe, 2008; Scharmann, Smith, James, & Jensen, 2005; Schwartz, Lederman, & Crawford, 2004). Finally, research suggests that even teachers who hold adequate conceptions of nature of science have difficulty integrating NOS into their own instruction (e.g. Akerson & Abd-El-Kalick, 2003; Bell, Abd-El-Khalick, & Lederman, 1998; Lederman, 2007).

Professional Development to Support Reform-based Science Instruction

Given the aforementioned barriers to reform-based science instruction, a recent focus of the science education community is professional development designed to increase teachers' knowledge of inquiry and nature of science instruction and ease in employing pedagogical approaches that support such instruction in science classrooms (Johnson, 2006, 2007; Loucks-Horsley et al., 2010; Supovitz & Turner, 2000). However, changing teachers' practice is a time-consuming and complex process (Lotter, Harwood, & Bonner, 2006). Research suggests that for science teacher professional development to elicit desired changes in teachers practices, it should be sustained and ongoing (e.g. Johnson, Khale, & Fargo, 2007; Supovitz, Mayer & Kahle, 2000). Further, effective professional development acknowledges teachers' current beliefs and practices, is context-specific, fosters collaboration, and provides teachers with opportunities for practice, reflection, and feedback (Desimone, 2009; Loucks-Horsley, Stiles, & Hewson, 1996; Supovitz & Turner, 2000; Wayne, Yoon, Zhu, Cronen, & Garet, 2008). There is also evidence that expert coaching can facilitate teachers' implementation of new teaching strategies into their instruction (Loucks-Horsley et al., 2010). However, previous attempts to prepare teachers to teach inquiry and nature of science have met with mixed results (e.g. Gates, 2008; Lederman, 2007; Roehrig & Luft, 2004; Schneider, Krajcik, & Blumenfeld, 2005).

The Virginia Initiative for Science Teaching and Achievement (VISTA) project incorporates key components of effective professional development to support reform-based science instruction. VISTA professional development is sustained and ongoing, context-specific, fosters collaboration, and provides opportunities for feedback, reflection, and practice. VISTA professional development incorporates a Learn, Try, Implement with Feedback and Research model with an emphasis on continuous teacher improvement. The structure of VISTA was heavily informed by two smaller-scale science teacher professional development programs (Sterling & Frazier 2010;

Sterling, Matkins, Frazier, & Logerwell, 2007). Statistically significant improvement in science instruction and student performance was reported for both of these professional development programs.

Specifically, VISTA provides professional development to support K-12 science teachers' inclusion of inquiry-based and explicit nature of science instruction in the context of problem-based learning. VISTA defined these constructs as:

- Problem-based learning: Students solving a problem with multiple solutions over time like a scientist in a real-world context; both the problem and context must be meaningful to students
- Inquiry: (1) Asking questions; (2) collecting and analyzing data; (3) using evidence to solve problems
- Nature of science instruction: the values and assumptions inherent to the development of scientific knowledge. Key elements include: (1) Scientific knowledge is empirical, reliable and tentative, based on observation and inference; (2) Scientific theories and laws are different; (3) Many methods are employed to develop scientific knowledge.

Not only is VISTA designed to develop K-12 teachers' reform-based instruction, it also is intended to facilitate the development of an infrastructure to support reform-based science instruction throughout Virginia. To support this goal, principal and science coordinators are included in the K-12 teacher professional development. The VISTA program also includes two other professional development academies, the New Science Coordinator Academy (NSCA) and Science Education Faculty Academy (SEFA) targeted toward science coordinators and science educators, respectively.

Purpose

This study reports the results of ongoing assessment of three primary components of the VISTA program: the elementary science institute (ESI), the new science coordinator academy (NSCA), and the science education faculty academy (SEFA). Specific research questions include:

1. How do VISTA participants' understanding of and confidence in implementing problem-based learning, inquiry, and nature of science instruction change as a result of participation in the VISTA professional development program?
2. What are participants' perceptions of positive and negative aspects of their respective VISTA professional development programs?

Methods

Elementary Science Institute

Participants. Participants in the VISTA Elementary Science Institute (ESI) were 9 males and 43 females from 17 different elementary school teams and 11 different districts in Virginia. There were 1 Asian, 1 Hispanic, 8 African American, and 42 Caucasian participants (Table 1). Participants' Virginia licensure and teaching and science experience are described in Table 2. All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Table 1. *VISTA Elementary Science Institute participant demographic data.*

Total	Gender		Ethnicity			
	Female	Male	Caucasian	African American	Hispanic	Asian
52	43 (82.7%)	9 (17.3%)	42 (80.8%)	8 (15.4%)	1 (1.9%)	1 (1.9%)

Table 2. *VISTA Elementary Science Institute participant teaching and science experience*.

Total	Virginia Licensure				Teaching Experience					Highest Degree in Education			Deg. in Science
	Elem. Sch.	Elem. Sci.	Middle Sch.	Sec Sci.	0-1yr	2-3yr	4-6 yr	7-10yr	>10 yr	Bachelors	Masters	PhD	
51	51 (100%)	1 (2.0%)	4 (7.8%)	2 (3.9%)	4 (7.8%)	8 (15.7%)	12 (23.5%)	12 (23.5%)	15 (29.4%)	25 (49.0%)	25 (43.0%)	1 (2.0%)	5 (3.9%)

Note. Gender and ethnicity data are for all 52 participants; 1 participant did not report other demographic data, thus, these data are reported for n=51 participants.

Context. The goal of the VISTA ESI is to facilitate elementary teachers' effective science instruction through professional development in which upper elementary (grades 4-6) teachers experience scientific, problem-based learning (PBL) and student-centered inquiry. Then, teachers work in teams to develop and implement inquiry-based science instruction for students in the context of summer camp and their own classrooms.

The ESI consists of summer professional development, academic year follow-up and coaching, and principal and science coordinator support (Table 3). The 4-week (152 contact hours) summer professional development component of the ESI was implemented at George Mason University, the College of William and Mary, and Virginia Commonwealth University from June 26 to July 22, 2011. Elementary teachers spent week 1 of the summer institute learning a particular area of science and how to conduct inquiry-based science teaching. Weeks 2 and 3 emphasized collaboratively teaching inquiry-based science to high-needs students in a problem-based summer camp setting and participating in teaching modules (one week each). During Week 4, participants reflected on their summer teaching experience and began planning ways to implement problem-based and inquiry-based teaching throughout the academic year. Teams of university science educators, scientists, and engineers, along with science classroom teachers and mathematics specialists, co-planned and co-facilitated the summer learning experiences. Further, participants' principals and school district science coordinators attended part of the summer institute to become acculturated with the science teaching and inquiry process. During the 2011-2012 academic year, teachers participated in a minimum of fourteen hours of follow-up sessions and coaches visited teachers' classrooms at least four times to video-record and provide feedback on participants' science instruction. For a complete description of the ESI intervention, see Mannarino, Logerwell, Reid, & Edmonson (2012).

Table 3. Elementary Science Institute Timeline

Elementary Institute	Summer	Academic year
Grade 4-6 science teachers	4 week institute	3 follow-up sessions Attend VAST conference 3 visits by classroom coaches
Principals	1 day during institute	Newsletters
Science Coordinators	2 days during institute	Attend VSELA conference
Coaches – experienced science teachers	5 days during institute	2 days coach training meetings

Data Collection. Data consisted of Perceptions surveys administered pre- and post- Institute to participants, attendance records, observations of the summer institute, follow-up interviews of a subset of participants, and artifacts including planning documents and participant-generated reflections.

ESI Perceptions Survey. The VISTA Perceptions Survey was administered to all VISTA participants prior to the Summer Institute component of the VISTA ESI. The Pre-Institute VISTA Perceptions Survey contained 11 Likert-scale items designed to assess the frequency and confidence with which participants incorporated problem-based learning, NOS, inquiry, and educational technology (including computer simulations) into their science instruction. It also included questions about teachers' classroom practices, beliefs about teaching, and level of collaboration with fellow teachers prior professional development. The scale ranged from 1 (not very proficient) to 5 (highly proficient). Open-ended questions on the survey asked participants' to define and describe inquiry, NOS, and problem-based learning instruction.

At the end of the Summer Institute, teachers completed a follow-up VISTA Perceptions Survey, asking them about their experiences in the Summer Institute and plans for incorporating what they had learned into their classrooms in the upcoming school year. This post-survey contained 10 Likert-scale items and 4 open-ended questions designed to elicit participants' perceptions of the effectiveness of specific components of the ESI and how they will use what, if anything, they learned during the ESI during the upcoming academic year. Support for face and content validity of this survey was established by a panel of three experts in science education, evaluation, and measurement.

Observations. Each of the three implementation sites was observed the same three days over the course of the VISTA ESI. The purpose of these observations was to characterize implementation of the VISTA professonal development model and to establish support for cross-site implementation fidelity. An observation protocol ensured observers at all three sites focused their observations and field notes on key aspects of the professonal development. These included: the nature of teacher/teacher and teachers/facilitator interactions, signs of engagment, fatigue, understanding, discontent, questions among participants, implementation of the institute as planned (e.g. administrative, structural issues), the nature of instruction related to inquiry, problem-based learning, and NOS, and evidence of enactment of the learn, try, implement with feedback and research model.

Interviews. Following analysis of the pre- and post-Perceptions survey, 10 teachers (approximately 20% of participants) were purposefully selected for a follow-up semi-structured interview about their experience. These participants, distributed among the three sites, were selected because their pre- and post-intervention survey responses indicated little, moderate, or great changes in their proficiency of key VISTA objectives (inquiry, PBL, and NOS instruction). Interview questions elicited participants' perspectives on the most and least valuable aspects of the professional development, components of the professional development they plan to implement, and suggestions for improvement. These interviews also served as a member-check of these participants' survey responses.

Artifacts. All planning materials were collected. These artifacts allowed for detailed characterization of the ESI components and were triangulated with participants' survey data and interview responses. Artifacts were also used to establish support for cross-site implementation fidelity of the Summer Institute.

Data Analysis. Participants' pre- and post-ESI definitions and descriptions of PBL, NOS, and inquiry instruction in the classroom were analyzed using systematic data analysis (Miles & Huberman, 1994). A multi-part rubric was developed to facilitate this process by assessing the extent to which VISTA participants' open-ended survey responses expressed views of problem-based learning, inquiry, and nature of science aligned with VISTA constructs (Appendix A). Support for face and content validity of the rubric was established by an expert panel. Participants' responses were coded as not aligned, partially aligned, and fully aligned for definitions and implementation of PBL, inquiry, and NOS instruction. Teachers' understanding that effective NOS instruction is explicit was also coded. Responses were coded holistically as non-aligned, partially aligned, or fully aligned for each construct pre- and post-ESI. Two raters independently coded each participants' open-ended responses related to PBL, inquiry, and NOS. Inter-rater agreement was established (~90%) by comparing independent analysis of approximately 50% of the data. All disagreements were resolved by discussion.

Data from Likert scale items on each participant's pre- and post-ESI Perceptions survey were analyzed using descriptive statistics. For each participant, an overall sum of all of the items and mean scores pre- and post-Institute were calculated along with an aggregate mean score for those survey items assessing inquiry, NOS, and problem-based learning. Changes in participants' scores pre- and post-ESI summer professional development were also calculated as overall change, average change, and change for those items assessing inquiry, NOS, and problem-based learning.

Analytic induction, as described by Bogdan and Biklen (1992), was used to analyze the open-ended survey responses regarding participants' experiences during the ESI, follow-up interviews, and artifacts. Patterns were identified in the data set with the goal of characterizing the experiences of participants. From these patterns, preliminary categories were developed, which were refined through comparison with the original data set.

New Science Coordinator Academy

Participants. Participants in the VISTA New Science Coordinator Academy (NSCA) included 3 males and 10 females ranging in age from 30 to 54 years of age from 12 different school districts in Virginia. There were 1 Asian, 2 African American, and 10 Caucasian participants. At the time of the NSCA, all of the participants held a M.Ed. or M.S. degree and 7 participants held or were in the process of earning an Ed.D. or Ph.D. in Education. All participants were in leadership positions in their respective school division (K-12 science coordinator, science lead teacher, science specialist, instructional coach, vertical team leader, beginning teacher advisor coordinator, elementary principal). Of the participants, 10 have led science professional development in the past. Participants' years of experience in their current leadership role ranged from 7 months to 13 years with an average of 3.7 years of experience. All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Context. The goal of the VISTA New Science Coordinator Academy (NSCA) is to build, support, and sustain the infrastructure of school district science leaders. The NSCA was implemented by a team of 6 facilitators from March 23 to 25, 2011 and May 12 to 13, 2011 (19 contact hours) at George Mason University. The stated objectives of the NSCA were:

1. Learn to make improvements in leadership, teacher learning, quality teaching, and student learning.
2. Develop a common understanding of inquiry, NOS, and problem-based learning.
3. Identify aspects of effective science teaching and learning.
4. Compare district models of creating standards-based science curricula.
5. Investigate available data sources to provide a focus for improvement of district science programs.
6. Develop a science program strategic plan.

Over the five days of the academy, participants engaged in presentations, activities, and discussions that addressed each of these objectives. Edmonson, Sterling, & Reid (2012) describe in detail the components of the NSCA.

Data Collection. Data consisted of a survey administered pre- and post- Academy, follow-up interviews of a subset of participants, and artifacts including planning documents and participant-generated reflections.

NSCA Perceptions Survey. The NSCA Perceptions survey, designed to elicit participants' current understanding of key objectives of the SEFA, contained 14 Likert-scale items. Nine items assessed participants' understanding of and capacity to evaluate and implement professional development associated with PBL, NOS, and inquiry science instruction. Additional questions assessed participants' proficiency in supporting research-based and standards-based science instruction, using data to improve district science programs, and developing division-wide strategic planning and infrastructure support for science education. The scale ranged from 1 (not very proficient) to 5 (highly proficient).

This survey was administered prior to and following the NSCA. In addition to the pre-assessment questions, the post-survey contained four additional open-ended questions designed to elicit participants' perceptions of the strengths and weaknesses of the NSCA and the quality of the NSCA relative to other professional development experiences. Support for face and content validity of this survey was established by a panel of three experts in science education, evaluation, and measurement.

Interviews. Following analysis of the pre- and post- NSCA survey, 3 participants (23%) were purposefully selected for a follow-up semi-structured interview about their experience. These participants were selected because their pre- and post- survey responses indicated little, moderate, or great changes in their proficiency of the key NSCA objectives (inquiry, problem-based learning, and NOS instruction) following the Academy. Interview questions elicited participants' perspectives on the most and least valuable aspects of the Academy, components of the NSCA they planned to implement, and suggestions for improvement. These interviews also served as a member-check of these participants' survey responses.

Artifacts. All planning materials and participant-generated reflections were collected. These artifacts allowed for detailed characterization of the Academy components and triangulated with survey data and interview responses.

Data Analysis. Likert-scale data from each participant's pre- and post- NSCA survey were analyzed using descriptive statistics. For each participant, an overall sum of all of the items and mean scores pre- and post-NSCA were calculated along with an aggregate mean score for those survey items assessing inquiry, NOS, and problem-based learning. Changes in participants' scores pre- and post-NSCA were also calculated as overall change, average change, and change for those items assessing inquiry, NOS, and problem-based learning.

Analytic induction, as described by Bogdan and Biklen (1992), was used to analyze the open-ended survey responses, follow-up interviews, and artifacts. Patterns were identified in the data set with the goal of characterizing the experiences of participants of the NSCA. From these patterns, preliminary categories were developed, which were refined through comparison with the original data set.

Science Education Faculty Academy

Participants. Participants in the VISTA Science Education Faculty Academy (SEFA) included 4 males and 4 females ranging in age from 30 to 62 years of age from 7 different universities and colleges in Virginia. There were 2 African American, and 6 Caucasian participants. Of the 8 participants, 6 held tenure-track positions (assistant professor of education, associate professor of education, assistant professor science content area, full professor); 2 participants were adjunct faculty at the time of the SEFA. All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Context. The 5-day (27 contact hours) SEFA was implemented by a team of 5 facilitators from May 23 to 27, 2011 at George Mason University. The primary purpose of the SEFA was to build infrastructure to support effective science teaching and learning in Virginia as described in McDonnough, Sterling, Matkins, & Frazier (2012). Over the five days of the academy, participants engaged in presentations, activities, and discussions related to the following SEFA objectives:

1. Collaborate to identify challenges and develop solutions in science teacher education at the licensure and advance levels,
2. Learn about new research related to effective science teacher development and science teaching,
3. Share effective teaching strategies for how to best meet the needs of elementary and secondary science teachers at the licensure and advanced levels through collaborative grant proposals, as well as collaborative

syllabi and experiences for implementation in methods courses and teacher professional development seminars, and

4. Network to establish an infrastructure of support among science education faculty across the state (Virginia Science Education Professors - VSEP) that augments and supports existing infrastructure for science teachers and coordinators in the state (VAST, VSELA).

Data Collection. Data consisted of a survey administered pre- and post-SEFA, follow-up interviews of a subset of participants, and artifacts including planning documents and participant-generated reflections.

SEFA Perceptions Survey. The SEFA Perceptions survey, designed to elicit participants' current understanding of key objectives of the SEFA, contained 15 Likert-scale items. Six of the items asked participants to assess their understanding of and proficiency in incorporating instruction associated with problem-based learning, NOS, and inquiry science instruction into their science methods instruction. Additional questions assessed participants' proficiency in supporting research-based science instruction, collaboration, ability to seek out funding, and the frequency with which they attend conferences. The scale ranged from 1 (not very proficient) to 5 (highly proficient).

This survey was administered prior to and following the Academy. In addition to the pre-assessment questions, the post-assessment contained five additional Likert-scale questions and 4 open-ended questions designed to elicit participants' perceptions of the strengths and weaknesses of the Academy and the quality of the Academy relative to other professional development experiences in which they have participated. Support for face and content validity of this survey was established by a panel of three experts in science education, evaluation, and measurement.

Interviews. Following analysis of the pre- and post- SEFA survey, 3 participants (37.5%) were purposefully selected for a follow-up semi-structured interview about their experience. These participants were selected because their pre- and post- survey responses indicated little, moderate, or great changes in their proficiency of the key SEFA objectives following the Academy. Interview questions elicited participants' perspectives on the most and least valuable aspects of the Academy, components of the SEFA they planned to implement, and suggestions for improvement. These interviews also served as a member-check of these participants' survey responses.

Artifacts. All planning materials and participant-generated reflections were collected. These artifacts allowed for detailed characterization of the Academy components and triangulated with survey data and interview responses.

Data Analysis. Data from each participant's pre- and post- SEFA survey were analyzed using descriptive statistics. For each participant, an overall sum of all of the items and mean pre- and post- assessment were calculated along with an aggregate mean for those survey items assessing inquiry, NOS, and problem-based learning. Changes in participants' scores pre- and post-Academy were also calculated as overall change, average change, and change for those items assessing inquiry, NOS, and problem-based learning.

Analytic induction, as described by Bogdan and Biklen (1992), was used to analyze the open-ended survey responses, follow-up interviews, and artifacts. Patterns were identified in the data set with the goal of characterizing the experiences of participants of the SEFA. From these patterns, preliminary categories were developed, which were refined through comparison with the original data set.

Results

The purpose of this investigation was to report the ongoing assessment results of three primary components of the VISTA program: the elementary science institute (ESI), the new science coordinator academy (NSCA), and the science education faculty academy (SEFA). Specifically, we sought to elucidate changes in participants' understanding of and confidence in implementing problem-based learning, inquiry, and nature of science instruction prior to and following participation in the VISTA professional development program and participants' perceptions of positive and negative aspects of their respective VISTA professional development programs. In this section, results of this analysis and supporting evidence, which represent a synthesis of the entire data set for each of the three components of VISTA, are presented for the ESI, NSCA, and SEFA, respectively.

Elementary Science Institute

The primary purpose of the VISTA Elementary Science Institute Intervention was to improve participants' knowledge and implementation of problem-based learning, inquiry, and nature of science instruction through a learn, try, implement with feedback and research professional development model. Analysis of the Perceptions surveys revealed changes in ESI participants' knowledge of and confidence in implementing problem-based learning, inquiry, and nature of science instruction prior to and following the summer professional development component of the ESI.

Knowledge of PBL, Inquiry, and NOS instruction. The extent to which VISTA participants' pre- and post-ESI definitions of and descriptions of classroom implementation of PBL, NOS, and inquiry instruction were aligned with VISTA constructs was assessed through participants' open-ended Perceptions survey responses (Tables 4 and 5). Results of this analysis suggest participants' knowledge of problem-based learning improved substantially, from 1.9% fully aligned pre-instruction to 50% fully aligned post-instruction. Participants' understandings of inquiry and nature of science improved less, from 1.9% to 13.5% fully aligned for inquiry and from 0% to 7.7% for nature of science prior to and following the VISTA ESI. However, these results also indicate participants' made substantial shifts from not aligned to partially aligned in their understandings of inquiry and nature of science.

Table 4. *Teachers' understandings of Problem-based learning, Inquiry, and NOS instruction.* (n=52, 100% responded)

	Pre-Instruction			Post-Instruction		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
PBL	42/52 (80.7%)	9/52 (17.3%)	1/52 (1.9%)	2/52 (3.8%)	24/52 (46.2%)	26/52 (50.0%)
Inquiry	34/52 (65.4%)	17/52 (32.7%)	1/52 (1.9%)	13/52 (25.0%)	32/52 (61.5%)	7/52 (13.5%)
NOS understandings	49/52 (94.2%)	3/52 (5.8%)	0/52 (0%)	25/52 (48.1%)	23/52 (44.2%)	4/52 (7.7%)

Pre- to Post-instruction results related to participants' understandings that effective NOS instruction is explicit were less impressive (Table 5). Prior to instruction all of the participants held the conception that students would learn about the nature of science through implicit approaches. Following the VISTA elementary science institute 71.2% of participants still expressed this perspective.

Table 5. *Teachers' understandings of that effective NOS instruction is explicit.* (n=52, 100% responded)

	Pre-Instruction		Post-Instruction	
	Implicit	Explicit	Implicit	Explicit
NOS instruction	52/52 (100%)	0/52 (0 %)	37/52 (71.2%)	15/52 (28.8%)

Confidence in Implementation. Participants' confidence in implementing PBL, inquiry, and explicit NOS instruction prior to and following the summer professional development component of the ESI were calculated from self-report Perceptions surveys data (Table 6). Likert scales ranged from one to five; means over 4.0 were considered to be strong indicators while means below 4.0 indicated potential areas of weakness. While teachers in the ESI reported the greatest gains in their confidence in implementing the NOS into their science instruction; overall post-ESI scores reflected only moderate confidence in implementing inquiry, NOS and PBL into instruction.

Table 6. *Changes in VISTA participants' pre- and post-ESI confidence in implementing PBL, inquiry, and NOS (100% responded)*

Item	Overall (n=52) Pre M (SD)	Overall (n=52) Post M (SD)
Confidence incorporating:		
Problem-based learning activities	2.1 (1.0)	3.3 (0.99)
Inquiry-based activities	2.3 (1.0)	3.6 (0.98)
Explicit NOS instruction	1.9 (1.1)	3.5 (0.90)

Effectiveness of the ESI Summer Professional Development. Participants' open-ended survey responses and follow-up interview indicated many found the summer ESI professional development to be more effective than previous professional development they had attended and they had not experienced professional development like VISTA before. For example, one participant noted:

> VISTA is all encompassing. Like most other trainings, we get a lot of bang for our buck, but with VISTA development, we also have the piece that we take back to our schools, are expected to implement and will have to show our use of the product. VISTA provided an opportunity to further understand what and why we teach as well as an opportunity to work with other professionals in a safe environment where we could make mistakes, and learn from each other. (E1C7-T23, Post-perceptions survey)

Additionally, most of the teachers found the VISTA ESI professional development to be more comprehensive, more applied, and a qualitatively better professional development experience than other professional development experiences because of the hands-on nature. For example, one participant noted:

> The VISTA Professional Development is much more hands on and intensive than other professional development experiences I've had in the past. I feel as though I can enter the classroom and teach a problem based learning unit and incorporate inquiry lessons into other units. (E1C6-T21, Post-perceptions survey)

Participant responses also indicated they received practical knowledge from VISTA that could be translated into classroom practice. They were able to learn about, plan for, and practice problem-based learning and inquiry-based instruction in the ESI. As a representative example, one participant noted that she perceived the opportunity to practice, receive feedback, and reflect as helpful in improving her science instruction:

> During the camp week, when we were with the campers, it was really beneficial to be able to try out our lessons and then also to watch the other people in our group try out their lessons and at the end of the day to have time to reflect and talk about what happened during the day as a group, that was really beneficial. (E1C6-T21, Interview)

Another noted the confidence she felt after practicing a PBL unit during the summer:

> VISTA has given me a lot of practical knowledge that I can take back to the classroom. It also has allowed me to practice PBL on students during a 1week summer camp. Time for doing what I have learned makes me feel much more confident with the implementation of PBL in the classroom. (E1C8-T28, Post-perceptions survey)

Participants clearly valued the structure and intensity of the VISTA professional development. Overall, participants expressed that participation in the ESI improved their science instruction. Teachers reported improved understanding of how to engage students in real world science through student-centered, problem-based learning, inquiry-based instruction, and NOS instruction following the ESI. The exposure to PBL, science inquiry, and NOS content and the time given to practice developing and implementing these approaches resulted in teachers feeling more confident. The teachers felt they had the ability to teach science with real world applications, use effective questioning strategies, and implement student-centered approaches. For example, one teacher noted:

> It really woke me up to the fact that teaching science is not just about cramming in the material for the benefit of [the state science assessment] but that it is about the students taking ownership in meaningful educational experiences through science. (E1C2-T9, Post-perceptions survey)

Similarly, another teacher stated:

> I think one of the most important things that was reinforced (although I already knew this) was that students need to be engaged in their learning. Using hands-on, inquiry, and PBL allows students to "take control" of their learning which then gives them ownership. Another thing learned was that if I am going to have students observe and investigate science, I need the experience to be as "real" as possible. Students should be using real science materials when appropriate, so they know what a "scientist" does. Having the experience to observe other teachers allowed me the opportunity to learn classroom management strategies as well as other strategies to be an effective teacher in

> the classroom. This professional development experience has "opened my eyes" to the importance of having students learn. (E1C1-T1, Post-perceptions survey)

Teachers' perceptions of the most important strategies and content they learned during the ESI provides further support for the effectiveness of the professional development, as these were closely aligned with the goals of the ESI. Many participants reported that implementing problem-based learning and learning about hands-on, inquiry, and NOS instruction were the most important things they learned during the ESI. For example, one participant responded, "I have gained knowledge of problem-based learning and NOS instruction and deepened my understanding of inquiry. I feel much more confident implementing these into my classroom" (E1C6-T21, Post-perceptions survey). Another noted the most important content of the ESI was "Learning about problem-based learning, science inquiry, and mostly the NOS" (E1C13-T49, Post-perceptions survey). Another participant indicated participating in the ESI helped her to understand the importance of explicit NOS instruction and to consider strategies to help make NOS instruction explicit:

> I feel like NOS was something that I was doing in the classroom but not maybe not explicitly discussing the NOS with kids and so this year something new that we will be doing is having a section in their interactive science notebook about NOS and after we are doing things in the classroom whether it be class or discussions or experiments or collecting data, we are going to talk about what scientists actually do and bring in those pieces to the NOS and talk about how in real life scientists do work together. And their ideas do change. (E1C10-T38, interview)

Similar to this participant, many others articulated in survey and interview responses that they planned to use the content and strategies they learned in VISTA in their future instruction.

Teachers reported the content and strategies obtained during the ESI were directly relevant to their classroom instruction and would help them improve instruction in the upcoming year. For example one participant noted, "The content, materials, and strategies I have learned in this experience are invaluable. The information I have in my binder about problem based learning, inquiry, and the NOS is information I will use almost daily when planning science lessons" (E1C6-T21, Post-perceptions survey).

Other participants also reported their intention to implement PBL, inquiry-based instruction, and NOS instructional strategies in their classrooms in the upcoming year. For example, one participant indicated:

> [The teacher team from our school] will implement the PBL unit we planned during the training. I will also incorporate what I learned about misconceptions, inquiry, NOS, and science discourse into my other units of science throughout the year. I will ask more "how" and "why" questions of my students and try to give up a lot of the control during science. (E1C9-T36, Post-perceptions survey)

Like this teacher, many others specifically referred to their intentions to implement the PBL lessons they developed during the ESI. As a representative example, one teacher noted:

> My team and I are in the process of revamping our entire science curriculum to follow the PBL process. We are combining units and addressing all standards, but with implementing the approach of PBL, I'm expecting to see higher student engagement, more critical thinking in students, curiosity driven questions, experiments, and activities, higher student achievement and clearer understanding of content. (E1C10-T38, Post-perceptions survey)

These teachers were clearly enthusiastic and recognized the content and strategies they learned during the ESI were applicable in their classroom settings. Both quantitative and qualitative survey and interview responses indicated participants found the structure and content of the ESI to be effective, and they reported improved confidence in incorporating PBL, inquiry, and NOS into their science instruction.

While participants' response to the ESI summer professional development was primarily positive, participants reported some areas for improvement. For example, time was an issue the first week of the ESI. Participants reported they felt rushed and fatigued by the quantity of new information presented during this week. Additionally, participants reported the timing of the science camp affected their perceived preparedness to teach the summer camp portion of the ESI. For example, those participants who taught during the second week of the ESI reported that they would have liked to have access to the summer camp content information prior to teaching. Participants who received this information in the second week and taught during the third week reported feeling prepared to teach camp in the third week. Participants perceived a need to have this information before camp to feel confident about the content they were to teach.

Overall, these results indicate participants' made moderate gains in their understandings of and confidence in implementing problem-based learning, inquiry, and nature of science into their science instruction. Further, participants found the VISTA elementary science institute to be an effective, practical and comprehensive professional development experience.

New Science Coordinator Academy

The primary purpose of the VISTA New Science Coordinator Academy (NSCA) was to build, support, and sustain the infrastructure of school district science leaders. One specific goal of the NSCA was to facilitate science coordinators' common understanding of inquiry, NOS, and problem-based learning and to identify these aspects of effective science teaching and learning.

Proficiency in supporting instruction. Analysis of the pre- and post-Perceptions surveys indicate participants' reported improved proficiency in their capacity to identify and evaluate teachers' inquiry, NOS, and PBL instruction and to create professional development to enhance teachers' instruction (Table 7). Participants made the greatest gains in their proficiency in identifying, evaluating and supporting teachers' implementation of PBL. Participants' made smaller gains in their proficiency to identify, evaluate and support teachers' implementation of NOS instruction. Overall, these results suggest participants' improved proficiency related to key VISTA goals following the NSCA.

Table 7. *Changes in VISTA participants' pre- and post-NSCA proficiency in identifying, evaluating and enhancing teachers' PBL, inquiry, and NOS instruction (11/13, 85% responded)*

Item	Pre M (SD)	Post M (SD)
Proficiency in identifying:		
Problem-based learning instruction	3.2(1.1)	4.4(.67)
Inquiry-based instruction	3.4(1.0)	4.5(.68)
Explicit NOS instruction	3.0(1.2)	3.8(.82)
Proficiency in evaluating:		
Problem-based learning instruction	3.0(1.1)	4.2(.75)
Inquiry-based instruction	3.2(.98)	4.2(.75)
Explicit NOS instruction	2.8(.98)	3.3(.84)
Proficiency in developing professional development to enhance teachers':		
Problem-based learning instruction	2.6(.92)	3.9(.94)
Inquiry-based instruction	3.0(1.2)	4.0(.77)
Explicit NOS instruction	2.5(.82)	3.5(.97)

Participant responses to open-ended survey questions and follow-up interviews provide further evidence to support these findings. Most participants responded similarly to NSCA1F10 who noted, "VISTA training provided me a better understanding of PBL from the science viewpoint. More importantly, a better understanding of scientific inquiry was presented" (Post-perceptions survey). Additionally, participants noted the need for even more emphasis on NOS instruction during the NSCA:

> …for focusing on … K-12, I think NOS is probably more abstract. It's one of the things that people maybe have an understanding of, but I don't know if it's as concrete as we want it to be, as meaningful and so that's something that's on my radar. The next question is, how can we embed it in some of the things we're doing? Or is it something we need to do new? …We spent probably much more time on inquiry and hands-on and sort of more, more job embedded things, and less on NOS. So I have information… it becomes a matter of sort of figuring out what is the best method to reach teachers effectively with what we do, just because we have limited time in terms of PD. And I don't know if it's an explicit NOS professional development workshop or is it embedded sort of contextually within we do something for science teachers and have it embedded within that. (NSCA1M3, Interview).

While this participant's response clearly indicated that he learned about professional development to support key components of VISTA, it also expressed the participant's perceived need for this to be even more concrete in order for them to apply this in professional development for teachers in his district.

Other participants expressed similar views, especially with regard to NOS instruction. For example, one participant suggested on her Perceptions survey, "Please give more time to NOS! (and how to share with our teachers)" (NSCA1F1, Post-perceptions survey). These interview and open-ended survey responses indicated participants perceived a continued need for support even after the NSCA, especially in designing effective professional development to support teachers' effective NOS instruction.

Effectiveness of the NSCA. Participants indicated the targeted nature of the NSCA, opportunities for collaboration with peers, new perspectives on professional development, flexibility in the flow of discussion topics, and the emphasis on evaluating and providing effective professional development to teachers were valuable components of the NSCA. Participants specifically reflected that attending a professional development experience intentionally focused on the needs of science coordinators contributed to their positive experiences during the NSCA:

> I would say is how appreciative I am of the targeted nature of this opportunity. While I have studied these topics before, I have not done so with a group of "parallel" leaders who are experiencing the topic through such a specific lens. I could not be more grateful for that. (I especially appreciated the "leadership" lens on our study of this topic – very helpful for me right now.) (NSCA1M1, Post-perceptions survey)

Many participants indicated that the opportunity to collaborate, learn from their peers across the state, and share resources was an aspect of the NSCA that made it particularly valuable. For example, NSCA1F7 reported, "…some of them were more experienced in science than I am. Listening to the experiences of others and others sharing how they've done things, that was very valuable" (Interview). Additionally, many participants commented on the effectiveness of using Dropbox as a means of distributing and sharing resources among themselves and facilitators.

Participant responses also indicated they received practical knowledge from VISTA they could use to provide support for science teachers in their district. These participants reported an intention to use resources and ideas from the VISTA NSCA to develop and implement professional development to support teachers' PBL, inquiry-based and NOS instruction. For example, one participant indicated that:

> I will use these resources to lead professional development in my own county. I've already used some of these tools with goals and actions in my own County's Science Curriculum Committee. I've used the inquiry rubric to more clearly identify what is/isn't inquiry lessons. Teachers have been given these tools to use with their own colleagues. Given the resources from the VISTA training, I feel like I have an arsenal of tools to help teachers assess their own science practice and ultimately towards impacting the change towards more inquiry in the schools. (NSCAF2, Post-perceptions survey)

These science coordinators were clearly enthusiastic and perceived the content and strategies they learned during the NSCA were applicable in their districts.

Participants' response to the NSCA was primarily positive; however, participants did report areas for improvement. Specifically participants identified the structure and administrative aspects including pacing, timing, number of breaks, length and structure of the sessions could be improved. Participants disagreed over the length of the NSCA; some participants noted that 5 days was too long; however, others noted breaking the NSCA into a 3-day and 2-day session gave them time to "digest and then take in more" (NSCA1F2, Post-perceptions survey).

Overall, the results of this analysis indicate the NSCA improved participants' proficiency and understanding of, developing professional development for, and evaluation of teachers' inquiry, NOS, and PBL instruction. Further, they were enthusiastic about incorporating what they learned during the NSCA to support effective science instruction through professional development within their district.

Science Education Faculty Academy

The primary purpose of the VISTA Science Education Faculty Academy (SEFA) was to build infrastructure to support effective science teaching and learning in Virginia. Two goals of the SEFA were to provide participants the opportunity to learn about new research related to effective science teacher development and science teaching and to share effective teaching strategies for how to best meet the needs of elementary and secondary science teachers through PBL, inquiry, and NOS instruction.

Proficiency in supporting instruction. Analysis of the Perceptions surveys indicated improvements in NSCA participants' self-reported knowledge of and proficiency in incorporating inquiry, NOS, and PBL instruction into their science methods instruction (Table 8). Overall, participants' perceived themselves to be proficient or highly proficient in their knowledge of and ability to enhance preservice science teachers' inquiry, NOS, and PBL instruction prior to and following the SEFA. Participants in the SEFA reported the greatest gains in their knowledge of and proficiency in enhancing preservice science teachers' NOS instruction in their science methods courses. Participants' gains in their knowledge of and proficiency in enhancing preservice science teachers' inquiry instruction through their science methods instruction were the smallest; however, participants still reported high proficiency on this indicator. These results suggest the professional development improved participants' knowledge of and proficiency in designing and implementing methods course instruction to support preservice teachers' inquiry, NOS, and PBL instruction.

Table 8. *Changes in VISTA participants' pre- and post-SEFA knowledge of and proficiency in instruction supporting preservice teachers' PBL, inquiry, and NOS instruction (8/8, 100% responded).*

Item	Pre M (SD)	Post M (SD)
Knowledge of:		
Problem-based learning instruction	4.2(.37)	4.5(.53)
Inquiry-based instruction	4.8(.46)	4.9(.35)
Explicit NOS instruction	4.1(.83)	4.5(.53)
Proficiency in methods course instruction to enhance preservice teachers':		
Problem-based learning instruction	3.9(.67)	4.7(.74)
Inquiry-based instruction	4.0(.76)	4.6(.52)
Explicit NOS instruction	3.7(.96)	4.6(.52)

Participant responses to open-ended survey questions and follow-up interviews provide further evidence to support these findings. For example, one participant noted, "I learned how to coach preservice teachers in problem-based learning, and NOS, something I was not very strong in previously" (SEFA1F4, Post-Perceptions survey). Another indicated she "learned more (depth) on the NOS" and "learned more about PBL units" (SEFA1F1, Post-Perceptions survey).

Effectiveness of the SEFA. Analysis of qualitative survey and interview data suggested participants valued many components of the SEFA. Most participants perceived the SEFA as one of the most effective science education-focused professional developments they had experienced. For example, SEFA1F3 indicated, "This VISTA College Science Academy is by far the best professional development opportunity I have ever had as a science education professor" (Post-Perceptions survey). Another participant echoed this sentiment, stating, "I can't think of a moment that wasn't powerful for me. Even from going out at night and just talking to each other and networking. It was just, I came back to work and sent an email to my colleagues and it said I had the most stimulating, intellectually and socially stimulating week of my life" (SEFA1F1, Interview).

Further evidence of the effectiveness of the SEFA related to participants' expressed desire to use their new knowledge in their science methods course instruction in the upcoming year. For example, one participant indicated she planned to "Use a PBL in my science content course" (SEFA1F2, Post-Perceptions survey). Similarly SEFA1F4 reported, "I will incorporate an assignment requiring students to design a PBL unit in my methods class" (Post-Perceptions survey). Another participant indicated her intention to visit the ESI teacher camp "to see PBL implementation" after learning more about PBL units (SEFA1F1, Post-Perceptions survey).

Participants repeatedly responded collaboration, networking, and sharing ideas were some of the most valuable aspects of the SEFA. Many noted an intention to continue to collaborate with their peers in the future both in terms of sharing ideas to support effective science instruction and to develop scholarship. For example, one participant indicated, "Several of us are writing a paper now on implementing PBL models in our science methods lessons" (SEFA1F3, Post-Perceptions survey).

Participants reported few areas for improvement including increasing the length of breaks between sessions or reducing the overall length of the day. For example, one participant explained:

> Because we were discussing things all day long and it was kind of like your brain was on. It would have been nice to have a little bit of a break. I very much need time to process, so discuss in the morning and then I can have a little break where I could get a little bit of down time where I could process and then come back in the afternoon. (SEFA1F2, Interview)

Participants perceived these structural changes would improve their productivity and capacity to process what they were learning.

Overall, participants' perceived themselves to be proficient or highly proficient in their knowledge of and ability to enhance preservice science teachers' inquiry, NOS, and PBL instruction prior to and following the SEFA. Even so, participants perceived the SEFA to be an extremely effective professional development experience, especially the opportunities for collaboration, networking, and sharing ideas afforded them as a result of attending the SEFA.

Discussion

The results from the first half-year of data collection suggest the VISTA professional development was moderately effective in developing participants' knowledge of and proficiency in implementing PBL, NOS, and inquiry instruction in their respective settings. Participants of all three VISTA professional development components reported improvements in confidence and proficiency in PBL, NOS, and inquiry instruction. Further, the majority of ESI participants expressed either partially or fully aligned understandings of problem-based learning, inquiry, and nature of science instruction following the ESI. Not surprisingly, participants in the SEFA had the highest overall scores and participants in the ESI had the lowest overall scores pre- and post-professional development with regard to the key VISTA objectives.

Elementary Science Institute

ESI participants made gains in their understanding of pedagogical approaches that support reform-based science instruction; however, fewer participants' expressed fully aligned understandings of inquiry and nature of science than those who expressed fully aligned understandings of problem-based learning. This result is not surprising as problem-based learning provided the primary context through which ESI participants learned about inquiry and nature of science instruction. The features of PBL were also emphasized, reinforced, and practiced throughout the ESI to a greater extent than inquiry and nature of science. Similar professional development experiences employing problem-based learning as the context to support development of teachers' reform-based science instruction reported similar results among preservice and in-service science teachers (Sterling et al., 2007).

The majority of participants reported moderate improvements in their confidence in implementing PBL and NOS instruction and retained their conception that students would learn about the nature of science through implicit approaches following the ESI. These modest improvements are not unexpected for a number of reasons. First, designing and implementing problem-based learning into instruction is a complex process that relying heavily upon students' exploration and synthesis of multiple science concepts within a coherent instructional unit to solve a problem with multiple possible solutions (Center of Excellence in Leadership of Learning, 2009; Sterling et al., 2007; Thomas, 2000). Thus, the process of designing and implementing PBL may be especially difficult for elementary teachers who may not be science content experts. Previous research suggests some degree of content knowledge expertise may be necessary but insufficient to facilitate teachers' effective science instruction (Abell, 2007). Second, that few ESI participants expressed only moderate knowledge of how to effectively teach NOS to students and confidence in teaching NOS, even after professional development, is consistent with a large body of literature (e.g. Bell, Abd-El-Khalick, & Lederman, 1998; Bell, Blair, Crawford, & Lederman, 2003; Lederman Lederman, Kim & Ko, 2012). Finally, the summer ESI constitutes only one component of the VISTA professional development experience. Participants are provided support throughout the academic year through follow-up sessions and coaching. These follow up sessions and coaching sessions are designed to reinforce what teachers initially experienced during the summer ESI. As these longitudinal and contextualized features of the VISTA ESI are often cited as essential features of effective professional development (e.g. Desimone, 2009; Johnson, Khale, & Fargo, 2007; Supovitz & Turner, 2000), it is possible teachers will exhibit further gains in their understanding and confidence in implementing PBL, inquiry, and NOS instruction as a result of the ongoing and contextualized nature of the VISTA professional development.

New Science Coordinator Academy

Results for participants in the NSCA were similar to those of the ESI. Participants' proficiency and understanding of, developing professional development for, and evaluation of teachers' inquiry, NOS, and PBL instruction improved following the professional development. Further, participants expressed enthusiasm about incorporating what they learned during the NSCA to support effective science instruction through professional development within their district.

Few studies explore the role of district-level science leaders in providing science teacher professional development (e.g. Rogers et al., 2007; Tracy, 1993), thus the results of this investigation begin to contribute to this body of literature and provide some insight into the design and implementation of effective professional development for science coordinators. The results of the present study provide support that the VISTA NSCA professional development, which aims to meet the specific and unique needs of district-level science coordinators, may be effective in supporting science coordinators' proficiency in supporting their teachers' reform-based science instruction.

Investigations of district-level science leaders are of particular importance in the science education community as recent research indicates district-level leadership often mediates professional development initiatives to support increased student learning and achievement (Corcoran, Fuhrman & Belcher, 2001; Firestone, Mangin, Martinez & Plovsky, 2005). Political and cultural factors such as an emphasis on standardized testing and a perceived disconnect between district-mandated content objectives and teaching with investigations and inquiry are barriers to reform-based instruction for many teachers (e.g. Keys & Kennedy; Johnson, 2006, 2007). Professional development for science coordinators, such as the one described in this study, may provide district-level science leaders the confidence and tools to help science teachers navigate these barriers and implement reform-based instructional practices in their science teaching.

Science Education Faculty Academy

Results of the present study indicated SEFA participants perceived themselves to be proficient or highly proficient in their knowledge of and ability to enhance preservice science teachers' inquiry, NOS, and PBL instruction prior to and following the SEFA. This is not surprising considering each participant reported extensive education related to science teacher preparation prior to participation in the SEFA. Even so, participants perceived the SEFA to be an extremely effective professional development experience, especially the opportunities for collaboration, networking, and sharing ideas.

The VISTA SEFA, which incorporates collaboration and expertise sharing, was modeled after *Science Education at the Crossroads*, a national professional development model for science teacher educators described by Johnston & Settlage (2008). In this model, Johnston and Settlage's (2008) *vexation and venture* approach facilitated collaboration and expertise sharing among participants. The results of the present investigation provide support for the efficacy of this model of science teacher educator professional development implemented at a state level. Two key components of the *Crossroads* model, critical review and practice community, were cited by participants as effective components of the SEFA.

Investigations of professional development experiences specifically designed for science education faculty are limited. Many studies of college science educators and science faculty resulting in professional development and changes in instructional practice take the form of action research combined with opportunities for reflection and peer collaboration (e.g. Capobianco, Lincoln, Canuel-Browne, & Trimarchi, 2006; Lynd-Balta, Erklenz-Watts, Freeman, & Westbay, 2006). Of this approach to college faculty professional development, Sunal and colleagues (2001) note, "sharing of expertise and collaboration enables faculty members to approach undergraduate teaching as they approach effective research in their own disciplines – using a team approach" (p. 249). Thus, results of the present study substantiate those of previous studies which suggest science educators' professional development and effective preservice science teacher instruction may be mediated in part through collaboration and expertise sharing.

Final Thoughts and Future Research

The preliminary results of this ongoing investigation reported here have the potential to inform professional development that supports educators' implementation of inquiry, NOS, and PBL instruction by in-service elementary science teachers, district science coordinators, and science education faculty. Each of the three components of VISTA (ESI, NSCA, and SEFA) described in this investigation incorporate key aspects of effective professional development (Desimone, 2009; Loucks-Horsley et al., 2010) and each appeared to facilitate participants' knowledge of and proficiency in implementing or supporting reform-based science instruction in their respective settings. Documenting professional development experiences that facilitate teachers' effective science instruction at the school, district, and state levels is essential as well-prepared teachers have the greatest impact on student achievement (Darling-Hammond 2000, 2003).

Analysis of additional collected data including videotaped classroom observations, instructional materials, and interviews will be triangulated with the self-report data described in the present study to provide a more complete picture of participants' understandings and classroom practices. Future research will explore whether VISTA ESI participants' understandings of inquiry, PBL, and NOS changed following coaching and follow-up sessions, whether their understandings of inquiry, PBL, and NOS were translated into their classroom practice, and whether relationships exist between participants' understandings, practice, and student achievement. Additional research will explore the extent to which participants' in the New Science Coordinator Academy and Science Education Faculty Academy continue to use what they learned in these professional development experiences in their professional endeavors and the extent to which VISTA facilitates the development of infrastructure that supports effective reforms-based science instruction in the state of Virginia.

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Appendix A

Perceptions Open-ended Response Coding Rubric

Description of Use
This rubric was developed to assess the extent to which VISTA participants' responses express views of problem-based learning, inquiry, and nature of science aligned with VISTA constructs. This rubric will be used to assess VISTA participants' responses to the following questions on the VISTA Perceptions survey:

1) Define problem-based learning.
2) Describe what teachers and students are doing during a typical lesson/activity that emphasizes problem-based learning.
3) Define science inquiry.
4) Describe what teachers and students are doing during a typical lesson/activity that emphasizes science inquiry.
5) Define nature of science.
6) Describe what teachers and students are doing during a typical lesson/activity that emphasizes nature of science.

I. Coding Understandings and Implementation of Problem-based learning and Inquiry.
Evidence of italicized components must be present for a response to be coded at this classification level. In general, coding of the definition and application to the classroom (teacher and student actions) provided by participants should be weighed in coming up with a classification for the response on a given dimension. If there are discrepancies between coding of the definition and explanation, the application component should carry more weight. For example, if the participant gives the VISTA definition verbatim (**fully aligned**), but their description of classroom application does not reflect aligned implementation, coding should err toward the response of the description of how this approach is enacted in the classroom.

Note: Non-aligned perspectives of the nature of science (e.g. "proving," overemphasis on "the" scientific method) in responses about PBL and inquiry should be taken into account when coding participants' NOS understandings.

	Non-aligned	Partially Aligned	Fully Aligned
Problem-based Learning (PBL)	Responses lack crucial elements of the VISTA definition. Definitions and examples align better with hands-on science or inquiry. Response may define hands-on instruction or inquiry without acknowledging the following: role of authentic context, the open-ended nature of the task, meaningful problem, and duration or response explicitly indicates participant doesn't know.	Definitions and examples suggest a partial understanding of PBL and its key features. Response indicates a **role for inquiry and authentic (real world) context** in PBL and may acknowledge *a subset of the following:* meaningful problem for students to solve, open-ended nature of the task or the extended duration of such lessons. Examples may overemphasize the teacher as the information provider.	Definitions/ examples accurately reflect the VISTA definition: *A form of **inquiry** in which students solve a meaningful problem with multiple solutions over time, as a scientist would in a **real world context**. The problem and context must be meaningful to students*. Essential components that may be included in response: theme, problem, student roles, scenario, resources, culminating project/assessment, safety.
Inquiry	Responses lack crucial elements of the VISTA definition (i.e. indicates only a role for questioning or hands-on, no indication of analysis of data on the part of students) or response is expanded to include PBL or response explicitly indicates participant doesn't know.	Definitions and examples suggest a partial understanding of inquiry and its key features. It may indicate that **students** do only one of the following: (1) *analyze data, (2) solve problems, (3) answer questions through investigation*. Participants may cite students conducting "investigations" without elaboration. Response may indicate inquiry <u>must</u> be hands-on or overemphasizes "the" scientific method and experimentation. Examples may overemphasize the teacher as the information provider.	Definitions/ examples accurately reflect the VISTA definition: *asking questions, collecting and analyzing data, using evidence to solve problems*. Key components that may be included in response: learners engage in scientifically oriented questions, gives priority to evidence, formulates explanations from evidence, connects explanation to scientific knowledge, communicates and justifies explanations.

II. Coding Nature of Science Understandings and Instruction

This two-part component of the rubric was developed to assess the extent to which VISTA participants' responses express tentative and revisionary view of the nature of science and the extent to which they understand that these aspects of the nature of science must be explicitly addressed in science teaching. This rubric will be used to assess VISTA participants' responses to the following questions on the VISTA Perceptions survey:

1) Define nature of science.
2) Describe what teachers and students are doing during a typical lesson/activity that emphasizes nature of science.

Responses will be coded based on the degree of alignment between participant responses and the VISTA description of understandings of the nature of science (below). Participants' responses to these two questions will be analyzed holistically.

Description of VISTA Understandings of the Nature of Science

Absolute (not aligned)	Revisionary (fully aligned)
Responses reflect absolutist conceptions of scientific knowledge. Responses indicate a lack of clear understanding of how evidence is used in science, that science is an social endeavor, and/or refer to THE scientific method or one scientific method. Responses indicate that scientific knowledge is made up mainly of the results of experiments and that scientific knowledge is inherently unbiased.	Responses reflect tentative and revisionary conceptions of scientific knowledge. While scientific knowledge is empirically-based, it is not derived directly from observation alone. Rather, inferences, theories, and social/cultural factors all play a role in the development of scientific knowledge. Science seeks to limit personal bias, often through formal processes; however, science can never totally eliminate subjectivity. Nor is totally eliminating subjectivity always a goal because of the important roles of imagination and creativity in science. Scientists do not follow a rigid algorithm but rather use a multitude of creative approaches to answer questions of interest. There is no single scientific method.

Absolute → **Revisionary**

(not aligned) **(partially aligned)** **(fully aligned)**

Coding Understandings of the Nature of Science.

	Non-aligned	Partially Aligned	Fully Aligned
Nature of Science (NOS)	Response includes statements that reflect absolute views of science. or Response does not address any key elements of the VISTA description of NOS or Response indicates the participant does not know.	Response indicates a partial understanding of the tentative and revisionary nature of science. Response lists key elements of NOS taught in VISTA without any elaboration. or Response does not include all of the key elements of the VISTA description of NOS. or Response includes all key aspects but includes misconceptions about these aspects.	Response reflects tentative and revisionary views of science consistent with the aspects of NOS taught in VISTA. Response **must** include the following key elements of the VISTA description of NOS: Scientific knowledge is tentative and revisionary. Scientific knowledge is empirically-based. Social/cultural factors play a role in the development of scientific knowledge.

Coding Nature of Science Instruction Understandings. With regard to teaching the nature of science, responses will either be coded as implicit, if the response indicates that students will learn about the nature of science from implicit approaches or explicit if the response indicates explicit instruction is required to effectively teach the nature of science.

Implicit	Explicit
Responses indicate that nature of science is taught effectively through implicit approaches and instruction. Responses indicate students will develop accurate conceptions of the nature of science as a byproduct of learning historical episodes of scientific knowledge and/or participating in authentic scientific investigations.	Responses indicate that nature of science is taught effectively through explicit instruction. Responses indicate students will develop accurate conceptions of the nature of science through instruction that intentionally draws attention to targeted aspects of the nature of science through such methods as discussion, reflection, and questioning.