Statewide Elementary Science Institute to Support Reforms-based Science Instruction: Results from Three Years of Implementation

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Abstract

The purpose of this investigation was to assess the effectiveness of the Virginia Initiative for Science Teaching and Achievement (VISTA) Elementary Science Institute (ESI) and characterize changes in participants' understanding and classroom implementation of problem-based learning, nature of science, and inquiry instruction following participation in the ESI. The ESI was aligned with the characteristics of effective professional development and situated learning theory. The ESI was assessed through a cluster randomized controlled trials (RCT) design. Treatment participants received an intensive 4-week professional development with sustained follow-up and coaching throughout the academic year, while control participants received no professional development or support. Across three cohorts, participants in the treatment group included 199 teachers and those in the control condition included 143 teachers. Data collection included Perceptions surveys administered to participants pre- and post- ESI and at the end of the year, post-Summer Institute and year-end interviews of a subset of participants, Pedagogical Content Knowledge (PCK) surveys, videotaped classroom observations and observation forms, observations of the professional development, and artifacts. Data were analyzed using systematic data analysis (Miles & Huberman, 1994) and inferential statistics. Results indicated the majority of ESI participants expressed either partially or fully aligned understandings of PBL, inquiry, and nature of science instruction following the ESI. Further analysis of classroom observations and PCK surveys indicated the ESI facilitated participants' implementation of PBL, inquiry, and nature of science into their classroom instruction. Finally, most participants expressed high levels of satisfaction with the main components of the ESI professional development. The situated nature and embedded components of effective professional development that characterized the VISTA ESI appeared to contribute to the overall effectiveness of the professional development experience. The results of this study have the potential to inform professional development supporting educators' implementation of reforms-based science practices by in-service elementary science teachers.

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 and engage in science-related matters as a reflective citizen. Students also need to understand the characteristics of science as knowledge and inquiry and how science and technology shape material, intellectual, and cultural environments (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

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4) participating productively in scientific practice and discourse (NRC, 2007, 2012). These interrelated strands represent the scientific knowledge, scientific practices, and nature of scientific knowledge 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 scientific practices 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).

Effective science instruction should develop students' scientific literacy through student-centered instruction (NRC, 1996, 2011). Such instruction should promote students' conceptual understanding and use of science concepts, provide students opportunities to learn about and practice science inquiry and the scientific practices necessary to conduct inquiry (e.g. AAAS, 1993; Donovan & Bransford, 2005; NRC, 1996). It should also include explicit instruction about the nature of scientific knowledge (e.g. Bell, Blair, Crawford, & Lederman, 2003; Lederman, 2007). This type of instruction places the teacher in the role of facilitator of learning and provides students opportunities for collaboration, scientific discussion, and debate (NRC 1996).

Asking questions, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and obtaining, evaluating, and communicating information are some of the key practices described in the *Framework for K-12 Science Education* (NRC, 2011). Taken together, these practices constitute the elements of scientific inquiry (Martinez, Borko, & Stecher, 2012). Therefore, at its simplest, inquiry instruction can be described as students analyzing data to answer a research question (Bell, Smetana, & Binns, 2005).

Instruction about the nature of science involves teaching students the values and assumptions inherent in the development of scientific knowledge. Researchers have converged on a set of ideas related to the nature of science appropriate to teach K-12 students. These ideas 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 (Lederman, 2007). Effective nature of science instruction makes these ideas explicit to students (e.g. Abd-El-Khalick & Akerson, 2004; Akerson & Hanuscin, 2007; Bell, Abd-El-Khalick, & Lederman, 1998).

Problem-based learning (PBL) is one instructional model that provides a context for reforms-based science instruction. Students are challenged to investigate a meaningful, real-world problem and present solutions to the problem based on their findings (Sterling, 2007). 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, engage students in inquiry-based activities, and increase student achievement (Sterling, 2006; Sterling, Matkins, Frazier, & Logerwell, 2007).

Reforms-based approaches to science instruction such as PBL represent dramatic shifts from traditional instruction and have proven difficult to implement (Loucks-Horsley &

Matsumoto, 1999). Many of the barriers contributing to some teachers' reluctance to implement reforms-based science instruction are institutional (e.g. standardized testing, disconnect between district-mandated content objectives and exploration of concepts through investigation) and technical (e.g. lack of resources or curricular materials) (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). For example, Ladewski, Krajcik, and Harvey (1994) found teachers' beliefs about effective use of time (i.e. allowing for student exploration versus covering state-mandated curriculum), the ill-structured, open-ended nature of PBL activities (i.e. all student investigations should result in the same outcomes), and whether instruction should be student or teacher-driven conflicted with implementation of PBL in middle school science classrooms. Another investigation reported time, classroom management, control, support of student learning, technology use, and assessment as barriers to effective PBL integration (Marx, Blumenfeld, Krajcik, & Soloway (1997)

Other barriers to reforms-based instruction 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). 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). Other teachers 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 other teachers do not recognize that to be effective nature of science instruction must explicitly address targeted nature of science conceptions through student reflection and discussion (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).

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 and classroom implementation of reforms-based pedagogy (Johnson, 2006, 2007; Loucks-Horsley et al., 2010; Supovitz & Turner, 2000). 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). 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). 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) Elementary Science Institute (ESI) that served as the context of the present investigation was guided by the aforementioned key components of effective professional development. The ESI is sustained and ongoing, context-specific, fosters collaboration, and provides opportunities for feedback, reflection, and practice. The structure of the ESI was heavily informed by two smaller-scale science teacher professional development programs that reported statistically significant improvement in science instruction and student performance (Sterling & Frazier 2010; Sterling, Matkins, Frazier, & Logerwell, 2007). Specifically, the ESI had the primary goal of supporting elementary science teachers' inclusion of inquiry-based and explicit nature of science instruction in the context of PBL. A second goal was to facilitate the development of a state-wide infrastructure to support reforms-based science instruction. To support this second goal, principals and science coordinators were also included in the ESI professional development.

McLellan's (1996) model of situated learning served as the theoretical lens through which we investigated the effectiveness of the VISTA ESI. Situated learning theory suggests learning is contingent on the interaction between the learner and the context in which learning takes place. Thus, learning occurs best in an authentic context and social interactions play an important role in learning (Orgill, 2007). Ultimately, learning should result in successful transfer of new knowledge to a new context. Transfer is facilitated through instruction that incorporates specific examples as well as examples with broad application and general principles (Engle, Lam, Meyer, & Nix, 2012; NRC, 2000). McLellan identifies five key components of situated learning that may facilitate knowledge transfer to new contexts: cognitive apprenticeship, coaching, opportunities for multiple practice, collaboration, and reflection.

The components of situated learning theory are well-aligned with both the characteristics of effective professional development and the format of the VISTA ESI. Throughout the program, implementers incorporated specific examples from science content aligned with appropriate instructional strategies to model implementation of nature of science, inquiry, and PBL instruction. During the summer component of the ESI, teachers engaged in *cognitive apprenticeship;* they worked closely with implementers, scientists, curriculum specialists, and mentor teachers who provided *coaching*, scaffolding, detailed *feedback*, and encouragement to the teachers as they began developing and teaching lessons that effectively integrated nature of science, inquiry, and PBL. *Coaching* was also a major component of the ESI experience. Expert science teachers served as classroom coaches, observing participants' classroom instruction, providing constructive feedback, and assisting in lesson planning throughout the academic year. These coaches also co-taught with teachers. Teachers had *multiple opportunities to practice* implementing PBL, inquiry, and nature of science to teach the PBL units they developed during the summer camp component of the ESI and during the academic year. *Collaboration* was emphasized throughout the ESI as teachers worked together in teams to develop PBL units for implementation during the camp and academic year. Opportunities for discussion and *reflection* on their experiences teaching PBL units, implementing inquiry, and incorporating explicit nature of science instruction were integrated throughout the ESI. In summary, the participants' experiences throughout the ESI were *sustained* throughout the year and emphasized reforms-based science instruction situated within an *authentic context.*

Purpose

The purpose of this investigation was to assess the effectiveness of the ESI and characterize changes in participants' understanding and classroom implementation of PBL, nature of science, and inquiry instruction following participation in the ESI. The following research questions guided the investigation:

1) How did participants' understandings of and confidence in teaching PBL, inquiry, and nature of science instruction change as a result of participation in the ESI?
2) How did participants' classroom practices related to PBL, inquiry, and nature of science instruction change as a result of participation in the ESI?
3) What were participants' perceptions of the ESI?

Methods

Evaluation of the VISTA ESI professional development utilized a cluster randomized controlled trials (RCT) design. Treatment participants received an intensive 4-week professional development with sustained follow-up and coaching throughout the academic year, while control participants received no professional development or support.

Participants

For each ESI cohort, school teams with completed applications were randomized via straight (textbook) random assignment into treatment or control groups. Retained in the treatment condition across three cohorts of the ESI were 199 teachers (27 males and 168 females) from 72 different elementary schools (Table 1). Across three cohorts, participants in the control condition included 143 teachers (17 male and 122 female) from 60 different elementary schools. Participants' Virginia licensure, teaching, and educational experience are described in Table 2. All demographic data were self-report. To maintain confidentiality, all participants were assigned a participant ID.

Table 1
VISTA Elementary Science Institute participant demographic data (Cohorts 1-3)

Condition	Gender		Ethnicity				
	Female	Male	Caucasian	African American	Hispanic	Asian	Native American
Treatment (n=199)	168 (86.2%)	27 (13.8%)	150 (76.9%)	39 (20.0%)	3 (1.5%)	2 (1.0%)	1 (.5%)
Control (n=143)	122 (87.8%)	17 (12.2%)	109 (79.0%)	25 (18.1%)	3 (2.2%)	1 (.7%)	0 (0%)

Note. Not all teachers reported gender and ethnicity information. Percentages reported are for respondents to each demographic question.

Context

The first two years of VISTA, 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. Virginia Tech was added as a professional development site in year 3. At each site, participants spent week 1 of the summer institute learning about problem-based learning, inquiry instruction, nature of science instruction, and collectively planning their PBL unit for implementation at a camp during weeks 2 and 3. 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). Participants spent one of these two 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 learning, explicit nature of science instruction, and inquiry-based teaching throughout the academic year. During Week 4, participants focused on creating a PBL unit that they could teach in the fall. Teams of university science educators, scientists, mathematics specialists, science classroom teachers, and engineers co-planned and co-facilitated the summer learning experiences. Furthermore, 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, participants completed a minimum of 14 hours of follow-up sessions and also attended the annual state science teachers' conference. In addition, coaches worked with participants in their classroom 22.5 hours across the academic year to co-plan, co-teach, observe and provide feedback on participants' science instruction. Table 3 describes the key features of the professional development. For a complete description of the ESI intervention, see Mannarino, Logerwell, Reid, & Edmonson (2012).

Data Collection

Data consisted of Perceptions surveys administered to participants pre- and post- ESI and at the end of the year, post-Summer Institute and year-end interviews of a subset of participants, Pedagogical Content Knowledge (PCK) surveys, videotaped classroom observations and observation forms, observations of the professional development, and artifacts including planning documents and participant-generated reflections.

Perceptions Surveys. The VISTA Perceptions Survey was administered to all treatment and control participants prior to the Summer Institute component of the VISTA ESI. This survey contained 11 Likert-scale items designed to assess the frequency and confidence with which participants incorporated problem-based learning, nature of science, and inquiry, and educational technology (including computer simulations) into their science instruction. It also included questions about participants' 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, nature of science, and problem-based learning instruction.

At the end of the Summer Institute, teachers in the treatment group completed the VISTA Perceptions Survey. In addition to pre-Survey questtions, the post-Perceptions Survey also asked participants about their experiences in the Summer Institute, understanding of PBL, nature of sceince, 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 planned to use what they learned in the summer institute of the ESI during the upcoming academic year.

Finally, at the end of the school year, participants in both the treatment and control conditions completed a final VISTA Perceptions Survey. In addition to items on the pre- and post-Perceptions Survey, this survey asked the treatment group 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 their classrooms. Support for face and content validity of the Perceptions Surveys was established by a panel of three experts in science education, evaluation, and measurement.

PCK Surveys. Pedagogical content knowledge (PCK) surveys were administered to all participants prior to the ESI (June), twice during the academic year (November and February), and at the end of the year (May). This survey is designed to elicit two components of PCK (1) teachers' beliefs about their knowledge of student science learning and conceptions and (2) their knowledge of specific teaching strategies and representations (Lee, Brown, Luft, & Roehrig, 2007). On the pre-survey, participants described a lesson they thought would be a high quality lesson, without constraint of when, across the year they taught the lesson. On subsequent surveys, participants selected and described how they planned and enacted what they consider to be one of their best, recently taught science lessons. In this description, they explained the content focus of the lesson, the key learning tasks, and what worked well in the lesson, what did not go well, and what they would change if they were given the opportunity to teach the lesson again. Then, they described the major factors they considered as they planned the lesson, described if they considered students' prior knowledge, variations in students' approaches to learning, and students' alternative conceptions and how they addressed these three aspects of PCK in the described lesson. Responses allowed for assessment of participants' knowledge of student learning and conceptions and specific instructional strategies and representations that are helpful for students to understand new concepts (e.g., examples, explanations, analogies, and illustrations).

Interviews. Following analysis of the pre- and post-Perceptions surveys, approximately 20% of treatment participants (n=40) across all cohorts and sites were selected for a follow-up semi-structured interview about their experience. These participants were purposively selected from three categories: those whose Perceptions survey responses indicated little change, moderate change, or great change in their proficiency of key VISTA objectives (inquiry, PBL, and nature of science instruction). Interview questions elicited participants' understandings of PBL, nature of science, and inquiry, 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 participants' survey responses.

Table 2

VISTA Elementary Science Institute participant teaching and science experience (Cohorts 1-3)

Condition	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	
Treatment (n=199)	185 (93.0%)	13 (2.8%)	19 (9.7%)	12 (6.3%)	12 (9.1%)	22 (11.9%)	38 (18.9%)	39 (20.3%)	83 (39.9%)	68 (43.1%)	114 (52.6%)	1 (.7%)	23 (7.9%)
Control (n=143)	129 (90.2%)	5 (3.5%)	25 (17.5%)	18 (12.6%)	8 (5.8%)	13 (9.5%)	26 (19.0%)	24 (17.5%)	66 (48.2%)	62 (49.2%)	64 (50.7%)	0 (0%)	14 (10.4%)

Note. Not all teachers reported licensure, experience, and degree information. Percentages reported are for respondents to each demographic question.

Table 3

Elementary Science Institute Timeline

Elementary Institute	**Summer**	**Academic year**
Grade 4-6 science teachers	4 week institute	3 follow-up sessions Attend VAST conference 3 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

Classroom Observations. A total of four classroom observations were conducted at regular intervals throughout the academic year (twice in the fall, twice in the spring), within the same three-week interval for all treatment and control participants. Observers visited each teacher's classroom once during each observation period to videotape their science instruction. Observers also collected contextual information regarding the observed lesson per a validated observation protocol (Appendix A). This information included lesson objectives, lessons that occurred prior to the observation, and what participants anticipate teaching in lessons that follow the videotaped lesson. The observation protocol also asked participants to identify if these lessons incorporated PBL, inquiry, nature of science, and/or educational technology, and if so, a justification. Responses to these questions served as another piece of evidence to support whether teachers understood what PBL, inquiry, and nature of science instruction look like in a classroom.

Professional Development Observations. Each professional development site was observed three days the first year and four days during the second and third years. The purpose of these observations was to characterize implementation of the professional development model. The days observed each year were selected in order to capture the breadth of the professional development across the three years of implementation. An observation protocol ensured observers at all sites focused their observations and field notes on key aspects of the professonal development. These included: the nature of teacher/teacher and teacher/facilitator interactions, signs of engagment, participant questions, implementation of the institute as planned, the nature of instruction related to inquiry, PBL, and nature of science, and evidence of enactment of the learn, try, implement with feedback and research model.

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

Complete data sets, including all instruments, were analyzed for Cohorts 1 and 2. Cohort 3 has completed the summer portion of the ESI, therefore, only pre- and post-Perceptions Survey data (understandings, confidence, and feedback on the professional development) were analyzed for this investigation. Classroom implementation data (PCK Surveys, observations) and year-end Perceptions survey data were analyzed for Cohorts 1 and 2.

Participants' pre-, post-, and year-end ESI definitions and descriptions of PBL, nature of science, and inquiry instruction in the classroom were analyzed using systematic data analysis (Miles & Huberman, 1994) and a validated multi-part rubric. This rubric assessed the extent VISTA participants' open-ended survey responses expressed views of problem-based learning, inquiry, and nature of science aligned with VISTA (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 nature of science instruction. Raters also coded whether participants' responses reflected an understanding that effective nature of science instruction is explicit. Two raters independently coded each participant's open-ended responses related to PBL, inquiry, and nature of science. 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-, post-, and year-end were calculated along with an aggregate mean score for those survey items assessing inquiry, nature of science, and PBL.

PCK surveys were analyzed following the systematic data analysis process (Miles & Huberman, 1994). Members of the research team coded each participant's response as limited, basic or proficient and assigned corresponding numerical values (1 = limited, 2 = basic, 3 = proficient) using *a priori* codes and a validated rubric (Lee et al., 2007). Prior to analysis, raters were trained to analyze participants' responses and to establish inter-rater agreement. For each subsequent round of analysis (e.g. June, November, February, and May), a randomly selected subset of the data was coded by at least two raters prior to analyzing all surveys in that round. This helped maintain consistency across raters in applying codes over time. Instances in which scores differed between raters were discussed in light of the data and a final score for each category and teacher was obtained by consensus. For each round of analysis, inter-rater agreement was approximately 90% for this subset of data.

Classroom observation data were analyzed with a modified and validated version of the CETP-COP observation instrument (Appeldoorn, 2004). The CETP-COP instrument assessed four dimensions related to participants' science instruction (i.e., instructional approaches, classroom engagement; cognitive activity; and quality of lesson). In the present study, only the instructional approaches dimension was reported. For instruction codes, the presence (1) or absence (0) of hands on activity, inquiry, explicit nature of science instruction, and whether the observed lesson was part of a PBL unit was coded. Prior to coding, raters attended an 8-hour training session. Each rater scored each teacher videotape on the instrument dimensions (items). The results suggested the generalizability coefficient was ρ=0.76 for the given completely crossed design with 11 raters. Extrapolating to a single rater, the relative reliability was ρ=.67. Approximately 6 months after initial training, all raters coded another video and discussed their coding, which served as a drift check. This helped maintain consistency across raters in applying codes over time.

Analytic induction as described by Bogdan and Biklen (1992) was used to analyze the open-ended survey responses, 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.

Results

The purpose of this investigation was to explore changes in participants' knowledge of and classroom implementation of PBL, inquiry, and nature of science instruction following participation in the VISTA ESI. Additionally, we assessed participants' perceptions of the positive aspects of the ESI and areas for improvement. Results from the first three years of implementation suggest ESI participants made gains in their understanding of pedagogical approaches that support reforms-based science instruction; the majority of ESI participants expressed either partially or fully aligned understandings of PBL, inquiry, and nature of science instruction following the ESI. Further analysis of classroom observations and PCK surveys indicated the ESI facilitated participants' implementation of PBL, inquiry, and nature of science into their classroom instruction. Finally, most participants expressed high levels of satisfaction with the main components of the ESI professional development.

Understandings of PBL, Inquiry, and Nature of Science

The extent to which VISTA participants' pre- and post-ESI definitions of and descriptions of classroom implementation of PBL, nature of science, and inquiry instruction were aligned with VISTA constructs was assessed through participants' open-ended Perceptions Survey responses (Tables 4 and 5). Results of this analysis indicate treatment participants' knowledge of problem-based learning improved substantially, from 0.5% fully aligned pre-instruction to 34.2% fully aligned post-instruction. Participants' understandings of inquiry and nature of science improved less, from 4.0% to 24.0% fully aligned for inquiry and from 0% to 19.9% fully aligned for nature of science prior to and following the VISTA ESI. However, these results also indicate participants' made substantial shifts from not aligned to partially aligned in their understandings of inquiry and nature of science.

Table 4

Treatment Participants' Understandings of Problem-Based Learning, Inquiry, and Nature of Science (NOS) Instruction, Cohorts 1 -3

	Pre-Instruction (n=199, % responding)			Post-Instruction (n = 196, 98.5% responding)		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
PBL	180 (90.5%)	18 (9.0%)	1 (.5%)	82 (41.8%)	47 (24.0%)	67 (34.2%)
Inquiry	122 (61.3%)	69 (34.7%)	8 (4.0%)	65 (33.2%)	84 (42.9%)	47 (24.0%)
NOS understandings	186 (93.5%)	13 (6.5%)	0 (0%)	56 (28.6%)	101 (51.5%)	39 (19.9%)

Pre- to Post-instruction results related to participants' understandings that effective nature of science instruction is explicit were less impressive (Table 5). Prior to instruction all participants held the conception that students would learn about the nature of science through implicit approaches. Following the VISTA elementary science institute 61.7% of participants still expressed this perspective.

Table 5

Treatment Participants' Understanding That Effective NOS Instruction Is Explicit, Cohorts 1-3

	Pre-Instruction (n=199, % responding)		Post-Instruction (n = 196, 98.5% responding)	
	Implicit	Explicit	Implicit	Explicit
NOS instruction	199 (100%)	0 (0 %)	121 (61.7%)	75 (38.3%)

Wilcoxon signed-rank tests indicated that for all indicators, ESI participants exhibited a statistically significant change (all p-values < 0.001) pre- to post-ESI median values (Table 6).

Table 6

Wilcoxon Signed Ranks Test For Pre-/Post-ESI Scores, Cohorts 1-3

	PBL (Post-Pre)	Inquiry (Post-Pre)	NOS Understandings (Post-Pre)	NOS Instruction (Post-Pre)
Z	-9.190[b]	-6.282[b]	-10.390[b]	-8.660[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test b. Based on negative ranks.

For cohorts 1 and 2 of the ESI, participants' year-end understandings of PBL, inquiry, and nature of science were also assessed. Table 7 and 8 indicate the changes in understanding for these participants. Many participants' understandings of PBL and nature of science 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' inquiry understandings. Whereas the percentage of participants at year-end who expressed partially or fully aligned views of PBL was less (16.1% year end vs. 37.4% post-ESI), the percentage of participants with year-end partially or fully aligned conceptions of inquiry and nature of science were approximately equal to post-ESI percentages for those concepts. Additionally, there was virtually no shift in participants' understanding that nature of science instruction should be explicit from the end of the ESI to the end of the year.

Table 7

Treatment Participants' Understandings of PBL, Inquiry, and NOS Instruction, Cohorts 1 and 2

	Pre-Instruction (n=117, 100% responding)			Post-Instruction (n =115, 98.3% responding)			Year End (n =112, 95.7% responding)		
	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned	Not Aligned	Partially Aligned	Fully Aligned
PBL	99 (84.6%)	17 (14.5%)	1 (.9%)	39 (33.9%)	33 (28.7%)	43 (37.4%)	52 (46.4%)	42 (37.5%)	18 (16.1%)
Inquiry	74 (63.2%)	38 (32.5%)	5 (4.3%)	30 (26.1%)	60 (52.2%)	25 (21.7%)	34 (30.4%)	45 (40.2%)	33 (29.5%)
NOS understandings	105 (89.7%)	12 (10.3%)	0 (0%)	32 (27.8%)	63 (54.8%)	20 (17.4%)	48 (42.9%)	47 (42.0%)	17 (15.2%)

Note. n = 49 participants from 2011

Table 8

Treatment Participants' Understanding That Effective NOS Instruction Is Explicit, Cohorts 1 and 2

	Pre-Instruction (n=117, 100% responding)		Post-Instruction (n = 115, 98.3% responding)		Year End (n =112, 95.7% responding)	
	Implicit	Explicit	Implicit	Explicit	Implicit	Explicit
NOS instruction	117 (100%)	0 (0 %)	79 (68.7%)	36 (31.3%)	83 (74.1%)	29 (25.9%)

For cohorts 1 and 2, treatment and control teacher teams' year-end understandings of problem-based learning, inquiry, and nature of science understandings and instruction were compared via univariate analysis of variance (Table 9). Results were statistically significant for all indicators (p-values less than 0.012) favoring the treatment group outcomes. Both cohort 1 and 2 treatment group means approached the middle of the scale (partially aligned) for each construct. The greatest differences were treatment and control groups' understandings of nature of science.

Table 9
Knowledge of Key Constructs, Adjusted Elementary Team Values, Cohorts 1 and 2

	Group Means		
	Treatment	Control	Sign.
PBL	1.69	1.05	<.001
Inquiry	2.06	1.5	<.001
NOS Understandings	1.76	1.16	<.001
NOS Instruction	1.29	1.02	<.001

Note. Adjusted = Year end (delayed post) means adjusted for baseline pre- measure, % Ell, % school-level science pass rate, average team teacher years' experience, for PBL, inquiry, and NOS understandings, scale ranges from 1 = not aligned to 3 = fully aligned. For NOS instruction, scale is dichotomous: 1 =implicit, 2 = explicit

Confidence in Teaching PBL, Inquiry, and NOS

Perceptions Survey responses indicated changes in participants' confidence following the summer portion of the ESI and at the end of the academic year. Across the three cohorts, the ESI program participants' confidence levels in incorporating problem-based learning activities, inquiry-based activities, and explicit nature of science instruction improved prior to and following the ESI (Table 10).

Table 10
Participant Confidence in Incorporating Key VISTA Constructs, Cohorts 1-3 (Mean, (SD))

	Treatment			Control	
Construct	Pre (n=199)	Post (n=197)	[1]Year End (n=113)	Pre (n=120)	[1]Year End (n=77)
Problem-based learning activities	2.29 (1.0)	3.60 (.89)	3.56 (.97)	2.65 (1.1)	2.40 (1.2)
Inquiry-based activities	2.51 (1.0)	3.83 (.92)	3.87 (.82)	2.94 (1.2)	2.60 (1.2)
Explicit nature of science instruction	2.04 (1.1)	3.85 (.91)	3.65 (.98)	2.48 (1.1)	2.2 (1.1)

Note. [1]Year End includes Cohort 1 and 2 responses only. Likert scale ranges from 1 = not confident to 5 = very confident

Following the ESI, participants in the treatment group reported significantly greater confidence than their peers in the control group for all constructs; when year-end outcome group means were adjusted for pre-measure scores, all p-values were <.001 except for nature of science confidence, which was p=.001.

The non-parametric Wilcoxon signed ranks test was conducted for each indicator to evaluate whether the difference in treatment participants' pre- and post-ESI scores was statistically significant. This test is appropriate for a repeated-measures design with an intervention when the data cannot be assumed to have a normal distribution (Green & Salkind, 2008). Wilcoxon signed-rank tests indicated that for all assessed indicators, ESI participants exhibited a statistically significant change (all p values < 0.001) pre- to post-ESI median values (Table 11).

Table 11
Wilcoxon Signed Ranks Test For Treatment Participants' Pre-/Post-ESI Scores, Cohorts 1-3

	Confidence PBL (Post-Pre)	Confidence Inquiry (Post-Pre)	Confidence Explicit NOS (Post-Pre)
Z	-10.334[b]	-10.297[b]	-10.877[b]
Asymp. Sig. (2-tailed)	.000	.000	.000

During the ESI, facilitators provided teachers definitions of PBL, inquiry-based instruction, and nature of science and explicitly taught these concepts. A subset of participants was interviewed regarding whether they perceived they had a good understanding of the concepts as a result of attending the ESI. Most participants perceived that they had a good understanding of the concepts. One participant described the process through which the facilitators introduced the concepts:

> We were given a set of definitions. …They first had us write down what we thought they were and then we compared and contrasted with what [the facilitators] say they are, talked about them. We actually had hands-on activities when we referred back to the definitions, we had an inquiry-based activity and then referred back to the definition. We practiced a problem-based learning scenario and of course we set one up for the students, and we practiced all of that and then the same for the nature of science… we were actually practicing it ourself…. I definitely have a better understanding now… I would say when we had to come up with our own definitions, I was clueless. … I've always kind of put inquiry and hands-on as being synonyms. And now I can see that the inquiry is where the students are actually asking the questions themselves and using evidence, rather than the teacher just generating everything. (E3-T310, U1, Interview)

This participant clearly perceived value in the structure of how the concepts were introduced during the ESI and indicated that following the ESI she had a better understanding of the constructs. Another participant described how participating in VISTA changed her perspective of how to teach science and how this relates to her confidence in implementing the key constructs she learned in VISTA:

> [After participating in VISTA] I now see science instruction as an active practice that doesn't involve a warehouse of facts and knowledge. [VISTA] has driven me to be more invested in the act of exploration, and I hope my students adopt that mindset in the coming school years. I am glad I have knowledge of problem-based learning and inquiry to take with me. I now know how to develop a problem-based exploratory unit and take the steps necessary to plan it. (E3-T334, U2, Survey)

Classroom Instruction

Analysis of data associated with classroom instruction was completed for ESI Cohorts 1 and 2. Across sites and cohorts, participants indicated they intended to implement the knowledge and skills they learned during the ESI. According to the post-ESI Perceptions Survey, participants said they were very likely to implement the material learned from the course (M = 4.9 on 5 point Likert scale, SD = .36). One participant noted,

> In just the units we have developed so far, we will be doing twice as many hands-on activities than we did in all of last year. With the strategies we have learned in this experience, I can see my whole outlook in how I teach science changing. I need to become a much less "sage on the stage." (E3-T384, U5, Survey)

Similarly, another described her plan for implementing the key ideas she learned during the summer ESI,

> I will be starting off my year with a lot of hands-on, inquiry-based activities to get my students to start thinking like a scientist, as well as to help develop a strong classroom community. I am very excited about implementing my PBL, and am happy that I will get to teach it 3 times to 3 different groups of kids. I think this will allow me to tweak anything that may not be working, as well as to add on to it if possible. (E3-T343, U2, Survey)

Not only did this participant indicate an intention to implement PBL into instruction following the summer component of the ESI, but she also reflected that she would have opportunities to extend and modify the PBL unit after teaching it.

Analysis of classroom observations with the modified CETP-COP instrument and PCK survey responses provided evidence of the extent to which ESI participants' actually incorporated PBL, inquiry, and nature of science into instruction. Analysis of classroom observations specified the percentage of participants who incorporated PBL, inquiry, and nature of science into their instruction (Table 12). These data suggest the vast majority who incorporated PBL did so during the fall semester. Similarly, nature of science instruction was more prevalent during the first fall observation window. Incorporation of inquiry was more prevalent in the fall and winter observations than in the spring observation.

Table 12
Inclusion of PBL, NOS, and Inquiry (from observations), Cohorts 1 and 2

	PBL			NOS			Inquiry		
	T (n=116)	C (n=93)	p-value	T (n=116)	C (n=93)	p-value	T (n=116)	C (n=93)	p-value
Obs 1	54 (46.6%)	4 (4.3%)	**<.001**	37 (31.9%)	2 (2.2%)	**<.001**	67 (57.8%)	36 (38.7%)	**.008**
Obs 2	44 (37.9%)	8 (8.6%)	**<.001**	23 (19.8%)	5 (5.4%)	**.006**	64 (55.2%)	35 (37.6%)	.067
Obs 3	22 (19.0%)	0 (0%)	**<.001**	25 (21.6%)	0 (0%)	**<.001**	57 (49.1%)	32 (34.4%)	.140
Obs 4	20 (17.2%)	2 (2.1%)	**.001**	20 (17.2%)	0 (0%)	**<.001**	40 (34.5%)	12 (12.9%)	**.005**

Note: T= treatment, C = control

In addition, when comparing treatment teachers' outcomes to control teachers' outcomes, more treatment teachers incorporated PBL, inquiry, and nature of science than control teachers across all observation windows (Table 12). Results of chi-square analysis indicated a statistically significant relationship existed between condition (treatment or control) and construct incorporation at each time point for PBL and nature of science (all p<.01). For condition and inquiry, a statistically significant relationship existed for observations 1 and 4.

Participants' PCK Survey responses were analyzed for evidence that participants incorporated PBL, explicit NOS instruction, and inquiry into their science instruction (Table 13). Consistent with observational data, more treatment participants described lessons that incorporated PBL in the fall. This result suggested that participants may have been motivated to try to include these features in instruction following participation in the ESI. Descriptions of explicit nature of science instruction and inquiry instruction were approximately the same across the year for participants in the treatment group.

Similar to the trend for observational data, when treatment participants' self-described instruction was compared to that of control participants, more participants from the treatment group incorporated PBL, inquiry, and nature of science than the control group across all time points (Table 13). Chi-square analysis indicated whether a statistically significant relationship existed between condition and construct incorporation at each time point. Statistically significant relationships existed between condition (treatment or control) and construct for fall and spring PBL and nature of science (p<.01) incorporation. For condition and inquiry, a statistically significant relationship existed for the spring and year-end survey responses.

Table 13
Analysis of Participants' Described Lessons for Key Constructs (from PCK surveys), Cohorts 1 and 2

	PBL			NOS			Inquiry		
	T (n=115)	C (n=81)	p-value	T (n=104)	C (n=80)	p-value	T (n=104)	C (n=79)	P-value
Pre	2 (1.7%)	0 (0%)	.233	0 (0%)	0 (0%)	-	38 (36.5%)	27 (34.2%)	.966
Fall	30 (26.1%)	0 (0%)	**<.001**	12 (11.5%)	2 (2.5%)	**.002**	44 (42.3%)	21 (26.6%)	.047
Spring	9 (7.8%)	0 (0%)	**.007**	10 (9.6%)	0 (0%)	**.005**	35 (33.7%)	13 (16.5%)	**.007**
Year End	6 (5.2%)	0 (0%)	.070	8 (7.7%)	1 (1.2%)	.031	42 (40.4%)	12 (15.2%)	**<.001**

Note. T= treatment, C = control

Perceptions of the Professional Development

Perceptions survey responses indicated the degree to which participants perceived the professional development to be effective. Across cohorts, participants in the treatment group indicated high levels of satisfaction with the various aspects of the ESI (Table 14). All means were greater than 4.00.

Table 14
Treatment Group Post-ESI Professional Development Outcomes, Cohorts 1-3, (Means (SD))

Item	Overall (n= 197)
Opportunities to develop problem-based instructional materials.	4.49 (.63)
Opportunities to practice problem-based instruction	4.50 (.72)
Opportunities to develop inquiry-based activities	4.36 (.71)
Opportunities to practice inquiry-based activities	4.35 (.82)
Opportunities to develop explicit nature of science lessons	4.32 (.75)
Opportunities to practice explicit nature of science lessons	4.30 (.84)
Opportunities to integrate educational technologies into science instruction	4.29 (.82)
Opportunities to integrate computer simulations to support inquiry instruction	4.09 (.95)
Perception of feeling part of professional learning community	4.20 (.90)

Note. Likert scale ranges from 1 = low satisfaction to 5 = highly satisfied

Consistent with the quantitative results, participants stated they felt they had adequate opportunities to practice PBL, nature of science and inquiry-based instruction at the ESI. One participant noted, "They definitely did a good job introducing them and then there were a lot of follow-up activities and different way we can reflect on what they were" (E3-T370, U5, Interview).

Further, most participants commented they were satisfied with the final week of the ESI in which they planned their PBL units with their colleagues. For example, one participant noted, "Well, it was easy to learn [PBLs] because I was doing them. I think if they just taught us what it was, it wouldn't have been as concrete as participating in it and planning it for campers." (E3-T370, U5, Interview). This participant continued,

> … we were given an opportunity to learn the series of it first, and then we were given an opportunity to actually apply what we've learned through a trial and error type thing. And then, even further, we were given an opportunity to assess others who were going through the teaching opportunity, so we got to see it from three different aspects, which really helped give more dimension to the learning process rather than just being in kind of like a direct instruction type role. (E3-T370, U5, Interview).

In addition, participants perceived the VISTA ESI to be more comprehensive and in-depth, with more opportunities for application and hands-on experience when compared with other professional development experiences. One participant described this on his survey:

> VISTA Professional Development has been more effective than many of the other professional development opportunities that I have experienced. Many of the concepts and strategies have been explicitly introduced, modeled, and practiced. I would rate this experience high compared to others. (E3-T387, U3, Survey)

Another participant was similarly positive:

> I find this professional development to be an amazing opportunity for ANY educator at ANY level. I went from being a teacher who did not want to teach science and dreaded it, to a teacher who is excited about teaching science in a way I never thought of before. (E3-T335, U2, Survey)

One participant commented on the transferability of what she learned in VISTA to other elementary content she taught. She noted:

> I have participated in some other science professional development but it was not nearly as in depth and immediately applicable to my classroom. I can see how what I learned will impact my teaching of not just science, but all subjects. (E3-T318, U1, Survey)

Participants reported the greatest positive difference between VISTA and other professional development opportunities they engaged in was the situated nature of VISTA. For example, participants noted the opportunity to develop their own PBL and inquiry activities with peers and then get immediate feedback by teaching real students in the camp was effective. Rather than just providing information, participants stated that VISTA provided "how to" pedagogical knowledge. One participant described the effectiveness of this format:

> Overall, the format for VISTA is easy to participate in and seems functional. I like the way we were learners first, then planned and implemented a PBL to practice, and then had time to work on beginning our own. (E3-T310, U1, Survey)

Similarly, another noted:

> VISTA professional development gave me the opportunity to practice what I'd learned on students immediately. I had to produce something that would be used right away which gave me motivation to make sure I knew how to incorporate all the aspects of VISTA. For example, we had one session on inquiry and then were expected to incorporate it in our camp PBL. I would have liked more examples/modeling done in that area. (E3-T320, U1, Survey)

The participants commented that they developed practical knowledge from VISTA that could be translated into classroom practice. They were able to learn about, plan with peers, and practice, problem-based learning and real world, inquiry-based instruction with real students in the ESI. The immediate feedback from peers, coaches, previous participants, scientists, and instructors was invaluable.

Suggestions for Improvement of the ESI. While participants' response to participating in the VISTA ESI was overwhelmingly positive, they did share some suggestions for future modification. Common themes suggested by the participants included improved communication, limiting teacher group sizes, providing more time for planning Camp and the PBL unit, having teachers work within their school teams for the entirety of the ESI, smaller groups of students during camp, completing all modules prior to camp, and encouraging the scientists to present content in a way that is more directly applicable to elementary teachers. The need for better communication and organization was a particularly common theme. Participants would have liked more detailed and explicit information about ESI components provided prior to signing up, a clearer outline of day by day activities the first week, and better communication between teachers and facilitators.

In addition, some participants perceived a discrepancy between the two camp weeks. The participants who taught in Camp A expressed that they did not get exposure to as much information on PBL, nature of science, and inquiry-based instruction conveyed during the modules that they could have incorporated into their instruction. For example, some participants were exposed to key modules before teaching Camp and others were not. Many participants recommended that all teachers engage in the discourse & technology modules before teaching in the Camp. Additionally, some suggested that participants from both Camps should have been able to see what the other was doing and view students at work. Others recommended all participants be included in daily camp debriefings. For instance, one participant made the following suggestion about the Camp component:

> I would suggest that teachers are given all the resources they may use before the camp starts. While some teachers were teaching camp, others were in the modules which gave wonderful strategies for teaching the students about energy. Those "module teachers," then had the opportunity to use what was learned in the modules to teach camp. The camp teachers did not get the opportunity to participate in the modules until their camp teaching time was over. (E3-T359, U3, Survey)

Participants also perceived that including all participants in daily debriefs would help them feel as though they are having a common experience, receiving the same information, and contributing to a single camp experience.

Another important emphasis in recommendations for improvement concerned the desire for more time to plan the PBL unit that teachers would bring back to their classrooms. One goal of the ESI was for participants to have a planned PBL unit present this on the last day. Many participants suggested revisions to the ESI schedule in order to provide more time for PBL school lesson planning.

> …I also think in order for teachers to make maximum use of this new found way of planning and teaching, we need more time to plan our own PBL for our school. I think during the modules, the ELL and SPED teachers should definitely come and show how to modify instruction for those students. I also think the scientists are an integral part as they can provide helpful experiments to incorporate into the teacher developed plans. However, I think we need more time to plan units so we can plan more than one, or have time to tweak other plans made by different teachers, to fit our classroom. (E3-T335, U2, Survey)

In sum, evidence from observations, surveys, and interviews indicated participants perceived attending the ESI was a valuable, effective professional development experience that helped improve their knowledge of and confidence in teaching problem-based learning, inquiry, and nature of science.

Discussion

The purpose of this study was to explore the effectiveness of the VISTA ESI in improving elementary science teachers' knowledge of and confidence and proficiency in implementing PBL, inquiry, and nature of science into their classroom instruction. Participation in the ESI facilitated treatment participants' knowledge of and confidence in implementing reforms-based science instruction in their classroom instruction. Statistically significant differences favoring the treatment group were noted for participants' knowledge of and confidence in teaching PBL, inquiry, and nature of science instruction. The ESI also appeared moderately effective in facilitating participants' classroom implementation of PBL, nature of science, and inquiry instruction. Statistically significant differences favoring the treatment group were present for PBL and nature of science across all time points and for inquiry at the beginning and end of the academic year. Participants noted key features of the professional development that facilitated knowledge development, confidence, and classroom implementation of PBL, nature of science, and inquiry instruction. Many of these features, including opportunities for practice in an authentic context, coaching, the sustained nature of the professional development. The results of this investigation suggest that professional development experiences that incorporate key features of situated learning theory may be effective in transferring teachers' knowledge into their instructional practices.

Knowledge, Confidence, and Instructional Practice

ESI participants made gains in their understanding of pedagogical approaches that support reforms-based science instruction; however, immediately after the ESI, fewer participants' expressed fully aligned understandings of inquiry and nature of science than those who expressed fully aligned understandings of PBL. Classroom observations indicated that participants integrated explicit nature of science instruction less than inquiry or PBL instruction. 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. Inquiry requires less time to implement than PBL, which may be another reason these instructional practices showed up more consistently in participants' lessons throughout the year. Nature of science instruction was not emphasized as much as PBL during week 4 of the professional development, which may be one reason why it was not as well-integrated or why participants' nature of science instruction tended to be more implicit. Similar professional development experiences employing PBL 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).

ESI participants expressed moderate knowledge of and confidence in effectively teaching nature of science to students after professional development; however, they retained their conception that students would learn about the nature of science through implicit approaches. This finding is consistent with a large body of literature that teachers do not incorporate explicit nature of science instruction (e.g. Bell, Abd-El-Khalick, & Lederman, 1998; Bell, Blair, Crawford, & Lederman, 2003; Lederman Lederman, Kim & Ko, 2012). Participants in the present study learned about nature of science instruction through a number of contextualized and decontextualized activities such as a card sort of nature of science ideas and an investigation in which teachers made observations and inferences about a rock then gathered more evidence and discussed the nature of science ideas (creativity, empirical evidence, tentative) that they used during the investigation. Thus, the findings of the present study contribute to the ongoing debate over the role context plays in nature of science instruction facilitates teachers' capacity to learn and transfer this knowledge to their own classroom instruction (e.g. Bell, Matkins, & Gansneder, 2011; Bell, Mulvey, & Maeng, in review; Herman, Clough, & Olson, 2013).

While the majority of participants reported improvements in their confidence in implementing PBL, a number of teachers reverted to partially aligned views of problem-based learning. Classroom observations revealed teachers incorporated PBL in the fall semester, in closer proximity to when they learned it, but incorporated it less frequently in the spring. 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). It is possible that the support they received during the follow up sessions and coaching was insufficient to support integration of such complex instruction

It is possible participants were more motivated to incorporate PBL, nature of science, and inquiry during the fall due to the focus on these constructs during the ESI. In addition, the final observation window occurred just prior to state-mandated testing, therefore, participants may have been focused on reviewing previously-learned content during that observation window. Spring may be a more difficult time to implement extended PBL units due to the end of school year focus on state testing.

Situated nature of Professional Development

The situated nature and embedded components of effective professional development that characterized the VISTA ESI appeared to contribute to the overall effectiveness of the professional development experience. Many participants cited that modeled lessons incorporating inquiry and nature of science instruction, opportunities to practice PBL, nature of science, and inquiry instruction in the context of camp prior to implementing these constructs in their own classrooms, collaborating with peers when designing instruction, receiving feedback from coaches and instructors, and the classroom coaching they received during the academic year encouraged integration of reforms-based practices into their instruction. These authentic and contextualized supports appeared to promote participants' transfer of what they learned in the ESI into their own reforms-based instruction.

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 participants initially experienced during the summer institute and promote transfer to the classroom environment. These longitudinal and contextualized features of the VISTA ESI are often cited as essential features of effective professional development (e.g. Desimone, 2009; Johnson, Khale, & Fargo, 2007; Supovitz & Turner, 2000). Results indicated the participants' retained their understandings of PBL, inquiry, and nature of science instruction across the year. In addition, participants integrated these constructs relatively consistently across the year, with slightly higher integration in the fall. Therefore, the results of the present study provide further support for the importance of including longitudinal components such as coaching, collaboration, and opportunities for practice, reflection, and feedback into context-specific professional development (Desimone, 2009; Loucks-Horsley et al., 2010).

One might expect higher gains in understanding and implementation of inquiry instruction compared to PBL because it is a simpler construct. Situated learning theory would suggest however that because inquiry was embedded within PBL during the summer institute, teachers had some difficulty teaching inquiry instruction outside of the context in which they had learned it. Also, control teachers implemented inquiry instruction more frequently than PBL and NOS suggesting that teachers were already more familiar with implementing this construct within the context of their classrooms.

Documenting professional development that facilitates teachers' reform-based science instruction at the school level is essential, as well-prepared teachers have the greatest impact on student achievement (Darling-Hammond 2000). 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 science teachers. Future research will explore whether relationships exist between participants' understandings, practice, and student achievement. Research will also explore the extent to which participants' understandings, practices, and students' achievement on state science assessment differed from teachers in the control condition.

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