REFINING INQUIRY-BASED SCIENCE INSTRUCTION THROUGH PROFESSIONAL DEVELOPMENT USING THE VISTA MODEL

Abstract

This study investigated how elementary teachers learned to teach using inquiry-based models. The goal of the Virginia Initiative for Science Teaching and Achievement (VISTA) model is to provide intensive support and effective interventions to help teachers learn science content and develop experience and confidence in teaching inquiry-based science. During year one, 52 participants attended a four-week summer institute offered at three sites. During week one, teachers learned science content and inquiry science based on a scientific theme selected from the lowest-scoring areas of science on standardized state tests. Also, in week one they collaboratively planned a problem-based learning unit (PBL) to use in weeks two and three. During weeks two and three, teachers collaboratively taught inquiry-based science to 60 high-needs students from 11 school districts in a PBL summer camp setting. In week four, teachers reflected on their summer teaching experience and planned a PBL unit to implement in their school using inquiry based science. Teams of university educators, scientists, math specialists ELL, and special education specialists, provided on-going support and training during the institute. Data collection before and after the institute focused on the effectiveness of professional development. Findings from preliminary data, surveys, and feedback indicate that teachers developed deeper understandings of inquiry-based learning. The VISTA model can be used to improve science instruction and provide a framework to teach PBL using inquiry-based science.

Authors
Anne Mannarino (amannarino@wm.edu), The College of William and Mary
Mollianne G. Logerwell (mlogerwe@gmu.edu), George Mason University
Victoria Reid (vbreid@wm.edu), The College of William and Mary
Elizabeth W. Edmondson (ewedmondson@vcu.edu), Virginia Commonwealth University

Introduction

The quality of science teaching at the elementary level can vary nationwide. Elementary teachers generally teach multiple subjects including science. Many have a teaching degree but often lack a solid foundation in the inquiry-based nature of science (Akerson & Abd-El-Khalick, 2003; NRC, 2007; NCMSTTC, 2000). Elementary teachers are often unprepared to teach an inquiry-based approach and lack the skills to teach conceptual understanding of science effectively. Unfortunately, the amount of professional development currently in place to change the teaching practice to improve student achievement is lacking. Professional development programs where teachers model inquiry provide a basis for teachers to continue their experiences with inquiry science in the classroom (McDermott & DeWater, 2000).

One goal of the VISTA model is to provide intensive support and effective interventions to help teachers learn science content and develop confidence through the experience of teaching student- centered inquiry-based science. VISTA is a partnership with 47 Virginia K-12 school districts, six universities, and the Virginia Department of Education to increase student performance through the establishment of an infrastructure to provide sustained, intensive science teacher professional development to increase science achievement. VISTA provides an intensive 4 week long professional development program to upper elementary teachers (grades 4-6) on how to teach science using inquiry-based models and training in problem-based learning (PBL) instruction. Teachers work in teams to design inquiry-based science lessons for students attending a summer science program. This Elementary Science Institute (ESI) also provides teachers with support from teams of university science educators, scientists, and specialists in mathematics, English language learning, and special education to plan and facilitate summer learning experiences. Throughout the summer institute and the academic year, the teachers are provided with a coach to support their learning process and to help them in the classroom. During the academic year, the teachers implement student centered inquiry-based instruction through problem-based learning, attend follow-up workshops, and attend the Virginia Association of Science Teachers (VAST) conference to further expand their understanding of inquiry-based science. This paper reports on the impact of the first ESI on teachers and their perceptions on the implementation of student-centered inquiry-based science using problem-based learning in the classroom.

Research Questions

The following research questions guided the assessment on the impact of the ESI: 1) What are teachers' perceptions of learning how to teach student-centered inquiry-based science using problem-based learning in the classroom? 2) How do teachers perceive the implementation of learning how to teach student-centered inquiry-based science using problem-based learning in their classroom? 3) What are teachers' perceptions of the ESI professional development, training and instructional support in improving their teaching of student-centered inquiry-based science using problem-based learning?

Effective Professional Development

Effective teacher professional development has been a high priority in improving the instruction in schools. Teachers today need an extensive knowledge of their subject matter and the most effective pedagogies for teaching the subject. Effective professional development should lead to teacher learning, subsequent changes in classroom practices, and improved student learning outcomes (Borko, 2004; Fishman, Marx, Best, & Tal, 2003). The research shows that when teachers participate in long-term or sustained problem solving or inquiry-based professional development, they will increase their use of inquiry in science classes (Luft & Pizzini, 1998) Professional development programs should be designed to target teacher beliefs as well as classroom practice. If professional development is done to implement new teaching practices, then factors that influence teacher efficacy must be addressed in the design process (Lakshmanan, Heath, & Elder, 2010).

Inquiry and Instruction

Studies indicate that inquiry based classroom instruction can increase the performance of students when compared to students taught by text-based instruction (Chang & Mao 1999; Johnson & Lawson, 1998; Muscheno & Lawson, 1999). A meta-analysis of 160 studies by Wise and Okey (1983) found that inquiry instruction improved student outcomes, including achievement. Teaching inquiry does not always result in higher achievement. If the inquiry instruction involves no teacher guidance except for the lesson objective, then it can be less effective than teacher-centered instruction (Khlar & Nigam, 2004).

Teachers' Conceptions of Inquiry and Problem-Based Learning

There have been many studies researching the conceptions teachers have on inquiry characteristics and teaching practices. Teachers will develop specific conceptions of inquiry that can influence their science instructional practices (Crawford, 2000; Wallace & Kang, 2004). Teachers are generally motivated and positive to introduce inquiry PBL or project-based learning in their classrooms, which can result in a deeper understanding of science practices and instruction (Rosenfield & Ben-Hur, 2001; Blumfield, 1994). However, not all elementary teachers are prepared to teach inquiry as they have never experienced this type of instruction. It can be a difficult task to prepare teachers with no experience to teach inquiry (Kielborn & Gilmer, 1999). One of the difficulties of preparing teachers to teach inquiry is that teachers have limited views of inquiry. They may refer to inquiry as projects, lab experiments, discovery learning, or activities, showing a lack of understanding (Windschitl, 2004).

Teacher Content Knowledge

Elementary teachers generally teach multiple subjects with inadequate content knowledge and pedagogical background. This practice can lead to severe results when elementary teachers teach science without the content background (Darling-Hammond, 1999; Hartshorne, 2005; NCSESA & NRC, 1996). Swars and Dooley (2010) found that inadequate science content knowledge leads to lowered personal self-efficacy, and suggest the importance of providing professional development with both content and pedagogical components. Other studies support the view that if you can deliver long-term effective professional development then the prior science content knowledge of the teacher is not an issue (Fennema, Carpenter, Franke , Levi, Jacobs, & Empson, 1996; Hiebert, Fennema, Fuson, Human &Murray, 1996; Simon & Schifter,1991; Smith, Desimone & Ueno, 2005).

According to recent research, teachers without degrees in science or science education had similar use rates of hands-on activities in their science classes, if they reported participating in over 35 hours sustained science or science-focused professional development (Smith, Desimone, Zeidner, Dunn, Bhatt & Rumyanteseva, 2007).

Structure of the Elementary Science Institute (ESI)

The ESI consists of a four-week summer institute with additional academic year support for elementary teachers (grades 4-6). The goal of the institute is to facilitate elementary teachers' effective science instruction through professional development. During the institute the teachers are provided with intensive support and effective interventions to learn science content through the experience of scientific, problem-based learning (PBL) and student centered inquiry instruction. The teachers work in teams to conduct inquiry-based science to elementary students. The schedule of the participants and support personnel is depicted in Table 1.

Table 1. *VISTA Elementary Science Institute Participant and Support Schedule*

Elementary Institute	Summer	Academic Year
Grade 4-6 science teachers	4 week institute	3 follow-up sessions VAST conference 3 classroom visits by VISTA coaches
Support Team of Experts	As needed during institute	
Principals	1 day during institute	Newsletters
Science Coordinators	2 days during institute	Attend VSELA conference
Coaches	5 days during institute	2 days coach training
High-needs elementary students	2 week science camp during institute	
Parents of high-needs elementary students	Last day of summer camp	

Each of the three VISTA sites delivered the same instruction to the participants as described in Table 2 (Appendix page 21). During week one teachers learned science content and how to conduct inquiry-based science instruction based on a scientific theme selected from the lowest-scoring areas of science on the state's standardized science assessments. Beginning in the first week VISTA instructors focused on teaching the participants about hands-on science, problem-based learning, nature of science (NOS) instruction, and inquiry instruction. VISTA defined these constructs as:

> Hands-on science: Students purposefully manipulating real science materials when safe and appropriate in a way similar to a scientist.
> 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: Students asking questions, collecting and analyzing data, and using evidence to solve problems.
> Nature of Science: the values and assumptions inherent to the development of scientific knowledge (i.e. the natural world is understandable, science demands evidence, science is a blend of logic and imagination, scientific knowledge is durable, scientific knowledge is subject to change, science is a complex social activity, and science identifies and avoids bias).

During weeks two and three teachers alternated between collaboratively teaching inquiry-based science to students from high-needs schools in a problem-based summer camp and participating in professional development modules for one week each. Week four included time for teachers to reflect on their camp teaching experience and to plan inquiry-based teaching units for the upcoming academic year. Academic and pedagogical support was given to the teachers by teams of university science educators, scientists, engineers, curriculum specialists (math, English language learners and special education) for the duration of the institute. During week four school principals and district level science coordinators were invited to the institute to attend inquiry-based science training and to show support to their elementary teacher participants. During the academic year, the teachers implemented inquiry-based science in their classrooms and collaboratively shared and analyzed student work samples. In-class coaches also provided on-going instructional support to the teachers throughout the academic year. In the fall of the academic year teachers attended the Virginia Association of Science Teachers (VAST) conference to continue their professional development at the state level. VISTA teachers also met as a large group to reflect on their VISTA experience and received additional professional development on hands-on, inquiry-based, PBL instruction that integrated NOS.

Another component of the ESI program included the opportunity for the parents of students with high-needs attending summer camp to learn about college admissions, financial aid, and career planning. On the final day of the summer camp (end of week 3), the parents are invited to learn about these college opportunities and to observe their children present solutions to problem-based issues investigated in camp and to meet the teachers who guided this instruction. A detailed schedule of the ESI is found in the appendix, page 21.

Methods

Participants

Fifty-two elementary teachers attended the 2011 summer institute at three ESI sites: 17 attended Virginia Commonwealth University; 23 attended George Mason University; and 12 attended The College of William and Mary. Participants in the VISTA Elementary Science Institute (ESI) were 9 males and 43 females from 17 different elementary school teams and 11 different districts in Virginia. There were one Asian, one Hispanic, eight African American, and forty-two Caucasian participants. Participants' Virginia licensure and teaching experience are described in Table 3 (Bell, Konold, Maeng & Heinecke, 2011). All demographic data were self-reported.

Table 3. *Licensure and Teaching Experience of the ESI VISTA Participants*
(Bell, Konold, Maeng & Heinecke, 2011)

Total	Virginia Licensure				Teaching Experience				
	Elem.	Elem. Sci.	MS	Sec Sci.	0-1yr	2-3yr	4-6 yr	7-10yr	>10 yr
51	51 (100%)	1 (2.0%)	4 (7.8%)	2 (3.9%)	4 (7.8%)	8 (15.7%)	12 (23.5%)	12 (23.5%)	15 (29.4%)

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

Measures

Data for this paper consisted of participant exit slips, daily ESI debriefs, discussions, and participant reflections collected from the start of summer 2011 ESI through the fall follow-up professional development sessions and included the Virginia Association of Science Teachers Conference. Responses were analyzed to determine the patterns (Patton, 2002) used by the participants to describe their experiences, perceptions on the ESI impact on their science instruction, and their perceptions of implementing student-centered inquiry-based science using problem-based learning in the classroom. Common patterns emerged from the data were identified initially through a reduction technique with methods that identified coded key words and phrases (Miles & Huberman, 1994). The data was reviewed individually by different researchers to finalize the themes and categories for the study.

Results/Findings

This study posed three research questions: 1) What are teachers' perceptions of learning how to teach student-centered inquiry-based science using problem-based learning in the classroom? 2) How do teachers perceive the implementation of learning how to teach student-centered inquiry-based science using problem-based learning in their classroom? 3) What are teachers' perceptions of the ESI professional development, training and instructional support in improving their teaching of student-centered inquiry-based science using problem-based learning? The findings for each research question are presented below:

Teachers' Perceptions of Learning How to Teach Student-Centered Inquiry-Based Science Using Problem-Based Learning in the Classroom

Teachers attended the ESI and experienced the process of developing understanding of teaching student-centered inquiry-based science. They were able to experience how to develop a PBL from direct instruction, teaching modules, modeling strategies, and applying this knowledge directly to students in the summer science camp. From responses from their teaching experiences and training several thematic categories emerged: development of PBL and components, critical thinking and research, real-world experiences and interactions with scientists/experts, planning, and student engagement.

Development of PBL and Components

Teachers in the ESI came to the institute with a variety of background knowledge of how to develop a PBL. Teachers participated in the institute to learn how to teach a PBL and were given the tools, professional development and application to do this. Throughout the institute the teachers reflected on their interpretation of how to teach a PBL. In the beginning of the ESI there was a lack of understanding of how to do this and how to teach it. Teachers noted:

> This is a guess. Proper background knowledge is provided to students. Then students are given an essential question. They are to attempt ways to solve a problem and record the process. In essence follow the Scientific Method using a question, hypothesis, materials, procedure, data collection, presentation, and new hypothesis. (Pre-ESI reflection)
>
> Problem-based learning is working with student using an essential question. Students generate a hypothesis and work in small groups to test their ideas. Usually hands-on

> approach. After the lesson, students can check their hypothesis and see where they were right/wrong. (Pre-ESI reflection)
>
> I would think that the teacher needs to release their "control" and allow students to become independent thinkers. The worse thing that could happen I think is that teachers present problems and solutions without allowing students to think for themselves and therefore, the students don't gain the appreciation of hypothesizing and testing problems/solutions for themselves. (Pre-ESI reflection)
>
> In my opinion, which of course is not necessarily those of the VISTA staff, problem-based learning is starting with a problem and then working backwards or forwards to solve that particular problem. And as more problems arise then the students find out what learning they need to have to solve the problems. (Pre-ESI reflection)

Each teacher was involved in planning and teaching the camp PBL. When the teachers finished teaching the summer camp for students they expressed they had a better understanding of how to teach a PBL. Teachers noted:

> Problem-based learning begins with stated problem or question. The teacher creates a believable scenario for the students to buy into and work under. The premise of the scenario is maintained throughout the investigation, by official message, phone calls, texts, Skype etc... Students work as scientists to solve a problem or answer a question, understanding that they are capable of solving the problem. (Post ESI reflection)
>
> The most important ideas for a teacher to learn in order to practice PBL in the classroom is what PBL is and the components. It's very important to develop the question map first so that you can plan out how the unit will go and make sure that everything is connected. You also need to make sure that everything relates back to the story/problem/scenario and that you always are thinking "Why am I including this?" and "What's the purpose of having this activity or experiment in my lesson?" It's also important to make sure that there are multiple solutions to the problem so that students really feel that there is ownership over their learning. If the solution is a definite answer, they might not fully buy into the story/problem. The students need to feel that they truly helped solve the problem. It's also very important to use hands-on and inquiry in the lessons. Hands-on is much more exciting to the students and then they can truly be like scientists. The inquiry part is important to make students be thinkers instead of being conditioned to recall information. There are many important ideas for teachers to know in order to use PBL effectively in a classroom. (Post ESI reflection)

Critical Thinking and Research

Teachers discussed the importance of learning how to teach students to think critically and to do research.

> After teaching the PBL in camp, I realize that I need help in getting the students to think at higher levels. We tend to teach content as opposed to thinking and understanding. I

> need help in this. Students used the computers to gain knowledge but did they understand? (Week 3 Camp debrief).
>
> PBL needs to involve solid research on behalf of the teacher and student. One group of teachers (teaching the camp) just struggled through the experiment and entire research gathering exercise. They needed to regroup. (Week 3 Camp debrief)
>
> I saw a major difference in my camp students in the beginning of the camp as opposed to the end. The students had developed better skills at supporting their scientific hypotheses and were able to challenge other students with scientific evidence. I believe they were beginning to think critically. Even the teachers, including myself, felt more confident in pushing the students into areas where they did not know all the answers but had to think about where they were heading. What a shift in thinking. (Post-ESI reflection)

Real-World Experiences and Interactions with Scientists/Experts

Part of an authentic PBL is the creation of a realistic problem for students to solve. Teachers created a problem scenario for the summer camp with the help of scientists, specialists, and other experts. Teachers also spent time with the scientists learning about their work. Teachers noted:

> Our school's unit involves a scenario describing devastation due to a forest fire. Parents actually called the school to find out where and when the fire occurred. (VAST PBL sharing session reflection)
>
> The students were engaged and looked forward to science. The PBL scenario was to take the school garden and turn it into a parking lot Students were invested and driven to save our school's garden. (VAST PBL sharing session reflection)
>
> I would like more time planning with experts and VISTA staff. Loved the whole experience/time with scientists. (Exit ticket fall follow-up session)
>
> Scientists were helpful. You could ask any questions and they would answer any questions. (Parent day-debrief)
>
> The scientists were more than a resource. They also learned from us (teachers). We taught the scientists about teaching. They were more than a resource. (Parent day-debrief)

Planning

Teachers in the ESI planned the camp PBL unit during the first week of the ESI. As they developed their camp PBL unit they identified areas that were important in the planning process.

> I really like the potential for PBL. The hardest part is trying to link plans to other days without talking constantly to other groups. There are so many different ideas and people – so trying to analyze plans can be difficult. I know it will eventually come together though. I also think there is <u>a lot</u> of graphing so far and I hope that aspect isn't boring to students. (Day 3 exit ticket)
>
> Get used to the kids doing MOST of the work. They can do anything and work hard to accomplish it! Keep the Nature of Science in mind. Classroom discourse-have students

> collaborating in teams and actually learning to talk to each other to share ideas and to actually learn to work in a team successfully. You need to learn not to be the "sage on the stage" and just let the kids talk! Your job is to just lead them in the right direction. (Post ESI reflection)
>
> In the classroom, the teacher needs to be very planned out so that objectives are met. (Post-ESI reflection)
>
> Create a question map with leveled questions. How to allow the students the opportunity to guide the inquiry and create their own experiments. How to integrate the subjects into one large unit that all relates to your scenario and problem. (Post -ESI reflection)
>
> Misconceptions that their students may have, how to use inquiry during lessons, how to provide real science materials and facilitate their use, how to address safety concerns, and how to integrate the theme and scenario into all aspects of the unit. (Post -ESI reflection)
>
> The most important idea for a teacher to learn in order to practice PBL in her/his classroom is to let the students drive to the solution of the problem. Let the students be driven by the level questions and let them come up with the solution. The teacher should not be afraid to let the students inquire and use their imagination to solve a problem. The teacher should also be aware of any misconceptions and be there to dispel any thoughts that might not be true. We want students to come away with what is real and true. (Post-ESI reflection)

Student Engagement

Teachers in the ESI were able to teach a PBL unit to camp students before they returned to their schools to start their own implementation of a PBL unit. Teachers also observed the student campers for student engagement. Teachers commented:

> PBL gave students a reason to learn. In fact many of the students probably didn't think of the last 2 weeks as learning but instead thought of it "as figuring out!" The students had a purpose and connection to the problem. They wanted to figure out what was going on and how they could fix it. (Week 3 Camp debrief)
>
> Engagement- the "story" worked very well. The campers felt they were truly investigating as a scientist would for a valid reason. The PBL totally engaged all the students giving them ownership of their learning and purpose (Week 3 Camp debrief)
>
> That students need to be able to learn for themselves and that they need to experience it learning, not just you showing them. The teacher needs to guide and facilitate the learning and not just give it to them. The students also need to be exposed to methods and tools that regular scientists would use. This will prepare them for the future and help them become better able to think through problems on their own. (Post ESI Reflection).

> Student engagement and enthusiasm has increased. My challenge students were actively participating and overall classroom climate was good. (VAST PBL sharing session reflection).

> Students are actively engaged and a part of the teaching and learning because they have a personal connection to the problem scenario. (VAST PBL sharing session reflection)

Teachers' Perceptions of Implementation of Learning How to Teach Student-Centered Inquiry- Based Science Using Problem-Based Learning in Their Classroom

After the summer institute the teachers were invited to attend the Virginia Association of Science Teachers Conference. At the conference they also attended additional VISTA follow-up professional development sessions and were asked about the status of their PBL unit. (Table 4)
Table 4. *Implementation Status of the PBL (as of November 2011)*

	Implementation Status of PBL			
Teachers Attending VISTA SITE	PBL Not Started	PBL in Progress	PBL Finished	Number of Responses (n=44)
George Mason University	5	11	3	19
Virginia Commonwealth University	4	5	5	14
The College of William & Mary	3	7	1	11
Total	12 (27.3%)	23 (52.2%)	9 (20.5%)	44 (100%)*

*Note: *44 of the 52 ESI teachers responded to this implementation query.*

Forty-four teachers responded to the status of their PBL unit, 72.7% have started and/or completed their PBL unit. 20.5% teachers had completed the PBL unit and 27.3% indicated that they had not started.

Teachers were expected to implement a PBL unit in their school after attending the ESI and their responses on the implementation process fell into the following thematic categories: time management and constraints, teaching resources, administration support and school concerns, assessment and SOL correlations and linking PBL to curricula in schools.

Time management and constraints

The implementation and development of a PBL unit was experienced by all teachers in the institute. The teachers expressed concerns as how much time this process takes. Teachers noted:

> There seems to be a lot of planning time involved. Realistically this can't really occur where I work. I love the idea of PBL and will possibly use it in a smaller scale due to time pacing, and lack of plan time. (VAST PBL sharing session reflection)

> Time-so much of our teaching time is pulled away for assemblies, guidance, school programs etc. (and I know they are important too). We lose valuable teaching time. (VAST PBL sharing session reflection)
>
> It takes time, and my concerns are we do not have enough planning time during the day to plan in this manner. But, I like how it makes the students think. It holds them accountable for their learning. (Week 1 Exit ticket)

Teaching Resources

As the units are developed the teachers used a wide variety of resources and supplies. Each VISTA site provided the science materials for the implementation of the camp. School teams were also provided with resources to use to implement their PBL unit at their school site. Teachers commented:

> I love having more time to plan and having so many resources available. I wish I could utilize the math specialists more. (Day 3 exit ticket)
>
> I have resources now- however in future years, it would be expensive to buy materials, when VISTA isn't buying. (Day 3 exit ticket)
>
> Now that I have experienced PBL, I would dig deeper into the topic and not be afraid to use more resources. (Week 3 Camp debrief)

Team Planning

Teachers came to the ESI as teacher teams of 2 or more with the intention that when they returned to their school they would implement the PBL as a team. Some VISTA sites split up the teams to teach the camp. All teachers were then reunited to plan for their school PBL unit during the planning sessions.

> I loved working with other teachers to see what other ideas are out there and get great ideas Co-planning is encouraged at my school, but, realistically, not happening. (Day 3 exit ticket)
>
> I know that we need to experience different teams/ideas/experiences, <u>BUT</u> I would have left the school teams intact to teach and share lesson plans during camp to build a stronger team to take back to our schools and implement a PBL. I would have liked to have been more integrated into the 1st week of camp to know more about their lessons and about the students. (Week 3 Camp debrief)
>
> A challenge is convincing the rest of my team at school to participate in the PBL. (Week 3 Camp debrief)

Administration Support and School Concerns

Fifty-two teachers from 17 different elementary school teams and 11 different districts in Virginia participated in the ESI. Each site invited the principals and science coordinators to the

ESI to learn more about inquired-based instruction and to support their school teams. One science coordinators and principal commented:

> This program has potential to help my teachers become better teachers. I have many questions about the program. We have many set times to teach curricula and benchmark our instruction. Will this interfere with our school instruction? I like the idea that inquiry-based learning is emphasized. My teachers seem to be excited about teaching this PBL. Keep me informed about your program. (Week 4 Science coordinator/principal discussion)

> As a principal instruction is my priority. If this (VISTA) can help my teachers and students improve instruction then I can support this. How much extra time is this going to take to do in my school? Teachers teach other subjects-not just science. We need to focus on all subjects and pass the SOLs. (Week 4 Science coordinator/principal discussion)

As teachers prepared the implementation of their PBL unit at their schools they shared some of the concerns they have:

> My school may have signed on to the VISTA project but I really don't think they (administrators) know what it is. I hope that they can see that I can do this and teach our content in a PBL. I hope they will support me and my team. (Week 4 discussion)

> How am I going to do this? My school dictates what is taught every day. It's going to be an uphill battle. I teach 4th grade so the emphasis is not on science so much, Math and reading are more important to our principal. (Week 4 discussion)

> I talked to our science coordinator today and I'm confident that she will help me and support teaching a PBL. She seems on board. Now all I have to do is get the principal to buy in to this. My principal did not show up today. I wish she did come so she would have seen how the VISTA program works. I can't see why anyone wouldn't support teaching this way. SOLs can be included. I'm just worried about the time factor, not the PBL. Come back and ask me at the end of the school year if it worked. I know it will. (Week 4 discussion)

Assessment and SOL Correlations

Teachers in the ESI institute incorporated the Virginia Standards of Learning (SOL) in their PBL unit as they were planning. Assessment of the science content within the PBL format was a difficult concept for teachers to grasp.

> I am concerned that there are holes in the SOL concepts with the PBL unit. Can we just go ahead and teach the remaining SOLs? (VAST PBL sharing session reflection)

> I was challenged to go back to the overall question. I found myself worrying more with my content and what my kids had to know for the SOLs. (VAST PBL sharing session reflection)

> Aligning the specific questioning students face on standardized tests with the nature of science was challenging. (VAST PBL sharing session reflection)

> I love the process and I do feel this is "best teaching practices", however with SOL objectives to cover, I think the guiding process we would need to do in order to cover all SOL objectives would take away from the problem-based learning process. I would be fearful that we would miss some important (minor) concepts which would be tested. (Day 3 exit ticket)

Linking PBL to curricula in schools

The majority of teachers in the ESI regularly teach science and other subjects in their school. They have set curricula and instructional timelines to follow and must adhere to instructional guidelines set by their school and district.

> I need to work on connections. The kids need to figure out connections. I must do this in my own classroom. Units must be connected to everything in our school curriculum – math, reading, writing, science and social studies. (Week 3 camp debrief)

> I planned a number of activities and only got through a select few. I have a curriculum to follow and it's hard to do it all. (VAST PBL sharing session reflection)

Teachers' perceptions of the ESI professional development, training and instructional support in improving their teaching of student-centered inquiry-based science using problem-based learning

Several themes emerged from the teacher responses on their perceptions of the ESI professional development: understanding inquiry based science (PBL, NOS, hands-on science and inquiry), incorporating inquiry in instruction, importance of questioning and discourse, technology and using computer science programs and professional growth.

Understanding inquiry based science (PBL, NOS, hands-on science and inquiry)

The ESI focused on preparing the teachers how to teach inquiry- based science and to implement a PBL unit. Table 5 shows the number of teachers that perceive that the ESI improved their preparation to teach science using student-centered inquiry-based science using PBL is 97.7 %. The data indicate that the teachers felt the ESI was useful to help them prepare to teach inquiry-based science.

Table 5: *Teacher perception of the ESI professional development in improving their teaching of student-centered inquiry-based science using PBL*

	Teacher Perception of the ESI Professional Development in Improving their teaching of student-centered inquiry-based science using PBL					
VISTA Outcome after Attending ESI	Strongly Agree	Disagree	Neither	Agree	Strongly Agree	Number of Responses (n=44)
Better prepared to	0 (0%)	0 (0%)	1(2.3%)	21(47.7%)	22(50%)	44(100%)

teach science						
Changed how I plan and teach science	0(0%)	0(0%)	1(2.3%)	19 (43.2%)	24(54.5%)	44(100%)

Note. Of the 52 participants 11 participants did not respond, thus, these data are reported for n=44 participants.

Teachers noted that the institute helped their understanding of inquiry-based science:

> I really had a great experience through the institute and want to incorporate more problem-based inquiry units. I did "oil spill", a smaller PBL (kind of practice) for another Science/US unit I taught in September. (Fall follow-up exit ticket)

> Actually DOING a PBL and working with other teachers to get a better understanding. I'm a visual person and learn better doing something rather than sitting down and hearing about it. (Fall follow-up exit ticket)

> I really appreciated understanding how we can change a cookbook lab into inquiry. I also appreciated in depth of NOS. (Fall follow-up exit ticket)

Incorporating Inquiry in Instruction

After attending the ESI, Table 6 shows that 34 of the 44 teachers who responded to the query felt comfortable with incorporating inquiry in their PBL. Three felt they were not comfortable and seven were neutral on the implementation issue.

Table 6. *Teacher Perception of Feeling Comfortable Planning and Implementing VISTA Constructs in their PBL*

	Teacher Perception of Feeling Comfortable Planning and Implementing VISTA Constructs in their PBL					
VISTA Construct	Strongly Agree	Disagree	Neither	Agree	Strongly Agree	Number of Responses (n=44)
Hands-on science	0 (0%)	0 (0%)	2 (4.5%)	29 (65.9%)	13 (29.6)	44 (100%)
Inquiry	0 (0%)	3 (6.8%)	6 (13.6)	22 (50%)	13 (39.6)	44 (100%)
PBL	0 (0%)	3 (6.8%)	7 (15.9)	25 (56.8%)	9 (20.5)	44 (100%)
NOS	0 (0%)	5 (11.4%)	11 (25%)	21 (47.7%)	5 (11.4)	44 (100%)

Teachers noted:

> At our school, we are always doing inquiry-based learning. It is similar. I'm not 100% comfortable with it yet. I like how it makes the students think higher level, but it is also time consuming. I feel I'm always behind now. It will take practice. (Day 3 exit ticket)

> It's also very important to use hands-on and inquiry in the lessons. Hands-on is much more exciting to the students and then they can truly be like scientists. The inquiry part is important to make students be thinkers instead of being conditioned to recall information. (Post -ESI reflection)

> It is important to keep the inquiry at the forefront and to not have students engage in activities that do not promote forward movement of learning. (Week 3 Camp debrief)

Importance of questioning and discourse

Teachers received professional development during the ESI on discourse and questioning. In addition, as they were developing a PBL unit for the camp they learned how to develop a question map. The teachers were encouraged by the facilitators to let students ask questions. Teachers noted:

> I believe the students were learning when they were asking questions about the information given. They wanted to find out more. You could actually see the sparkle in some of their eyes. They had smiles on their faces and they were talking to each other. (Week 3 Camp debrief)
>
> I respond to student questions in science with a question instead of giving them the answer. They come up with the answer. They must use terms like observe, interact. They do hands-on science more. PBL lesson grabs students' interest better than old lessons. (Week 3 Camp debrief)
>
> I need more practice with feedback. (Fall follow-up exit ticket)
> The students will get a greater understanding (and take ownership of their learning) if they are discussing their ideas with others (Fall follow-up exit ticket)

Technology and Using Computer Science Programs

During the ESI the use of technology was encouraged. Teachers planned to incorporate technology in the summer camp. The campers used scientific probes for data collection, computers for blogging, word processing, researching, and communicating. Teachers received professional development on technology and were introduced to simulation programs such as Explore Learning Gizmos.

> I loved all the new technology devices we saw today. I liked how the motion graphs can be made realistic and come to live. I can also see using the temperature probes for measuring and the light sources for various colors (attract/repel light). (Day 2 exit ticket)
>
> I would like to discover explorelearning.com (Gizmos) and use more simulations in my teaching as well as go to area foundations online to keep science real! (Day 2 exit ticket)
>
> The story is coming to life using technology, "government agencies" and real life experiences. We are engaging students using hand on investigative procedures. (Day 2 exit ticket)
>
> Technology helps us research information that you do not know Using the internet to get real-time data helps me as a teacher keep the PBL real. (Day 2 exit ticket)

Professional Growth

Professional growth of teachers supports the VISTA goal to provide intensive support and effective interventions to help teachers learn science content through experience and develop confidence in teaching inquiry-based science. The ESI provided teachers with an opportunity to grow professionally. Teachers shared:

> I use a lot more hands-on science and I realize that hands-on is using Real materials. I also realize the importance of inquiry instead of giving students answers and information. (Fall follow-up exit ticket)
>
> All my lessons are hands-on activities. I lead the students very carefully to answers if they have trouble. I ask them questions instead of giving them answers,.(Fall follow-up exit ticket)
>
> It [ESI] really made me sit back and ask myself how I can incorporate NOS;inquiry, and manipulatives into my science curriculum to have students grasp a better understanding of science. (Fall follow-up exit ticket)
>
> The experience allowed me to build confidence in myself, for example in asking questions to students. (Week 3 debrief discussion)
>
> I believe I have come a long way since the start of this institute. I think I do understand how to teach using inquiry science. I was clueless about PBLs but the whole experience and the development of the PBL was valuable to me and my teaching. I never realized that I could let go of the traditional teaching methods and still get students to learn. I know I have grown in my ability to teach. I will incorporate inquiry in all my lessons not just science. Professionally this summer has taught me that I can influence my students' thinking and still teach all the content. I would like to return and continue learning about inquiry, PBLs and NOS instruction. (Fall follow-up discussion)
>
> I wasn't expecting much from this experience but I gained a whole new insight to teaching. As a teacher we often attend professional development programs and get little or no value from them. This institute was long but it went fast. I was able to see myself change slowly from using what I thought was "inquiry" to "real-life inquiry". I'm still not an expert but I think I can teach more effectively now than before. The hardest thing about this was letting go of control of the learning and let my students discover solutions to problems. I've grown professionally into a better teacher. (Fall follow-up discussion)

Discussion and Limitations

The goal of the Virginia Initiative for Science Teaching and Achievement (VISTA) model is to provide intensive support and effective interventions to help teachers learn science content through experience and develop confidence in teaching inquiry-based science and problem-based learning. This is the first year of the VISTA model study, so more data will be needed and collected over the rest of the academic year to ascertain whether teachers sustain their deeper understanding of inquiry and the concepts promoted through VISTA and how well they are implemented in the classroom. This study investigated how elementary teachers learn how to teach using inquiry-based models. Professional development programs where teachers model inquiry provide a basis for teachers to continue their experiences with inquiry science in the classroom (McDermott & DeWater, 2000). Based on the participant exit slips, daily ESI debriefs, discussions, and participant reflections collected for this study, this research supports that claim. Findings on learning how to teach inquiry-based science, implementation of inquiry-based science and professional development are discussed.

Learning How to Teach Inquiry-based Science

With respect to learning how to teach inquiry-based science, the findings illustrate that the teachers in the program felt they had expanded their understanding of inquiry. With this understanding they can learn ways to teach inquiry, engaging students through problem-based learning. Factors that need to be considered when learning how to teach inquiry-based science are student engagement, planning, real world experiences, research, development of PBL, and ideas. This study shows that teachers do not need to implement new science programs to teach inquiry science, but can adapt their methods of teaching. This study supports the research that teachers need professional development that is interactive with their teaching practices, is on-going and updated, and allows the teacher to assimilate and reflect on its content. (Blumenfield, Soloway, Marx, Krajcik, Guzdial, & Palinesar, 1991; Kubitskey, 2006).

Implementation of Inquiry-Based Science

Teachers are often overwhelmed when asked to implement new science programs (Bybee, 1993; Crawford, 2000). As inquiry-based science is implemented several important areas need to be considered: time management, teaching resources, team planning, administrative support, assessments, and curriculum. The VISTA model provided the teachers with the training, tools, and support to implement inquiry-based science in their classroom. Teachers in this study were confident that they could implement inquiry-based science in their classroom. This does not support similar nature of science (NOS) research of Akerson and Volrich (2006) who found that teachers who were trained in NOS, do not introduce NOS in their instruction unless there is ongoing feedback to monitor their progress. The VISTA model does include feedback and support to the teachers by providing instructional coaches in the classroom. Future research could examine if the instructional coaches are effective in providing feedback to the teachers on inquiry-based instruction. At this time that information is still being collected.

Professional Development

Elementary teachers need models, opportunities to teach inquiry science, and professional development to develop the confidence to teach inquiry-based science. The VISTA model provides the professional development opportunity for this to occur. The study reveals that this type of professional development of inquiry-based science has important factors to consider such as understanding and incorporating inquiry, questioning and discourse, the use of technology, and professional growth of the teacher. Often professional development for teachers is too short with limited follow-up opportunities to sustain its effectiveness (Brown, 2004). The VISTA model of professional development could provide the basis to study sustained professional development with multiple support systems interacting with teachers.

The main goal of professional development programs is to improve outcomes of students and to increase student achievement. From this preliminary study of the first year of the VISTA model, it is clear that this type of professional development can change teachers' perceptions on how to teach inquiry-based science. Future research (including four more years of the VISTA model with new sets of teachers joining the project) on teachers' perceptions on how to teach inquiry-based science will enable researchers to understand in greater depth how teachers can change their practice. No studies are planned to follow the first group of teacher throughout the five years duration of the VISTA project. Future studies should consider the long-term effect of professional development on teacher practices of inquiry-based learning.

References

Akerson, V. L. & Abd-El-Khalick, F. (2003). Teaching elements of nature of science: A yearlong case study of a fourth-grade teacher. *Journal of Research in Science Teaching, 40*, 1025-1049.

Akerson, V. L. & Volrich (2006). Teaching nature of science in a first-grade internship setting. *Journal of Research in Science Teaching*, *43,* 377-394.

Bell, R.L., Konold, T., Maeng, J.L.,& Heinecke, W.F. (2011). *VISTA research and evaluation annual report: Year 1*. Unpublished Report for George Mason University.

Blumfield, P. (1994). Lessons learned: How collaboration helped guide middle grade science teachers learn project-based instruction. *Elementary School Journal,* 94, 539-551.

Blumenfield, P. , Soloway, E., Marx, R., Krajcik, J. , Guzdial, M., & Palinesar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist,* 35, 149-164

Borko, H. (2004). Professional development and teacher learning: Mapping the Terrain. *Educational Researcher,* 33 (8), 3-15

Brown, J. L., (2004). *Making the most of Understanding by Design.* Washington, DC: Association for Supervision and Curriculum Development.

Bybee, R.W. (1993). *Reforming Science Education*. *Social Perspectives and Personal Reflections.* Teachers College Press, New York.

Chang, C.Y., & Mao, S.L. (1999). Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction. *Journal of Educational Research,* 92, 340-346

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, 37, 916-937.

Darling-Hammond, L. (1999). *Teacher Quality and Student Achievement: A Review of State Policy Evidence.* Center for the Study of Teaching and Policy, University of Washington, WA.

Fennema, E. , Carpenter, T. P. , Franke, M.L. , Levi, L. Jacobs, V.A, & Empson, S. B. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal of Research in Mathematics Education*, *27*, 403-434.

Fishman, B.J., Marx, R. W., Best, S., & Tal, R.T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*, 19, 643-658

Hartshorne, R. (2005). Effects of integrating hypermedia into elementary science professional development on science content knowledge. *Journal of Science Education and Technology*, 14, 415-424

Hiebert , J. , Fennema, T.P., Fuson, K. , Human, P. , Murray, H. (1996). Problem solving as a basis for reform in curriculum and instruction: The case of mathematics. *Educational Researcher*, 25,12-21.

Johnson, M.A. & Lawson, A.E. (1998). What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes*? Journal of Research in Science Teaching*, 35, 89-103.

Khlar, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. *Psychological Science*, 15, 661-667

Kielborn, T.L., & Gilmer, P.J. (1999) Meaningful science: Teachers doing inquiry + teaching science. Tallahassee, FL:SERVE

Kubitskey, B. *Extended professional development for systemic reform* (2006). Doctoral dissertation, University of Michigan, Ann Arbor.

Lakshmanan, A., Heath, B.P. & Elder, M. (2010). The Impact of Science Content and Professional Learning Communities on Science Teaching Efficacy and Standards-Based Instruction. *Journal of Research in Science Teaching*, 48, 534-551

Luft, J. & Pizzini, E. (1998) *The demonstration classroom in-service: Changes in the classroom.* New York: John Wiley.

McDermott, L. C., & DeWater, L. S. (2000). In J. Minstrell & E. H. v. Zee (Eds.), *Inquiring into inquiry learning and teaching in science*. National Academy Press: Washington, D.C.

Miles, M.B. & Huberman, A.M. (1994). *Qualitative data analysis.* Thousand Oaks, CA: Sage

Musheno, B.V., & Lawson, A. E. (1999). Effects of learning cycle and traditional text on comprehension of science concepts by students at differing reasoning levels. *Journal of Research in Science Teaching*, 36, 23-37

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late*. U.S. Department of Education . Retrieved from http://www.ed.gov/americacounts/glenn

National Commission on Science Education Standards and Assessment and National Research Council (1996). *National Science Education Standards.* National Academy Press: Washington, DC.

National Research Council (2007) *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. National Academies Press: Washington, DC. Retrieved from http://books.nap.edu/catalog.php?record_id=11463

Patton, M.Q. (2002). *Qualitative evaluation and research methods.* Newbury Park: Sage

Rosenfield, S., & Ben-Hur, Y. (2001). Project-based learning in science and technology: A case study of professional development. In *Proceedings of the IOSTE Symposium in Southern Europe on Science and Technology Education: Preparing Future Citizens, Greece, 2001*

Simon, M. A. & Schifter, D. (1991). Towards a constructivist perspective: An intervention study of mathematics teacher development. *Educational Studies in Mathematics,* 22, 309-331

Smith, T. , Desimone, L. & Ueno, K. (2005). "Highly qualified" to do what? The relationship between NCLB teacher quality mandates and the use of reform-oriented instruction in middle school math. *Educational Evaluation and Policy Analysis,* 27, 75-109.

Smith, T. , Desimone, L. , Zeidner, Dunn, Bhatt, Rumyanteseva (2007). Inquiry oriented instruction in science: who teaches that way? *Educational Evaluation and Policy Analysis,* 29, 169-199.

Swars, S. L. & Dooley C.M. (2010). Changes in teacher efficacy during a professional school-based science methods course. *School Science and Mathematics*, 110, 193-202

Wallace, C. S. & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41, 936-960.

Windschitl, M. (2004). Caught in the cycle of reproducing folk theories of " Inquiry" How pre-service teachers continue the discourse and practices of an atheoretical scientific method. *Journal of Research in Science Teaching*, 41, 481 – 512.

Wise, K.C., & Okey, J.R. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching*, 20, 419-435

APPENDIX

Table 2*: Sample Schedule from VISTA site. (The actual times may vary but the instructional content and delivery of that content at all 3 VISTA sites is the same)*

Week 1- Learning the VISTA Model of Inquiry-Based Instruction Using PBL		
Day 1	8:30am –8:40am	Welcome and Introductions Getting to know you
	8:40am – 9:30am	VISTA Assessment # 1 Overview of VISTA Journaling
	9:30am – 12:30pm	Introduction to Inquiry in the context of PBL in a rich context (Duck Lab). Teachers experience the beginning process of how to solve a problem through inquiry instruction. The concept of using a question map is introduced with 3 levels of questions and how to identify solutions to a problem. Teachers discuss the implementation of this process and how they as learners felt during this inquiry-based activity.
	12:30 pm – 1pm	Lunch
	1pm – 1:45pm	PBL, Inquiry, Hands-on NOS (Linking the morning's activity to the VISTA definitions). Introduce Inquiry rubric and applications to the classroom.
	2pm – 3:45pm	PBL Camp Theme is introduced. Teachers then develop topics for possible scenarios through brainstorming in small groups or whole group. Identify problem, scenario, student role, culminating activity (assessment), and resources/materials. Consult with scientists and curriculum math specialists to determine scientific grounding and feasibility of scenarios Scenarios
	3:45 pm – 4pm	Overview of General Camp Schedule Exit Ticket
Day 2	8am – 8:30am	Welcome Back/Parking Lot Camp logistics
	8:30am – 9:30am	Nature of Science (instructional training)
	9:30am – 10:30am	Technology Fair (instructional training)
	10:30am – 11:30am	Initial Planning for Camp
	11:30am – 12pm	Lunch
	12pm – 2:15pm	Question Map Planning
	2:15pm – 4pm	Lesson planning with teaching team Exit Ticket/Reflection
Day 3	8am – 11:30am	Planning Share Lesson plans Gallery Walk

	11:30am – 12pm	Lunch
	12pm – 4pm	Planning Exit Ticket/Reflection
Day 4	8am – 9:30am	Lesson Review Finalize Supply list
	9:30am – 11:30 am	Planning
	11:30 am – 12pm	Lunch
	12pm – 4pm	Planning Exit Ticket/Reflection
Day 5	8am – 11:30am	Planning
	11:30am – 12 pm	Lunch
	12pm – 4pm	Camp Overview Presentations VISTA Assessment # 2
Week 2- Implementing PBL unit or Professional Development		
First Week of Camp with Students Teachers not teaching will actively participate in instructional modules and field/lab activities with scientists		
Week 3- Implementing PBL unit or Professional Development		
Second Week of Camp with Students Teachers not teaching will participate in modules and field/lab activities with scientists Last day of camp – Final Presentations of PBL / Parent Visitation Day		
Week 4- Planning a PBL to Implement at Participant's School		
Day 1	8am – 10am	Camp Debrief
	10am – 11:30am	Planning with school team
	11:30am – 12:30pm	Lunch
	12:30pm – 12:45pm	Sharing Session
	12:45pm –4pm	Planning with school team/VISTA Team Consulting
Day 2	8am – 9:30am	Best ELL practices in Science
	9:30am – 11:30am	ELL consulting
	11:30am – 12:30pm	Lunch
	12:30pm –4pm	Planning with school team/Sharing and Peer Feedback/VISTA Team Consulting
Day 3	8am – 9:30am	Best Practices with Special Ed students in Science
	9:30am – 11:30am	Special Ed consulting
	11:30am –	Lunch

	12:30pm	
	12:30pm –4pm	Planning with school team Groups Report Out/Peer and VISTA Team Review
Day 4	8am – 11:30am	Planning and Consulting
	11:30am – 12:30pm	Lunch
	12:30pm –4pm	Coach consulting
Day 5	8am – 11:30am	Peer teaching
	11:30am – 12:30pm	VISTA Assessment # 4
	12:30pm – 1pm	Lunch
	1pm-4pm	Concluding Thoughts (Follow up info, VAST registration, Communication protocols)