

**Statewide professional development to support reforms-based science instruction:  
Results from Two Years of Implementation.**

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**Abstract**

This investigation characterized the experiences of teachers, science coordinators, and science education faculty enrolled in a research-based professional development program. Additionally, we assessed changes in participants' understanding of and confidence in implementing problem-based learning (PBL), nature of science (NOS), and inquiry instruction. The contexts for the assessments were four components of a statewide professional development: the Elementary Science Institute (ESI), Secondary Teacher Program (STP), New Science Coordinator Academy (NSCA), and Science Education Faculty Academy (SEFA). Participants included 145 elementary teachers, 52 beginning secondary teachers, 28 science coordinators, and 13 science educators. Data consisted of responses to pre-/post Perceptions surveys and interviews designed to elicit participants' professional development experiences and their understandings and intentions to implement PBL, NOS, and inquiry instruction.

Preliminary analysis of the Perceptions surveys and interviews suggested that participants in the professional development perceived positive changes in their perceptions of the program's key objectives. Participants in all four 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. Ultimately, the results of this investigation may inform science teacher preparation and professional development that supports implementation of PBL, NOS, and PBL instruction by in-service elementary and secondary science teachers, science coordinators, and college science educators. Future research will explore the extent to which the interplay between the four PD components facilitated the development of a state-wide infrastructure to support reforms-based science instruction.

**Introduction**

The recently released *Framework for K-12 Science Education* identifies scientific literacy as a principal goal of science education (National Research Council [NRC], 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 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. (NRC, 2007)

These interrelated strands represent the scientific knowledge, methods of science, and nature of scientific knowledge that K-12 science students need to develop scientific literacy and actively participate 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).

### **Reforms-based Science Instruction**

Reforms documents indicate students develop scientific literacy through student-centered instruction addressing three important aspects of science: scientific knowledge, processes of science, and nature of science (NOS) (NRC, 1996, 2011). 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 (e.g. AAAS, 1993; Bell, Blair, Crawford, & Lederman, 2003; Donovan & Bransford, 2005; Lederman, 2007; NRC, 1996). This type of instruction places the teacher in the role of facilitator of learning and provides with students opportunities for collaboration, scientific discussion, and debate (NRC 1996).

Problem-based learning (PBL) is one instructional model that provides a context for reforms-based science instruction. PBL incorporates an authentic context, problems with multiple or divergent solutions, inquiry experiences, and collaboration among students (Hmelo-Silver, 2004). 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 reforms-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 reforms-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 reforms-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 (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 into their own instruction (e.g. Akerson & Abd-El-Kalick, 2003; Bell, Abd-El-Khalick, & Lederman, 1998; Lederman, 2007).

### **Professional Development to Support Reforms-based Science Instruction**

Given the aforementioned barriers to implementation of reforms-based science instruction, a recent focus of the science education community is professional development designed to increase teachers' knowledge of and classroom implementation of reforms-based pedagogy (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 that served as the context of this investigation was guided by these key components of effective professional development to support reforms-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 smaller-scale professional development programs.

Specifically, the Elementary Science Institute (ESI) and Secondary Teacher Program (STP) (K-12 components of VISTA) had the goal of supporting K-12 science teachers' inclusion of inquiry-based and explicit nature of science instruction in the context of PBL. 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 kinds of knowledge; (3) Many methods are employed to develop scientific knowledge (Mannarino, Logerwell, Reid, & Edmonson, 2012).

Not only were the ESI and STP designed to develop K-12 teachers' reforms-based instruction, they also are intended to facilitate the development of an infrastructure to support reforms-based science instruction throughout Virginia. To support this goal, principals 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. Like teachers in the ESI and STP, science coordinators and science educators attending NSCA and SEFA learn about problem-based learning, inquiry, and nature of science. They also learn to support educators with whom they work in implementing these reforms-based practices into their own instruction. Thus, participants in all components of VISTA learn common definitions and experience common examples of reform-based science instruction. These cross-component commonalities are designed to promote the development of an infrastructure to support reforms-based science instruction across all levels of science education in Virginia.

### **Purpose**

The purpose of this investigation was to assess the effectiveness of four principal components of the VISTA program: ESI, STP, NSCA, and SEFA. Specifically, our goal was to characterize changes in participants' understanding of and confidence in implementing PBL, NOS, and inquiry instruction and their experiences during VISTA. The following research questions guided the investigation:

1. How did participants' understandings of and confidence in implementing PBL, inquiry, and NOS instruction change as a result of participation in the VISTA professional development?
2. What are participants' perceptions of positive and negative aspects of their respective professional development?

## Methods

### Elementary Science Institute (ESI)

**Participants.** Participants in two cohorts of the VISTA Elementary Science Institute (ESI) were 23 males and 122 females from 58 different elementary school teams and 24 different districts in Virginia (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.

**Context.** The ESI consisted 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. Elementary teachers spent week 1 of the summer institute learning about problem-based learning, inquiry instruction, nature of science instruction and planning their PBL unit for camp. 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 (e.g. discourse, technology integration). Teachers spent one of these weeks teaching in the camp setting and the other week doing the teaching modules. 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 familiarized with reforms-based science instruction including problem-based learning and inquiry instruction. During the academic year, teachers participated in a minimum of 14 hours of follow-up sessions. Teachers also attended the annual state science teachers' conference. Further, coaches worked with teachers in their classroom 22.5 hours across the academic year to co-plan, co-teach, observe and provide feedback on participants' science instruction. For a complete description of the ESI intervention, see Mannarino, Logerwell, Reid, & Edmonson (2012).

Table 1. *VISTA Elementary Science Institute participant demographic data (Cohorts 1 and 2, n=145)*

Gender		Ethnicity			
Female	Male	Caucasian	African American	Hispanic	Asian
122 (84.1%)	23 (15.9%)	107 (73.8%)	35 (24.1%)	2 (1.4%)	1 (.69%)

Table 2. *VISTA Elementary Science Institute participant teaching and science experience (Cohorts 1 and 2, n=145).*

Virginia Licensure				Teaching Experience					Highest Degree in Education			Deg. in Science
Elem. Sch.	Elem. Sci.	Middle Sch.	Sec.	0-1yr	2-3yr	4-6 yr	7-10yr	>10 yr	Bachelors	Masters	PhD	
135 (93.8%)	4 (2.8%)	14 (9.7%)	9 (6.3%)	13 (9.1%)	17 (11.9%)	27 (18.9%)	29 (20.3%)	57 (39.9%)	59 (43.1%)	72 (52.6%)	1 (0.7%)	11 (7.9%)

Note. Gender, ethnicity, and licensure data for all 145 participants. 1 participant did not report licensure (n=144), 2 participants did not report teaching experience (n=143), 8 participants did not report highest degree earned (n=137), 5 participants did not report whether they have a degree in science (n=140).

Table 3. *Elementary Science Institute Timeline*

<b>Elementary Institute</b>	<b>Summer</b>	<b>Academic year</b>
Grade 4-6 science teachers	4 week institute	3 follow-up sessions Attend VAST conference 3 classroom coach visits
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 to participants pre- and post- Institute and at the end of the year (Cohort 1 only), 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 to 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, understanding of PBL, nature of science, and inquiry instruction, 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, if at all, they plan to use what they learned during the summer institute of the ESI during the upcoming academic year.

Finally, at the end of the school year, teachers (Cohort 1 only) completed a final VISTA Perceptions Survey. In addition to items on the pre- and post-Perceptions survey, this survey asked teachers about their interactions with classroom coaches, their participation in each of the components of the VISTA program, and how they have implemented what they have learned in their classrooms. Support for face and content validity of all three Perceptions surveys was established by a panel of three experts in science education, evaluation, and measurement.

**Observations.** Each of the three implementation sites were observed for three days simultaneously the first year and for four days simultaneously during the second year. The days observed in year one and year two were different in order to capture the breadth of the professional development across the two years. The purpose of these observations was to characterize implementation of the VISTA professional 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 professional development. These included: the nature of teacher/teacher and teacher/facilitator interactions, signs of engagement, fatigue, understanding, discontent, participant questions, 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, 28 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 surveys reflected the range of possible responses: 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 ESI planning materials were collected from the implementation team at each site. 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 ESI.

**Data Analysis.** Participants' pre-, post-, and year-end (Cohort 1 only) 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 defined above (See Maeng & Bell, 2012, Appendix A). Review by an expert panel provided support for face and content validity of the rubric. Participants' responses were coded as not aligned, partially aligned, and fully aligned for definitions and implementation of PBL, inquiry, and NOS instruction. Raters also coded participants' understanding that effective NOS instruction is explicit. Two raters independently coded each participant's open-ended responses related to PBL, inquiry, and NOS. Inter-rater agreement was established (~90%) by comparing independent analysis across approximately 50% of the data. All disagreements were resolved by discussion.

Data from Likert scale items on each participant's pre-, post-, and year-end 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-, post-, and year-end 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 and common themes in participants' responses were identified in the data set with the goal of characterizing the experiences of participants. From these patterns, preliminary categories were developed and refined through comparison with the original data set.

### Secondary Teachers Program (STP)

**Participants.** Participants across two cohorts of the Year 1 STP were 52 beginning science teachers (18 males and 34 females). Teachers in the STP were first or second-year secondary science teachers who taught grades 6-12 science (e.g. 8<sup>th</sup> grade physical science, biology, earth science, chemistry) (Table 4). All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Table 4. *VISTA secondary participant demographic and experience data (n=52).*

Gender		Ethnicity			Holds Virginia License	Science Major <sup>1</sup>			
Female	Male	Caucasian	African American	Asian		Bio	Chem	Physics	Earth Science
34 (65.4%)	18 (34.6%)	43 (82.7%)	6 (11.5%)	3 (5.8%)	30 (57.7%)	22 (42.3%)	6 (11.5%)	3 (5.8%)	7 (13.5%)

<sup>1</sup> Of those reporting having a major in a science field.

**Context.** The goal of the VISTA STP was to support beginning (first and second year) uncertified, provisionally certified, or certified secondary science teachers for two years. Four types of support were provided: a basic science methods course, an advanced science methods course, in-class coaching, and a website of resources. In the present study, we focus only on the first-year STP course.

The first-year science methods course included one week of planning before the school year begins and seven follow-up sessions during the fall semester in which teachers analyzed samples of their students work. The three implementation sites, George Mason University, the College of William and Mary, and Virginia Commonwealth University, hosted this course. Those participants hired prior to August attended an intensive week before the school year began, while those participants hired in mid-August attended makeup sessions at the beginning of the semester. The contact time for each of these format was

approximately 30 hours. Beginning in October, both groups attended seven follow-up sessions (approximately 15 hours) during the fall semester.

The course built fundamental knowledge of: (1) standards-based curriculum design, (2) research-based teaching strategies, (3) inquiry-based lessons for students to investigate science, (4) assessing student understanding of science, and (5) classroom management strategies. Specific topics of study included: classroom management, effective standards-based science teaching, lesson planning, inquiry, laboratory formats and safety, classification, questioning, addressing student misconceptions, learning strategies and multiple intelligence theories, nature of science, assessment, and unit planning. The teachers created an annual instructional plan, taught an inquiry-based lesson they would teach the first week of school, and planned a ready-to-teach four-week unit with all support materials. During the fall semester, the teachers observed videotapes of themselves teaching and students learning. Furthermore, they analyzed their students' learning using assessment data.

In-class coaches, many retired science teachers, helped the new teachers plan, teach, and problem-solve. In year 1, coaches provided in classroom support the equivalent of 12 days (72 hours) during the school year. The courses and coaching enabled teachers to develop professional knowledge about effective teaching and learning. To provide a broader perspective of teaching and learning, teachers also attended the annual state science teachers' conference.

**Data Collection.** Data consisted of perceptions surveys administered to participants pre-, post-, and year-end (Cohort 1 only) VISTA year one secondary science methods course, observations of the science methods course, follow-up interviews of a subset of participants, and artifacts (e.g. planning documents and participant-generated materials).

**Perceptions Surveys.** Participants completed the VISTA Perceptions Survey three times: prior to the science methods course, at the end of the science methods course, and at the end of the academic year (cohort 1 only). This instrument was developed by the VISTA research and evaluation team and validated by an expert panel. The VISTA Pre-Perceptions Survey contained 18 five-point Likert-scale items which assessed the frequency and confidence with which participants incorporated NOS, inquiry, educational technology (including computer simulations), assessment, and effective classroom management into their science instruction. It also included questions about teachers' classroom practices, teaching beliefs, and prior professional development experiences. Open-ended questions asked participants' to define and describe inquiry and NOS instruction. Problem-based learning was not assessed on this instrument as it is not included in the first-year STP course. At the completion of the STP course, participants completed a follow-up VISTA Perceptions Survey. This post-survey was designed to elicit participants' perceptions of the effectiveness of specific components of the science methods course and how they planned to use what they learned in their own instruction. At the end of the school year, participants completed a final VISTA Perceptions Survey. On this survey, teachers responded to additional items about their interactions with classroom coaches, their participation in each of the components of the VISTA program, and how they implemented what they learned in the STP in their classrooms.

**Interviews.** Following analysis of the pre- and post-STP Perceptions survey, 13 participants (approximately 25%) were purposefully selected for a follow-up semi-structured interview about their experience. These participants were selected from among the three sites and implementation conditions (summer intensive vs. weekend make-up). Selection was also stratified across participants' pre- and post-intervention survey responses to ensure that the variety of participants' experiences in the STP was captured. Selection included one participant who indicated little changes in their proficiency of key VISTA objectives, one who indicated moderate change, and one who indicated substantial changes. Interview questions were designed to elicit 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.

**Observations.** The evaluation team conducted multiple observations of the first-year secondary science methods course at each implementation site to characterize implementation of the course.

Extensive training and an observation protocol ensured observers at all three sites focused their observations and field notes on key aspects of the professional development and to establish cross-site and format fidelity. These included: the nature of teacher/teacher and teachers/facilitator interactions, signs of engagement, fatigue, understanding, questions among participants, implementation of the institute as planned (e.g. administrative, structural issues).

**Artifacts.** Artifacts, including the syllabi, course packs, and handouts, allowed for detailed characterization of the STP components. These artifacts were triangulated with survey data and interview responses and increased the internal validity of the findings.

**Data Analysis.** Participants' pre-, post-, and year-end (Cohort 1 only) STP definitions and descriptions of 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 defined above (See Maeng & Bell, 2012, Appendix A). Review by an expert panel provided support for face and content validity of the rubric. Participants' responses were coded as not aligned, partially aligned, and fully aligned for definitions and implementation of inquiry and NOS instruction. Raters also coded participants' understanding that effective NOS instruction is explicit. Two raters independently coded each participant's open-ended responses related to PBL, inquiry, and NOS. Inter-rater agreement was established (~90%) by comparing independent analysis across approximately 50% of the data. All disagreements were resolved by discussion.

Data from Likert scale items on each participant's pre-, post-, and year-end STP Perceptions survey were analyzed using descriptive statistics. For each participant, an overall sum of all of the items and mean scores pre- and post-assessment was calculated along with an aggregate mean score for those survey items assessing NOS, inquiry, and educational technology (including computer simulations), assessment, and effective classroom management. Changes in participants' pre- and post-methods course scores were calculated as overall change, average change, and change for those items assessing NOS, inquiry, and educational technology (including computer simulations), assessment, effective classroom management. Inferential statistics were not calculated due to the small sample sizes.

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

### **New Science Coordinator Academy**

**Participants.** Participants across two cohorts of the VISTA New Science Coordinator Academy (NSCA) included 8 males and 20 females from 25 different school districts in Virginia (Table 5). 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 district science coordinator (DSC), science lead teacher, science specialist, instructional coach, vertical team leader, beginning teacher advisor coordinator, elementary principal). Of the participants, 21 had led science professional development in their district. Participants' years of experience in their current leadership role ranged from none 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.

Table 5. NSCA Participant Demographic Information (n=28)

Gender		Highest Degree			Current Position			Years In Position		
Female	Male	M.Ed./ MS	Ed.D./ Ph.D. (in progress) Ed.S.	Earned Ed.D./ Ph.D.	DSC/ Specialist	Science Lead Tchr/ Instr.Coach	<sup>1</sup> Other	0-2	3-5	5-7
20 (71.4%)	8 (28.6%)	17 (60.7%)	7 (25.0%)	4 (14.3%)	17 (60.7%)	6 (21.4%)	5 (17.9%)	10 (35.7%)	12 (42.9%)	2 (7.14%)

Note: <sup>1</sup> Principals, central office administrators, beginning teacher advisors, curriculum support

**Context.** The goal of the VISTA New Science Coordinator Academy (NSCA) was to build, support, and sustain the infrastructure of school district science leaders. The NSCA was implemented across 5 days (30 contact hours) by a team of 6 facilitators 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-, post-, and one year after the NSCA, follow-up interviews of a subset of participants, observations of the NSCA, 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 NSCA, 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 to participants prior to and following the NSCA and one year after participation (Cohort 1 only) in 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.

The delayed-post Perceptions survey elicited participants' perceptions of the NSCA experience a year after participation. This survey included the same 14 Likert-scale items as the pre- and post-Perceptions surveys and an additional eight open-ended questions designed to elicit participants' perceptions of the effectiveness of the NSCA and how participants implemented aspects of the NSCA throughout the year. 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, 5 participants (approximately 18%) were purposefully selected for follow-up interviews. 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 NSCA. 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. One

year later, 5 different participants (approximately 18%) were purposefully selected for a follow-up semi-structured interview about their experience during the NSCA and how, if at all, they have used what they learned in the year since attending. 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 NSCA 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, nature of science, 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 and refined through comparison with the original data set.

### Science Education Faculty Academy

**Participants.** Participants across two cohorts of the VISTA Science Education Faculty Academy (SEFA) included 4 males and 9 females from 10 different universities and colleges in Virginia (Table 6). There were 1 Asian American, 4 African American, and 8 Caucasian participants. Of the 13 participants, 11 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. Of the 8 Cohort 1 participants, 4 also attended the VISTA SEFA during the second year SEFA. All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Table 6. *SEFA Participant Demographic Data*

Cohort	Total	Gender		Position					
		Female	Male	Assistant Professor Education	Associate or Professor, Education	Assistant Professor, Science Area	Associate or Professor, Science Area	Other (Adjunct, Education and Continuing Studies)	Caucasian
1	8	4 (50%)	4 (50%)	2 (25%)	2 (25%)	1 (12.5%)	1 (12.5%)	2 (25%)	6 (75%)
2	5 <sup>1</sup>	5 (100%)	0 (0%)	3 (60%)	1 (20%)	0 (0%)	1 (20%)	0 (0%)	2 (40%)
	13	9 (69.2%)	4 (30.8%)	5 (38.5%)	3 (23.1%)	1 (7.7%)	2 (15.4%)	2 (15.4%)	8 (61.5%)

Note: <sup>1</sup>Participants are only included in analysis for the first year in which they participated.

**Context.** The 5-day (27 contact hours) SEFA was implemented by a team of 5 facilitators at George Mason University. The primary purpose of the SEFA was to build infrastructure to support effective science teaching and learning in Virginia. Prior to the SEFA, participants submitted a vexation/venture for review and comment by the other participants during the first day of SEFA. This process is fully described in Logerwell, Sterling, Matkins, & McDonnough (2013). In addition to this Over the five days of the SEFA, participants also 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-, post-, and one year after (Cohort 1 only) the SEFA, follow-up interviews of a subset of participants, observations of the SEFA, 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 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 SEFA. 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 SEFA and the quality of the SEFA relative to other professional development experiences in which they have participated. Approximately one year after participation in the SEFA, participants (Cohort 1 only) completed a follow-up Perceptions survey. In addition to the questions on the pre-/post-Perceptions survey, the follow-up survey asked participants to estimate the broader impacts of SEFA on preservice and inservice teachers and K-12 students, indicate the extent to which they implemented what they learned in SEFA over the year, and whether they would be interested in a follow-up session in the future. A panel of three experts in science education, evaluation, and measurement provided support for face and content validity of this survey.

**Interviews.** Following analysis of the pre- and post- SEFA survey, 5 participants (approximately 38%) 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 SEFA. Interview questions elicited participants' perspectives on the most and least valuable aspects of the SEFA, components of the SEFA they planned to implement, and suggestions for improvement. These interviews also served as a member-check of participants' survey responses.

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

**Data Analysis.** Likert scale data from each participant's pre-, post-, and delayed-post (Cohort 1 only) 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-SEFA 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 and refined through comparison with the original data set.

## Results

The purpose of this investigation was to report the ongoing assessment results of four principal components of the VISTA program: the elementary science institute (ESI), the secondary teacher program (STP), 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. We also wanted to investigate 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 four components of VISTA, are presented for the ESI, STP, 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-summer institute, post-summer institute, and year-end 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 7 and 8). Results of this analysis suggest participants' knowledge of problem-based learning improved substantially, from 0.7% fully aligned pre-instruction to 42.6% fully aligned post-summer institute. Participants' understandings of inquiry and nature of science improved less, from 4.7% to 20.6% fully aligned for inquiry and from 0% to 17.7% for nature of science prior to and following the summer portion of the ESI. However, these results also indicate participants made substantial shifts from not aligned to partially aligned understandings of inquiry and nature of science.

For the first cohort of the ESI, participants' year-end understandings of problem-based learning, inquiry, and nature of science were also assessed. Many participants' understandings of problem-based learning and inquiry shifted from fully to partially aligned between the end of the summer institute and the end of the academic year, though this shift was not observed for participants' NOS understandings. The percentage of participants at year-end who expressed partially or fully aligned views of PBL was less than those expressing partially or fully aligned views of PBL at the end of the summer (59.5% year end versus 89.9% post-summer institute). The percentage of participants with year-end partially or fully aligned conceptions of inquiry and nature of science were approximately equal to post-summer institute percentages for those concepts (75.5% year end versus 70.3% post-summer institute) for inquiry and (51.1% year end versus 53.1% post-summer institute) for nature of science.

Table 7. *Elementary teachers' understandings of Problem-based learning, Inquiry, and NOS instruction.*

	Pre-Summer Institute (n=144)			Post-Summer Institute (n=141)			Year End <sup>1</sup> (n=47)		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
PBL	123 (85.4%)	20 (13.9%)	1 (0.7%)	44 (31.2%)	37 (26.2%)	60 (42.6%)	19 (40.4%)	23 (48.9%)	5 (10.6%)
Inquiry	89 (61.8%)	48 (33.3%)	7 (4.7%)	36 (25.5%)	76 (53.9%)	29 (20.6%)	14 (29.8%)	20 (42.6%)	13 (27.7%)
NOS understandings	128 (88.9%)	16 (11.1%)	0 (0%)	34 (24.1%)	82 (58.2%)	25 (17.7%)	23 (48.9%)	20 (42.6%)	4 (8.5%)

Note: Total participants were 49 in Cohort 1 and 95 in Cohort 2. <sup>1</sup> Year-end data for Cohort 1 participants only.

Pre- to post-summer institute results related to participants' understandings that effective NOS instruction is explicit were less impressive (Table 8). Prior to instruction all of the participants held the conception that students would learn about the nature of science through implicit approaches. Following the summer institute 66.7% of participants still expressed this perspective. Additionally, for Cohort 1 participants, there was virtually no shift in participants' understanding that NOS instruction should be explicit from the end of the ESI (28.6%) to the end of the year (27.7%).

Table 8. *Elementary teachers' understandings that effective NOS instruction is explicit.*

	Pre-Instruction (n=144)		Post-Instruction (n = 141)		Year End <sup>1</sup> (n =47)	
	Implicit	Explicit	Implicit	Explicit	Implicit	Explicit
NOS instruction	143 (99.3%)	1 (0.7 %)	94 (66.7%)	47 (33.3%)	34 (72.3%)	13 (27.7%)

Note: Total participants were 49 in Cohort 1 and 95 in Cohort 2. <sup>1</sup> Year-end data for Cohort 1 participants only.

**Perceived 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 9). Likert scales ranged from one to five; means over 4.0 were considered to be strong indicators of confidence while means below 4.0 indicated potential areas of weakness. While participants 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. Additionally, participants' confidence remained similar from the end of the summer institute to the end of the academic year for all three constructs.

Table 9. *Pre- post-, and year-end Elementary Science Institute confidence in implementing PBL, inquiry, and NOS.*

Item	Pre-Summer Institute (n=145) M (SD)	Post- Summer Institute (n=143) M (SD)	<sup>1</sup> Year End (n=47) M (SD)
Confidence incorporating:			
Problem-based learning activities	2.3 (1.0)	3.5 (0.92)	3.5 (1.1)
Inquiry-based activities	2.5 (.98)	3.7 (0.92)	3.9 (.87)
Explicit NOS instruction	2.0 (1.1)	3.7 (0.90)	3.4 (1.0)

Note: Total participants were 49 in Cohort 1 and 95 in Cohort 2. <sup>1</sup> Year-end data for Cohort 1 participants only.

The influence of the ESI on teachers' thinking about PBL, NOS, & inquiry-based instruction was apparent in their survey and interview responses. For example, some participants who initially held very limited knowledge of the key concepts developed real and applied conceptual understanding of those concepts. In an interview, one teacher described how the ESI had influenced his thinking about the primary strategies of PBL, NOS, & inquiry-based instruction:

*...without a doubt, I have a much better understanding. I wasn't familiar at all with the nature of science. Problem based learning and inquiry? Yes. But now I'm absolutely feel confident about it, but I see that also developing more as I work through more problem-based learning activities with my students... I think I have a deeper understanding. I knew inquiry was about thinking and students talking it out and learning on their own, but I think when you become the student, it deepens your understanding when you're actually going through the process. That was the first time I ever went through the whole process as a student. (Interview, E2-T202)*

Similarly, another participant noted,

*... Inquiry, I thought was something a little bit different before this [professional development]. I had no idea what nature of science was, so that has changed. All of them are a positive change. I think that the fact that this whole program was more student centered, and I could actually see it implemented as a student centered, as more student directed, that was very positive.*  
(Interview, E2-T250)

Overall, the data suggest positive trends in participants' understanding of and confidence in integrating PBL, inquiry, and nature of science instruction as a result of attending the VISTA ESI and that to some extent, these understandings were retained at the end of the year.

**Perceived Effectiveness of the ESI Summer Professional Development.** Participants' open-ended survey responses and follow-up interviews indicated many found the summer ESI professional development to be more effective than previous professional development they 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)

Similarly, another responded:

*VISTA is a much more comprehensive experience than other science professional development experiences because it is longer and more intensive, there is an incentive because of the pay, I had an opportunity to get a large amount of feedback. The principles I learned in VISTA went deep to the heart of my teaching unlike other professional development experiences that were more "on the surface."* (E2-T212, 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 during the summer before trying it out in their own classroom. As a representative example, one participant noted 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)*

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)*

Many others also 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 strategies they learned 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:

*I will implement the PBL that we have planned as a grade level within the first few months of school. I would like to plan PBLs for other science units throughout the year. The NOS poster will be hung in the room to reference throughout the year and while students are learning. I also plan to implement many of the strategies learned during the ELL and SPED module in all subjects, not just science. (E2-T236, Post-perceptions Survey)*

Another teacher noted that in addition to implementing the PBL unit they planned, she was going to incorporate other aspects of high-quality science instruction they learned during the ESI:

*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.

Although participants' response to the ESI summer professional development was primarily positive, participants reported some areas for improvement. For example, in year one, 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 camp during the second week of the ESI reported that they would have liked to have access to teaching module content prior to the camp. In contrast, participants who went through the teaching modules during the second week reported feeling prepared to teach camp in the third week. Participants perceived a need to have the information from the teaching modules before camp to feel confident teaching during the camp week.

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. 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. Further, participants found the VISTA ESI to be an effective, practical and comprehensive professional development experience.

### **Secondary Teacher Program**

The primary purpose of the VISTA Secondary Teacher Program was to improve participants' knowledge and implementation of inquiry and NOS instruction through a "Learn, Try, Implement with feedback" professional development model. Analysis of the Perceptions surveys revealed changes in STP participants' knowledge of and confidence in implementing inquiry and nature of science instruction prior to and following the first year science methods course. Most participants indicated the STP impacted their thinking about teaching with targeted VISTA strategies (inquiry, nature of science) and the ability to share ideas with teachers about inquiry strategies was the most valuable component of the program. Teachers found the practical applications of the instructional strategies they learned to be among the most important components of the STP. Observations and interview data indicated teachers' experiences varied with regard to course format, classroom coaching, and factors related to the school context in which they were teaching.

**Knowledge of Inquiry and NOS instruction.** During the first-year STP course VISTA identified two target constructs for participants to master. These constructs were nature of science instruction and inquiry instruction. The third construct, problem-based learning, is taught during the second year STP course; therefore, we do not report outcomes related to this construct in the present study.

The extent to which VISTA participants' pre- and post-STP definitions of these three constructs were aligned with targeted conceptions was assessed through participants' open-ended Perceptions survey

responses (Tables 10 and 11). Results of this analysis suggested participants' knowledge of inquiry-based instruction improved moderately, from 10.0% fully aligned pre-instruction to 15.4% fully aligned post-instruction. For nature of science prior to and following the VISTA STP, participants' understandings shifted from 0% fully aligned to 11.5% fully aligned. These results also indicated participants' made substantial shifts from not aligned to partially aligned understandings of inquiry and nature of science.

For the first cohort of the STP, participants' year-end understandings of inquiry and nature of science were also assessed. All participants' understandings of inquiry and nature of science reverted from fully to partially aligned between the end of the science methods course and the end of the academic year.

Table 10. *Secondary Teachers' understandings of Inquiry and NOS instruction.*

	Pre-Methods Course <sup>1</sup> (n=50)			Post-Methods Course (n =52)			Year End <sup>2</sup> (n =9)		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
Inquiry	27 (54.0%)	18 (36.0%)	5 (10.0%)	21 (40.4%)	23 (44.2%)	8 (15.4%)	6 (66.7%)	3 (33.3%)	0 (0%)
NOS understandings	44 (88.0%)	6 (12.0%)	0 (0%)	20 (38.5%)	26 (50.0%)	6 (11.5%)	8 (88.9%)	1 (11.1%)	0 (0%)

Note: Total participants were 11 in Cohort 1 and 41 in Cohort 2. <sup>1</sup>Two participants in Cohort 2 did not complete the Pre-Perceptions survey. <sup>2</sup>Two participants in Cohort 1 did not complete the Year-end Perceptions Survey.

With regard to participants' understanding that nature of science instruction should be explicit, 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 STP 84.6% of participants still expressed this perspective (Table 11). Additionally, there was virtually no shift in Cohort 1 participants' understanding that NOS instruction should be explicit from the end of the secondary methods course to the end of the year.

Table 11. *Secondary Teachers' understandings that effective NOS instruction is explicit.*

	Pre-Methods Course <sup>1</sup> (n=50)		Post-Methods Course (n = 52)		Year End <sup>2</sup> (n =9)	
	Implicit	Explicit	Implicit	Explicit	Implicit	Explicit
NOS instruction	47 (94.0%)	3 (6.0%)	44 (84.6%)	8 (15.4%)	6 (66.7%)	3 (33.3%)

<sup>1</sup>Two participants in Cohort 2 did not complete the Pre-Perceptions survey. <sup>2</sup>Two participants in Cohort 1 did not complete the Year-end Perceptions Survey.

Participants' interview responses were aligned with the survey data; they understood inquiry better than nature of science. For example, one participant's interview response reflected a practical understanding of inquiry and the levels of inquiry. The participant noted about inquiry levels: *One of the things that has kind of stuck with me since the beginning of the course is when we started talking about inquiry – levels of inquiry, meaning completely closed inquiry, level 0 they called it, where there's really no inquiry going on. Everything's given to the students, everything's told to the student, there's a certain definite answer that they're supposed to get. That's the typical cookie cutter lab where you know if you didn't get this answer then you did it wrong. And then there were, I believe, levels 1, 2, and 3 after that. And 3 was completely open inquiry where basically you tell the students 'Here's the issue, I want you to learn about it', and they have to come up with what problem or question are they going to test. They have to come up*

*with the experimental design; they have to obtain their resources and really kind of run themselves through the entire scientific process. (S1-T20, Interview)*

Another participant's interview response about understanding the nature of science was representative of the majority of participants:

*...I would not say a solid understanding [of nature of science], but I would say I have a moderate understanding of what it looks like in my classroom. . . . if you were to ask me right now to define what those are I don't think I can give you the exact technical definition of it. But I think I would be able to explain what a lesson might look like that's inquiry based or that involves the nature of science... Nature of science - I think that's probably the one I'm the weakest on understanding. (S1-T19, Interview)*

It was evident the inquiry-related instruction during the STP resulted in improved understandings of inquiry. Improvements in participants' nature of science conceptions and confidence in teaching nature of science were less dramatic. Therefore, nature of science related instruction during the STP is an area for improvement and additional focus in the future.

**Perceived Confidence in Implementation.** Participants had varying levels of confidence in their ability, based on the course, to translate the knowledge about inquiry and nature of science. Participants were asked to rate their confidence incorporating targeted VISTA skills into their science instruction (Table 12). Prior to attending the STP participants reported low levels of confidence incorporating inquiry-based activities and explicit nature of science instruction in their science classes ( $M=2.7$ ,  $SD=.88$  and  $M=2.5$ ,  $SD=1.1$ , respectively). These confidence levels rose moderately for inquiry instruction and nature of science ( $M=2.6$ ,  $SD=.93$  for inquiry and  $M=3.4$ ,  $SD=1.1$  for NOS) as a result of STP participation. Pre- and post-confidence levels for incorporating educational technology were moderate ( $M=3.3$ ,  $SD=1.0$ ) and rose following participation in the STP course ( $M=4.0$ ,  $SD=.92$ ). Confidence in using technology to support inquiry-based instruction was low prior to ( $M=2.8$ ,  $SD=1.1$ ) and improved to moderate levels ( $M=3.4$ ,  $SD=1.1$ ) following participation in the program. Additionally, the participants' reported moderate levels of confidence using computer simulations ( $M=3.6$ ,  $SD=1.2$ ) following the methods course. Confidence in assessing students' learning in science rose from a mean of 3.0 ( $SD=.8$ ) to 3.8 ( $SD=3.8$ ) following STP participation.

Table 12. *Pre- and post-Secondary Teacher Program confidence . (1=not confident, 3=confident, 5=highly confident)*

Item	Pre (n=51) M (SD)	Post (n=52) M(SD)
Confidence incorporating:		
Inquiry-based activities	2.7 (.88)	3.6 (.93)
Explicit nature of science instruction	2.5 (1.1)	3.4 (1.1)
Educational technology (Gen.)	3.3 (1.0)	4.0 (.92)
Technology to support inquiry	2.8 (1.1)	3.4 (1.1)
Computer simulations	3.1 (1.2)	3.6 (1.2)
Student assessment	3.0 (.80)	3.8 (.87)
Classroom management	3.1 (1.1)	3.7 (.94)
Adapting inquiry instruction to meet students' diverse learning needs	2.6 (1.1)	3.2 (.96)

**Perceived Effectiveness of the STP Professional Development.** After the STP course, participants rated the effectiveness (on a Likert scale of 1-5) of the course in terms of opportunities to: develop and practice inquiry-based activities and NOS lessons, modify instruction to meet the needs of diverse learners, and integrate technology and simulations into science instruction and practicing student assessments of learning (Table 13). Likert scale means of 3.0 were interpreted as moderately effective and those greater than 4.0 were interpreted as effective. Participants' responses indicated the STP was

moderate to highly effective at offering opportunities to develop and practice inquiry-based instruction, but somewhat less effective on the development and practice of nature of science instruction and incorporation of educational technology.

Table 13. *Perceived effectiveness of secondary methods course components (n=52, 100% responded)*

Item:	M (SD)
Opportunities to:	
Develop inquiry-based activities.	4.1 (.80)
Practice teaching inquiry-based activities	4.1 (.94)
Practice modifying inquiry-based activities	3.8 (1.0)
Develop explicit nature of science lessons	3.7 (.91)
Practice teaching explicit nature of science lessons	3.6 (1.0)
Integrate educational technologies into science instruction	3.8 (1.0)
Integrate computer simulations for inquiry instruction	3.9 (1.0)
Practice assessment of students' understanding of science	3.9 (.85)

Most participants were satisfied with the STP course. They rated the VISTA STP a higher quality than similar professional development experiences and perceived the content to be useful and relevant. According to the Post-STP Perceptions survey, participants indicated they were very likely to implement the material learned during the course (M = 4.5, SD= .78 on 5 point Likert scale). Evidence from observations across sites also indicated participants learned about hands-on learning, inquiry, nature of science, and assessing student work during the STP. Across sites and courses, participants perceived that the program offered opportunities to develop, practice, and modify inquiry-based instruction. Participants found the practical applications of the instructional strategies learned and the ability to share ideas about inquiry strategies to be among the most important components of the STP.

Participants were enthusiastic and expected to use the content, materials, and/or strategies learned during the VISTA secondary methods course. For example, they considered adapting “cookie-cutter” science lessons to engage students in science inquiry. About implementing inquiry activities, one participant noted:

*I will use the inquiry approach in as many lab activities as possible. Writing and implementing design briefs for use in the classroom has been particularly helpful. One of the books given to us in this course ("Students and Research" by Cothron et al.) had excellent ideas on how to initiate inquiry-based student research that I will definitely be using in future research projects. (S1-20, Post-perceptions survey)*

Participants also indicated that they planned to implement nature of science strategies and computer simulations in their classrooms. As a result of STP participation, participants specifically intended to implement inquiry and nature of science instructional strategies in an effort to engage students in direct experiences with science learning.

### **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. Results indicate participants improved with regard to their capacity to support teachers PBL, inquiry, and NOS instruction. Science coordinators cited opportunities for collaboration and that the professional development was targeted to their particular role as contributing to the value of the NSCA.

**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 14). 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 and that these improvements were retained one year after participation.

Table 14. *Impact of VISTA NSCA on Selected Participant Outcomes.*

Item	Pre (n=28)	Post (n=28)	<sup>1</sup> Delayed Post (n=9)
	M (SD)	M (SD)	M (SD)
PBL	3.0 (1.0)	3.8 (1.0)	4.0 (0.8)
Inquiry	3.2 (0.9)	3.9 (1.0)	4.0 (0.9)
NOS	2.8 (0.8)	3.5 (0.8)	3.7 (0.7)
Strategic planning	2.8 (1.1)	3.7 (1.0)	3.8 (0.7)
Improve science instruction	3.1 (0.9)	3.6 (0.7)	3.8 (0.8)

Note: <sup>1</sup> Delayed post only available for Cohort 1 (n=13, 9 responded).

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 suggested he learned about professional development to support key components of VISTA, it also indicated that he perceived a need for this instruction to be even more concrete. He perceived this would facilitate his application of nature of science and other reform-based constructs into professional development for teachers in his own 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 interviews 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.

**Perceived 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™ (a file sharing website) 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: (1) to provide participants the opportunity to learn about new research related to effective science teacher development and science teaching and (2) to share effective teaching strategies for how to best meet the needs of elementary and secondary science teachers through PBL, inquiry, and NOS instruction. SEFA participants' reported great proficiency in their capacity to enhance preservice and inservice teachers' science instruction. Results also indicated they found SEFA to be a valuable professional growth experience.

**Proficiency in supporting instruction.** Analysis of the Perceptions surveys indicated improvements in SEFA participants' self-reported knowledge of and proficiency in incorporating inquiry, NOS, and PBL instruction into their science methods instruction (Table 15). 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. These improvements were retained or dropped slightly one year after participation.

Table 15. *Impact of VISTA SEFA on Selected Participant Outcomes.*

Item	Pre (n=13) M (SD)	Post (n=13) M (SD)	<sup>1</sup> Delayed Post (n=6) M (SD)
PBL	3.9 (.7)	4.6 (.5)	4.1 (.7)
Inquiry	4.0 (.8)	4.6 (.5)	4.8 (.4)
NOS	3.5 (1.1)	4.5 (.5)	4.1 (.8)
Research-based Strategies	3.6 (1.0)	4.5 (.5)	4.3 (.5)
Seeking Funding	3.2 (.8)	4.5 (.5)	3.7 (1.5)
Collaborative Interactions	3.6 (.8)	4.8 (.4)	4.0 (.6)
<sup>2</sup> Extent Future		4.8 (.6)	4.8 (.4)
<sup>2</sup> Implementation			
<sup>2</sup> Feel Networked		4.7 (1.1)	4.7 (.5)

*Note:* Analysis performed on data from all participants in their first year of SEFA. <sup>1</sup> Delayed post only available for Cohort 1 (n=8, 6 responded). <sup>2</sup> Item only assessed on post and delayed-post.

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).

**Perceived 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. They also planned to implement what they learned during SEFA into their science methods courses.

### **Discussion**

The results from the first year two years 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 four VISTA professional development components reported improvements in confidence and proficiency in PBL, NOS, and inquiry instruction. Furthermore, 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. Participants in the SEFA had the highest overall scores and the beginning teachers in the STP had the lowest overall scores pre- and post-professional development with regard to these key VISTA objectives.

#### **Elementary Science Institute**

ESI participants made gains in their understanding of pedagogical approaches that support reforms-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' reforms-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 but retained their conception that students would learn about the nature of science through implicit approaches following the ESI. The modest improvements are not unexpected for a number of reasons. First, designing and implementing PBL into instruction is a complex process. It relies 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, few ESI participants expressed moderate knowledge of how to and confidence in effectively teaching nature of science to students, even after professional development. This finding 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 institute constituted only one component of the VISTA professional development experience. Participants were provided support throughout the academic year through follow-up sessions and coaching. These follow up sessions and coaching sessions were designed to reinforce what teachers initially experienced during the summer institute. These longitudinal and contextualized features of the VISTA science institute are often cited as essential features of effective professional development (e.g. Desimone, 2009; Johnson, Khale, & Fargo, 2007; Supovitz & Turner, 2000). Results indicated the teachers' retained their understandings of inquiry and nature of science instruction; however, a number of teachers reverted to partially aligned views of problem-based learning. It is possible that teachers incorporated PBL in the fall semester, in closer

proximity to when they learned it, but incorporated it less frequently in the spring. It is possible that this hypothesis will be supported by our planned analysis of teachers' classroom instruction across the academic year.

### **Secondary Teacher Program**

Participants perceived the first year of the STP positively impacted their thinking about reforms-based science instruction, specifically with regard to inquiry and nature of science instruction. Participants also perceived the STP as encouraging them to think about how to change their instructional practice. As a result of the STP, participants expressed improved confidence in incorporating inquiry activities and student assessment in instruction and in implementing effective classroom management strategies. Additionally, participants' expressed improved understandings of inquiry following the first year of the STP. Across sites, participants perceived that the program offered opportunities to develop, practice, and modify inquiry-based instruction. Participants found the practical applications of the instructional strategies learned and the ability to share ideas about inquiry strategies to be among the most important components of the STP. Thus, it appears the inquiry-related instruction during the first-year methods course resulted in these participants improved understandings of inquiry.

Results also indicated minor improvements in participants' confidence in integrating explicit nature of science instruction and technology to support reforms-based science instruction. Consistent with a large body of literature, few STP participants expressed only moderate knowledge of how to and confidence in effectively teaching nature of science, even after professional development (e.g. Bell, Abd-El-Khalick, & Lederman, 1998; Bell, Blair, Crawford, & Lederman, 2003; Lederman, Lederman, Kim & Ko, 2012). Nature of science appeared to be integrated into the course to a lesser extent in terms of developing and teaching lessons, which may be one reason why, participants did not experience as dramatic improvement in their NOS understandings following the STP. Given that few participants' conceptions of nature of science were partially or fully aligned with the VISTA conception of nature of science, it is probable that participants' nature of science instruction will be either implicit or include alternative conceptions about NOS. Therefore, nature of science related instruction during the STP is an area for improvement and more focus in the future. Our planned analysis of classroom observations may support or refute this hypothesis.

The results of the STP participants differed from those of the Elementary Science Institute (ESI) participants, which may be related to teacher experience and/or the nature of the professional development. First, most ESI participants were experienced teachers, whereas the STP participants were all first and second year teachers. Research suggests beginning teachers need support to develop beliefs and practices that align with reforms-based science instruction during their induction years (Luft et al., 2011). Second, differences in the ways the STP and ESI were implemented may have also contributed to the lower performance of the STP participants. The ESI participants learned target concepts much more thoroughly than the STP participants and they had the opportunity to teach during the summer institute component of the ESI. However, similar to the ESI, STP participants were provided support throughout the academic year through coaching. Duration and authentic context are often cited as essential features of effective professional development (e.g. Desimone, 2009; Johnson, Khale, & Fargo, 2007; Supovitz & Turner, 2000); however, the results of the present study suggest that coaching alone as follow-up may not be enough to overcome barriers encountered by these novice teachers in developing their understanding of reform-based practices.

### **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 aiding their teachers' reforms-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). Emphasis on standardized testing and a perceived disconnect between district-mandated content objectives and teaching with investigations and inquiry are barriers to reforms-based instruction for many teachers (e.g. Keys & Kennedy, 1999; 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 reforms-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 community of practice, 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 by science educators.

### **Final Thoughts and Future Research**

The preliminary results reported here suggest that the VISTA program was at least moderately effective in supporting participants' proficiency in implementing PBL, NOS, and inquiry instruction. In addition, each of the four VISTA components described in this investigation appeared to facilitate participants' knowledge of and proficiency in implementing or supporting reforms-based science instruction in their respective settings. All VISTA components incorporated key aspects of effective professional development (Desimone, 2009; Loucks-Horsley et al., 2010). Thus, our results provide

further support for the efficacy of the importance of including coaching, collaboration, and opportunities for practice, reflection, and feedback into context-specific professional development. Documenting professional development that facilitates teachers' reforms-based 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). Ultimately, the results of this study have the potential to inform professional development supporting educators' implementation of inquiry, nature of science, and PBL instruction by in-service elementary and secondary science teachers, science coordinators, and college science educators.

Analysis of additional collected data including videotaped classroom observations, instructional materials, and interviews will be triangulated with the 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 and STP participants' understandings of inquiry, PBL, and NOS were translated into their classroom practice and whether relationships exist between participants' understandings, practice, and student achievement. Research will also explore the extent to which participants in the ESI and STP components of VISTA understandings, practices, and students' achievement on state science assessment differed from teachers in the control condition. 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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