TEACHING THE NATURE OF SCIENCE THROUGH INQUIRY: THE RESULTS OF A THREE-YEAR PROFESSIONAL DEVELOPMENT PROGRAM

This study assessed the components of a three year professional development program on participants' views nature of science (NOS), instructional practice to promote students' appropriate NOS views, and the influence of participants' instruction on elementary student NOS views. Using the VNOS-B and associated interviews the researchers tracked the changes in NOS views of teacher participants throughout the professional development program. The teachers participated in an explicit-reflective activities, embedded in a program that emphasized scientific inquiry, along with training in pedagogy, to help them improve their own elementary students' views of NOS. Elementary students were interviewed using a modified VNOS-B to track changes in their NOS views, using classroom observations to note teacher influences on student ideas. Analysis of the VNOS-B and modified VNOS-B showed that teachers and most grades of elementary students improved their views of NOS. The teachers also improved in their science pedagogy, as evidenced by analysis of their teaching. Implications for teacher professional development programs are made.

Valarie L. Akerson, Indiana University
Deborah Hanuscin, University of Missouri-Columbia

Problem Statement

It has been long recommended that one of the best teaching approaches for science is through inquiry methods (DeBoer, 1991). Though the *National Science Education Standards* (NRC, 1996) recommend that elementary teachers help their students understand science content and science as a discipline separate from other disciplines through inquiry teaching, it has been shown that teachers themselves do not generally have informed conceptions of the nature of science (NOS) (e.g., Lederman, 1992) or inquiry (e.g., Kielborn & Gilmer, 1999). Despite interventions it has proven difficult to help preservice teachers retain appropriate conceptions of NOS (Akerson, Abd-El-Khalick, & Lederman, 2000). However, recent research shows that sustained support in the classroom helps inservice teachers develop, and teach, NOS conceptions through inquiry science methods (Akerson & Abd-El-Khalick, 2002).

Most elementary teachers are not science specialists, having K-6 certification without a science degree. Their lack of experience with science affects their knowledge of science content (Atwater, Gardener, & Kight, 1991; Schoeneberger & Russell, 1986), and results in lower confidence about their skills in teaching science (Cox & Carpenter, 1989; Perkes, 1975; Tilgner, 1990). It is assumed that with improved understanding of science content, these teachers can increase their confidence and improve their abilities to effectively deliver science instruction that is at the level of national reforms (NRC, 1996). This need for professional development in science has been identified by K-8 teachers themselves in a national survey (*2000 National Survey of Science and Mathematics Education*, 2002).

Like those teachers in the national survey, a need for professional development in science ranked high for faculty and administration of Arlington Heights Elementary School, who expressed concern about scientific literacy of their students and accountability for the newly legislated Indiana Academic Standards for Science (Indiana State Board of Education, 2000). The school had already demonstrated a commitment to excellence in science teaching for its K-6 students through dedicating a space in the school for use as a science laboratory, in which science supplies have been pooled and organized for easy access during lessons and investigations. Having no members of her faculty with specialized training in science, the principal of the school expressed a desire to provide professional development to her elementary teachers in hopes that the laboratory would be used effectively.

Two university science educators/researchers and the faculty and administration of Arlington Heights Elementary worked collaboratively to address these concerns, through a grant from the Indiana University School of Education Office of Research and Development. The professional development program that was created, *Learning Science by Inquiry*, reflects recent reforms in science education by focusing on teaching science as inquiry, while making elements of NOS explicit through instruction. As Loucks-Horsley, Hewson, Love, and Stiles (1998) emphasize, professional development activities should allow teachers to consider the nature of the disciplines they teach. Given that appropriate conceptions of nature of science (NOS) are related to scientific inquiry, these became dual foci of the project. Because this project was both a professional development *and* research study, investigators were interested in determining (a) teachers' conceptions of NOS and inquiry and (b) specific supports effective in helping teachers improve their understandings and practice of teaching inquiry and NOS.

Theoretical Background

Prior research into both pre-service and inservice teachers' understandings of inquiry and nature of science has been conducted in the context of methods courses and professional development programs. Findings from these studies have pointed to effective methods for helping teachers both learn and teach science as inquiry. The following sections describe research in these areas that was used to inform the design of the project.

Inquiry and Nature of Science

According to *National Science Education Standards* (NRC, 1996) inquiry refers to "…the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p 23). Among the reasons teachers give for not implementing inquiry in their classrooms are confusion about the meaning of inquiry, inadequate preparation in inquiry methodology, and viewing inquiry-based instruction as difficult to manage (Welch et al., 1981). "Prospective teachers have limited knowledge of and experience with the processes by which scientific knowledge is generated. This puts serious limitations on their ability to plan and implement lessons that will help the students develop an image of science that goes beyond the familiar 'body of knowledge'" (Gallagher, 1991). This statement could just as easily apply to inservice teachers who lack experience in scientific inquiry. Having teachers participate in inquiry science experiences has been shown to help them better conceptualize inquiry and how to teach it to their own students (Kielborn & Gilmer, 1999).

Portraying science in such a way that goes beyond thinking of science simply as a body of knowledge requires an understanding of the nature of science (NOS) itself. Typically, NOS refers to science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). While there is no consensus of what constitutes NOS (Duschl, 1990), few would disagree on the importance of several more general aspects of NOS, such as the requirement of evidence to support scientific claims. Six aspects of NOS believed accessible to K-6 students and relevant to their daily lives include that scientific knowledge is both durable and tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective or theory-laden (influenced by prior-knowledge and theoretical frameworks of the researcher), partly the product of human inference, imagination, and creativity (involving the invention of explanation), socially and culturally embedded (both influences and is influenced by the cultural milieu), and utilizes both observation and inference (Abd-El-Khalick, Lederman, & Bell, 1998).

Through interventions it has proven possible, though difficult, for elementary teachers to develop informed conceptions of these aspects of NOS through an explicit reflective approach, rather than implicit means (Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson & Abd-El-Khalick, 2003; Abd-El-Khalick & Akerson, in press), and in the context of scientific inquiry (Schwartz & Crawford, 2003). Implicit approaches, which have been found ineffective in changing teachers' views of NOS, assume that an understanding of NOS is simply a by-product of participating in scientific inquiry (Lederman, 1992). An explicit reflective approach, not to be confused with didactic instruction, views NOS as a cognitive outcome and "intentionally draws learners' attentions to relevant aspects of NOS through instruction, discussion, and questioning…in the context of activities, investigations and historical examples used in daily science instruction" (Schwartz & Lederman, 2002, p. 207). Recent work indicates an explicit reflective approach, combined with classroom modeling of lessons emphasizing aspects of NOS is effective for in-service teachers in developing their own NOS conceptions and abilities to teach NOS to their students (Akerson & Abd-El-Khalick, 2003).

Professional Development

Designers of professional development can be guided by the extensive body of research into how effective change occurs in educational settings (Loucks-Horsley et al., 1998). Bell and Gilbert's (1996) science teacher development model includes three components: (a) *personal development* in which the teacher must be aware there is a need for professional development and acknowledge the desire to acquire new ideas or strategies, (b) *social development* in which the teachers have opportunities to discuss ideas with other teachers, and to collectively renegotiate what it means to teach science and be a teacher of science, and (c) *professional development* in which the teachers are supported in implementing the new ideas and strategies in their classroom practice, drawing on the changes they make personally, and socially. These three components are viewed as essential to building on teachers' commitment to enact change within their own classrooms and professional communities. Identifying teachers committed to personal development can be useful in selecting participants while social development and professional development aspects of the model can be used in designing teacher development programs.

Additional characteristics of successful teacher development models that we drew upon include providing enough time to allow for acquisition of new views, along with practice, feedback, follow-up, and maintenance of the new skill or idea, allowing the teacher to reflect on the new idea or implementation of the new skill, and modeling, or allowing the teacher to see the new skill or strategy in practice (Henriquez, 1998; Loucks-Horsley, et al 1998). Many teachers find it difficult to change how they teach having experienced science instruction as students that differs greatly from the vision of science teaching described by current reforms. These experiences served as models for their own teaching; teachers tend to teach as they were taught. It logically follows that *new* models of science teaching can be used to break this cycle. Harmon (2001) emphasized the importance of on-site modeling, while Luft and Pizzini (1998) found that using a demonstration classroom where teachers were invited to view inquiry lessons enabled teachers to better implement the strategies in their own teaching. Current work with in-service teachers shows that sustained support that allows teachers to view model inquiry lessons that emphasize NOS aspects in their classroom triggers them to develop and teach appropriate NOS conceptions to their own students through inquiry science methods (Akerson & Abd-El-Khalick, 2003). Modeling of instruction within elementary teachers' own classrooms is consistent with the perspective of situated cognition (Brown, Collins, & Duguid, 1989) in which contextual learning is important. Simply understanding content and pedagogy is not enough; understanding how to teach a particular content *in one's own context* is crucial.

Description of the Project

The project examined the impact of the professional development program on teacher conceptions of NOS and inquiry and their classroom practice. Figure 1 provides a timeline for activities in the program. Project staff consisted of a project director (first author) and assistant (second author), both former elementary classroom teachers, who were responsible for planning, facilitating, and organizing all aspects of the professional development program and associated research.

Setting and Participants

Built in 1959, Arlington Heights is located in a university town in the Midwest. The school serves grades K-6 and has a student population of about 300. The majority of the students are white and 29% qualify for free or reduced lunches. Of the sixteen faculty (14 of whom are classroom teachers), six participated in the project. Three elementary teachers (all of whom consented to participate in our research) are the focus of this paper. These teachers were Kerry (Kindergarten), Amy (first grade), and Melissa (sixth grade). While Kerry had 29 years of experience, all at the kindergarten level, the other teachers had ten or fewer years of experience at various grade levels. None had specialized science training, or any particular interest in science; however, each recognized science as their weakest instructional area, and expressed a desire to improve. This commitment to personal development (Bell & Gilbert, 1996) allowed us to tailor the professional development we provided to meet individual teachers' needs. A description of each aspect of the professional development program follows.

Professional Development Program

Learning Science by Inquiry consisted of series of monthly half day workshops for the teachers at Arlington Heights Elementary, as well as regular on-site visits by project staff. The program lasted three years. Activities during these visits were designed to support teachers in their efforts to implement new strategies from the workshops in their classrooms. Both were important components of the professional development.

Monthly Workshops. Workshops were designed to immerse them into science inquiry and to focus on the nature of science. These workshops were designed under the assumption that teachers benefit from inquiry experiences grounded in the same pedagogical principles they are expected to implement with their own students and that a change in teachers' conception of the nature of science teaching and learning happens over an extended period of time, not through "one-shot" workshops (Loucks-Horsley et al., 1998). Based on conversations with faculty in which needs and concerns were identified, the topics included in the table were the focus of the schoolyear workshops. The final workshop of the second schoolyear consisted of a debriefing session in which teachers viewed lessons taught by peers, and provided feedback to each other. Additionally, participants shared their perceptions of the professional development with the project staff, enabling planning of the next year of the program.

Participants requested planning time in the second year to help them adapt lessons and units that were inquiry based and emphasized nature of science elements. With the support of the project personnel much of the final year of the project became devoted to curriculum and lesson adaptation. Teachers brought curricula and state science frameworks to each workshop session and spent time revising and adapting. They also shared ideas and provided feedback to one another regarding instruction. They again planned and presented a session at the state science conference, this time titled "The Myth of the Scientific Method" during which they shared strategies for emphasizing NOS in classroom investigations. They became involved in writing about the change in their instruction to describe their ideas to others (Hollinger & Akerson, in press; Rooney & Hanuscin, in press). At the final workshop of the project they discussed the changes in their views as well as their instruction. All workshops were audiotaped for analysis of the influence of the professional development program on their views and instruction.

Table 2. Monthly Professional Development Workshops.

	Workshop Topic	Month/Year of Workshop
1	*An Introduction to the Nature of Science (NOS)*	January 2002
2	*Conducting Scientific Inquiry*	February 2002
3	*Assessing Inquiry Learning*	March 2002
4	*Strategies for Adapting Activities to be Inquiry-Based*	April 2002
5	*Identifying Where Inquiry and NOS Fit Our Curricula*	May 2002
6	*Goal-setting for New School Year*	August 2002
7	*Modifying Existing Curricula/Collaborative Planning*	September 2002
8	*Using Children's Literature to Teach NOS Elements*	October 2002
9	*Modifying Existing Curricula/ Collaborative Planning*	November 2002
10	*Presentation at HASTI Conference*	February 2003
11	*Accessing Materials Inexpensively*	March 2003
12	*Debriefing/ Reflecting on Goals & Successes*	May 2003

13	*Setting Goals for the Year*	September 2003
14	*Curriculum Planning and Adaptation of Lessons*	Oct. Dec. 2003
15	*Planning for HASTI Presentation*	January 2004
16	*HASTI Presentation*	February 2004
17	*Curriculum Planning, Sharing Classroom Strategies*	March-April 2004
18	*Final Project Debrief—Successes/Remaining Challenges*	May 2004

The involvement of qualified instructors who have used techniques successfully with students is critical to the success of professional development efforts (Loucks-Horsely et al., 1998). Project staff led the majority of workshops, utilizing vignettes and anecdotes from their own classroom teaching to demonstrate aspects of scientific inquiry and the nature of science. Guest speakers were employed to present the *Introduction to NOS*, *Identifying Where Inquiry and NOS Fit into Our Curricula*, and *Using Children's Literature to Support Teaching NOS Elements* workshops. These guest speakers were skilled in explicit reflective NOS instruction, as well as the use of children literature for support NOS instruction at the elementary level.

On-Site Support. Project staff served as mentors for teacher participants, providing individualized on-site support as they implemented new strategies in their classrooms. These mentoring activities consisted of (a) providing support to teachers in their endeavors to teach science through inquiry, (b) modeling inquiry lessons in the teachers' classrooms, (c) observing teachers' efforts to implement inquiry in their classrooms to better design future workshops and support, and (d) debriefing and discussing teachers' efforts to implement change. Additional support included assisting teachers in adapting curricula and designing assessments for use in their classroom.

Peer debriefing, as well as staff-participant debriefing, provided a venue for social development through discussing teachers' developing understanding of NOS, inquiry, and ways to implement this understanding in their classroom practice (Bell & Gilbert, 1996). As Loucks-Horsley et al (1998) emphasized, "reflection by an individual on his or her own practice can be enhanced by another's observations and perceptions" (p. 127). Because members of the project staff were former elementary teachers, they could serve as "credible peers" (Bandura, 1997) and reliable sources for professional development. This has been identified as a critical element to the success of professional development programs (Loucks-Horsley, et al., 1998), enabling teachers to trust that they are capable of implementing the same strategies within their own classrooms.

While some concerns were common to all teachers in the program, individuals encountered their own idiosyncratic problems and obstacles to implementing inquiry in their respective classrooms. These challenges are expected of teachers working to master new materials and teaching practices (Loucks Horsley et al, 1998) and can be addressed through on-going assistance. One of the benefits of the on-site mentoring visits was the ability to tailor professional development to individual teachers' changing needs over the duration of the project. The specific supports that each teacher received is described in detail within each of their individual teaching profiles.

Research Procedures

The present investigation was interpretive and emergent in nature (Tobin, 2000). Data collection and interpretation informed the delivery of subsequent professional development workshops and on-site support. Thus, the design of the professional development program was modified as the data was collected and analyzed. Such modifications are characteristic of emergent designs in which field observations often lead to reconceptualization of goals and questions, and modification of data collection methods. To maximize the study's flexibility and responsiveness, the authors adopted a model of analytic induction for collecting data (Bogdan & Biklen, 1998). Data collection was continuous and the data were constantly consulted and interpreted to inform future data collection, as well as future professional development supports.

Data Collection. As part of the research component of the project, data collected included (1) field notes taken at each workshop, (2) videotaped sessions of teachers and project personnel teaching inquiry lessons, (3) transcripts of stimulated video recall interviews of teachers after selected inquiry lessons, (4) teacher responses to the Views of Nature of Science (VNOS-B) questionnaire used annually pre and post to determine changes in conceptions of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz) (5) teacher responses to the Views of Scientific Inquiry questionnaire (VOSI) annually, (Schwartz, Lederman, & Thompson, 2001)(6) records of email and verbal conversations between the project personnel and teachers regarding successes and difficulties associated with inquiry teaching, and (7) teachers' description of their lesson adaptations from their presentation at the state science teachers' conference. Additionally, a sample of elementary students from each of the teachers' classrooms were interviewed to assess the impact of teachers' instruction on their ideas about the nature of science.

Field notes from the workshops were used in conjunction with transcripts of each session, and provided insight into teachers' developing ideas about the nature of science and inquiry. Videotaped sessions of teachers and project personnel teaching inquiry lessons were transcribed and provided valuable data to give insight into the ways teachers approached inquiry science, and how their approaches changed over time and with further professional development. Field notes and transcripts of debriefings of inquiry lessons, whether taught by the teachers themselves or modeled by project staff, provided important information regarding teachers' beliefs about the challenges they faced or the successes they felt in teaching inquiry science.

Video stimulated interviews took place during the second year. Videotaped inquiry teaching sessions were reviewed and project personnel selected stopping points in the videos at which points teachers were asked to articulate their rationale for using particular strategies or actions. Samples of questions asked include "Tell me what was going through your head after the students asked that question." and "What influenced your decision to ask students to develop *their own questions* on that topic?" Questions specific to the teaching episodes were designed for each video segment. Teachers were encouraged to stop the video tape at any time they wished to talk about the lesson. The video stimulated recall lessons provided important information regarding teacher thought processes and decision-making during delivering inquiry instruction.

The VNOS-B open-ended questionnaire combined with interviews (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was used to determine teachers' initial views of NOS, and was administered again at the end of each year in a pre-post format to determine change in

conceptions. Teachers completed the 7-item questionnaire in a paper-and-pencil format prior to the first workshop, and again at the end of each year of the program.
Email correspondence and other informal communications between teachers and project personnel were collected and examined to help discern challenges and successes associated with inquiry teaching. For example, when teachers emailed questions regarding their inquiry instruction, and obtained feedback from project personnel, these written conversations provided important data regarding the nature of teachers' concerns during the development of inquiry teaching. Furthermore, questions regarding scheduling of workshops, substitutes, classroom visits, etc., provided data relating to school and classroom constraints that mediate the process of change for the teachers.

An important source of data regarding teachers' understandings of and abilities to teach NOS and scientific inquiry were the lessons teachers adapted and implemented in their classrooms. Teachers' critiques of their existing textbook lessons, as well as the adaptations they made to these lessons, provided a venue for identifying the ways in which they strategized including NOS within an inquiry lesson. Their lesson plans, coupled with observations of teachers implementing them and debriefing sessions during which teachers shared what they had accomplished, allowed for identification of changes in their teaching that resulted from the professional development.

In the second and third years of the program, a subset of elementary students from each class was interviewed using a modified VNOS-B (see appendices). Questions were posed to students during audiotaped interviews that took place both at the beginning and end of the school year. Student responses to these questionnaires were used to track the influence of teachers' instruction on students' views of NOS. We believe that the ultimate measure of teachers' abilities to teach NOS are positive changes in students' NOS views. If teachers are using strategies that are not influencing student understandings of NOS then new approaches need to be found.

Data Analysis. Each investigator conducted separate analyses of the data using the methods described below. The two analyses were compared and degree of correspondence was noted. Any remaining differences were resolved by further consultation of the data and/or consensus. Primary data sources included the VNOS-B or modified VNOS-B in the case of student understandings, transcripts and field notes from workshops, and transcripts and field notes from teachers' lessons. Secondary sources, which allowed for triangulation of data, included transcripts and field notes from lesson debriefings, stimulated video recall interviews, and collections of notes from email and verbal conversations between the project personnel and teachers.

Project staff met prior to administration and analysis of the VNOS-B to discuss common misconceptions about each aspect of NOS that had been identified by previous research. For example, we addressed the importance of recognizing misconceptions teachers may have regarding the existence of a single scientific method, a hierarchal view of scientific knowledge in which theories become laws, and a view of scientific knowledge being absolute (McComas, 1996). Because there were so few participants the researchers were able to describe individual teachers' NOS views of each target aspect over time. Each researcher described the NOS views of each participant, and these descriptions were compared to ensure reliability of the interpretive schema. Next, the same procedure took place to generate profiles of the post-intervention questionnaires. Summaries of teacher understanding were made and differences between pre and post-intervention knowledge were noted and categorized to assess changes in participants' NOS views. These summaries were conducted each year of the project to track changes in NOS views over time.

Data analysis consisted of a thorough review of all sources with notation of initial or "raw" codes (Carspecken, 1996). A second reading of the data allowed for grouping and combining of specific codes into broader categories, such as "use of modeled strategy" and "explicit NOS reference," enabling the researchers to identify themes and note specific instances and factors that were barriers to inquiry and NOS instruction or contributing factors in situations in which inquiry and NOS teaching were effectively facilitated. Themes were cross-checked against multiple data sources and were used to develop a description of teachers' typical patterns for teaching science using what they considered inquiry strategies. We used this analysis to create profiles of the changes in each participants' views and teaching over the course of the project.

Professional Development Program

What is nature of science (NOS)?

At the initial workshop, participants engaged in 10 different activities that explicitly address the seven target aspects of NOS. Detailed descriptions of these activities can be found elsewhere (Lederman & Abd-El-Khalick, 1998). Two of the activities address the function of, and relationship between scientific theories and laws. Two other activities ("Tricky tracks" and "The hole picture") addressed differences between observation and inference, and the empirical, creative, imaginative, and tentative nature of scientific knowledge. Four other activities ("The aging president," "That's part of life!" "Young? Old?" and "Rabbit? Duck?") target the theory-ladenness and the social and cultural embeddedness of science. Finally, two black-box activities ("The tube" and "The cubes") were used to reinforce participants' understandings of the above NOS aspects.

The activities were purposefully selected to be generic in nature (not content-specific) given the participants' limited science content backgrounds, and the fact that as teachers of different grade levels, the specific science content and topics they teach differs. Each activity was followed by a whole-group discussion aiming to explicitly highlight the target aspects of NOS and involve teachers in active discourse concerning the presented ideas. This initial activity-based explicit NOS instruction provided participants with a NOS framework by introducing and, in a sense, sensitizing them to the target NOS aspects. These aspects were revisited throughout the remainder of the workshops in the context of scientific inquiry and literature experiences.

During the workshop the teachers wrestled with the new ideas, and the implications of these ideas for their teaching. In the exchange below debriefing the tubes activity between the workshop facilitator and the teacher participants, it is apparent that the teachers were beginning to acknowledge science is not absolute, yet realizing that it might be easier to teach science were it actually absolute in nature:

> Facilitator: Can you know what is in the tube? And does it matter? Irrespective of how you built your tube, your tube still works.

Amy: No, the goal was to make the tube like the other tube.

Facilitator: Let's think of something similar. You can look up chemical reactions in the sun. Have you ever wondered how they know the temperature of the sun? You literally cannot open the sun and "open" it to see what is inside the sun. But what is the virtue of what we know about the sun? It is consistent with observations, but we still can't tell what the sun is for sure. How does this activity relate to science? Discuss with your neighbor.

~~Judy~~Kerry: Well it is interesting because we can't physically observe everything, but it is a study of patterns, and we figure out what those patterns mean. There is something about absolute truth. We will never know for sure.

Facilitator: The interesting thing is we can kind of know what happens even though we can't see it. Most of the time in science all we can do is make observations, and try to construct a model of reality to try to draw inferences that behaves, and predicts what happens in reality. It is not necessary to know how the tube works in the inside. Why don't we say there is a little guy (or girl) pulling on the strings inside the tube?

Amy: Because it is not reasonable.

Facilitator: But is it more reasonable that we say the whole universe was the size of a needle, became very dense and then exploded into what it is now? Big Bang Theory. How reasonable is that? Somehow in science we don't believe in supernatural. We believe in materialistic stuff. Does this thing with absolute truth have anything to do with teaching science in the classroom?

Amy: It is so much easier that you teach them it is the truth. You don't have them question how we know this.

Facilitator: That is a valid point. But when you are doing this, what [definition] of science are you [addressing]?

Amy: Body of knowledge. You're not teaching them about the processes, or how science works at all.

During this initial month, classroom observations of the teachers' science teaching were made. Not surprisingly, no teachers were approaching science via inquiry methods, and neither were they emphasizing any of the six target NOS elements. Rather, they still relied on their adopted curriculum, which made no explicit references to NOS and though claimed to be "inquiry based" provided little or no opportunity for students to engage in scientific inquiry.

Engaging teachers in scientific inquiry. A key to understanding scientific inquiry and developing abilities necessary to conduct inquiry is *actually participating* in scientific inquiry (NRC, 2000). In this workshop the teachers participated in a guided inquiry investigation as a model for their own instruction. As Loucks-Horsley et al. (1998) point out, teachers must be challenged at their own level of competence, rather than doing student activities. This particular inquiry was selected because it included a focus on science content (pH) and a product about which teacher participants would have some prior knowledge (commercially-available antacids). After an overview of pH concepts (generated from a discussion with the teachers to solicit their prior knowledge), teachers were given the question “Which antacids neutralize stomach acid the best?” A solution of 0.1N HCL was used to simulate stomach acid, and teachers were provided an assortment of generic and name-brand antacids to test, such as Rolaids, Tums EX, Mylanta, Maalox, and Pepcid AC.

The first task consisted of clarifying the questions by operationally defining “best” (i.e., fastest neutralizing? longest lasting neutralizer?). Once a definition was agreed upon, teachers were asked to design a “fair test” to determine the best antacid. Several of the teachers exhibited a degree of impulsivity, starting to begin testing immediately, while others expressed concern about variables and reaching a consensus on how the tests should be conducted before actually beginning. While this restraint may seem positive in terms of abilities to conduct inquiry by identifying variables and considering the type of data to collect, and alternative interpretation seems plausible given the comments made by those teachers:

> Judy: Are we supposed to test them by mixing them together?
>
> Kerry: I don’t know; (to facilitator) are we doing this right?

Teachers held a naive view of scientific inquiry and the existence of a single “scientific method.” They were trying to do the investigation the “right” way. This notion was supported by the fact that the school had posted the steps of the scientific method on the bulletin board of their science lab, and earlier that year the faculty had performed a song with these steps set to music at the faculty meeting in which the new lab was introduced.

Though the conceptual and procedural abilities to conduct inquiry as outlined by the *National Science Education Standards* (NRC, 1996) suggest a logical progression from identifying questions that can be answered through scientific investigations, designing and conducting investigations, using appropriate tools to gather, analyze, and interpret data, and develop explanations using evidence, these “should not be interpreted as advocating a ‘scientific method’…[and] do not imply a rigid approach to scientific inquiry” (p.144). Rather than address this particular issue immediately, the facilitators waited until the conclusion of the inquiry, when the teacher participants had designed and carried out their tests, analyzed their data, and formulated an explanation for which antacid was “best.” The teacher comment about doing it “right” was used as a springboard for discussion about the nature of scientific inquiry, e.g. whether results might be different had they conducted a different test, selected a different operational definition of “best,” etc. Data collected the following semester through the VOSI and follow-up interviews provided confirmatory evidence for teachers’ initial naïve views of inquiry, and also of their developing understanding:

> Judy: I thought ‘yes’, there is one scientific method because of the posters that you’d seen—I mean, this is the ‘scientific method’ and you LEARN about that, as being quote unquote THE scientific method. And that’s why I thought that there was only one scientific method. I think there are other METHODS that you can USE, but they’re not called THE SCIENTIFIC METHOD.

> Interviewer: OK; so there's something called "the scientific method," but scientists don't always use that.
>
> Judy: Right—they can use other things that work for them, but this scientific method has a certain name.

The experience was concluded with a discussion of what made their investigation "scientific," and those aspects of NOS which were illustrated by the activity. These were noted as a model of how NOS could be made explicit to their own students. It was evident that teachers were struggling to internalize the ideas of the workshop. Though Amy commented, "it helps to see us doing the lesson" in terms of anticipating how her own students might participate, she also seemed puzzled how one of her curricular topics like *weather* could be made into a similar inquiry. Her question would be addressed in an upcoming workshop on modifying and adapting curricula, in which the facilitators provided examples and guided teachers in the process to modify their lessons to focus on inquiry and NOS.

<u>Assessing student understanding in inquiry lessons.</u> As was the case in each month, NOS was emphasized at the outset of the monthly workshop. In this case, the fictional children's book *Earthmobiles as Explained by Professor Xargle* (Willis, 1991) was read to the participants. Professor Xargle is an alien who leads his fellow visitors from outerspace on a tour of Earth. Though many of his interpretations of "earthmobiles" (cars, trucks, planes, etc.) are quite logical inferences based on observation, to an inhabitant of the planet Earth, they seem quite comically incorrect. The purpose of this activity was to help reinforce the NOS elements they were introduced to in the initial workshop, and to illustrate to them a way to use children's' literature to introduce the NOS concepts to their own students. Participants discussed elements of NOS that were apparent in this book, especially the socio-cultural embeddedness of science, the role of subjectivity (theory-ladenness) and the tentative nature of science. At this early stage, participants needed much coaching in recognizing the target aspects of NOS.

The main focus of the workshop, however, was to provide teachers with strategies for assessing inquiry science. Inquiry is a teaching model that does not easily lend itself to multiple choice questions or memorization of terms. Alternative assessment strategies were introduced that could help the teachers assess student knowledge of content and abilities to conduct scientific inquiry. The alternative assessment strategies focused on assessing student understanding of science content and their abilities to conduct scientific investigations and included (a) identifying students' prior knowledge and misconceptions, (b) using science notebooks or journals, and (c) use of checklists to monitor student work as they conducted investigation. Teachers were asked to bring samples of student science work from their own classes and examples of assessments they used. Facilitators and participants worked together to identify outcomes and appropriate assessment techniques for their particular grade levels and science topics being investigated in their classrooms.

To help participants become more aware of students' prior knowledge and possible misconceptions of science as formative assessments, the facilitator shared questions she had raised to her own primary-grade elementary students to gather their ideas about science content prior to instruction, such as "How do we think electricity works?" Student responses had been recorded on the charts, which were shared with participants. Participants then viewed similar charts on which student responses to the same questions had been recorded post-instruction. Thus, participants noted that the classroom teacher could compare students' initial ideas to post-instruction ideas to assess change in science conceptions over the course of instruction.

Teachers were then shown examples of actual primary students' science journals from that investigation. The students had responded to journal prompts that were similar to the prompts on the classroom charts. One advantage of the journals that was emphasized was how they enable teachers to get a picture of individual student conceptions of science, whereas the charts give a whole class flavor of ideas. Participants could see that carefully constructed prompts could enable them to assess student conceptions of science content over the course of a unit, and track development of student ideas toward more scientific conceptions.

Participants then reviewed samples of various assessment checklists that could be used while students are engaged in science explorations (Dickinson, Burns, Hagen, & Locker, 1997). The facilitator suggested duplicating the checklists and placing them on a clipboard for the teacher to carry around while the students were working. It was suggested that the teachers focus on a small group of students rather than try to assess all students in an in-depth fashion at each lesson. The teachers can note on the checklist whether students are engaging in inquiry, and areas that students may require more support. A video segment of the facilitator using these checklists in her classroom was shown.

In subsequent classroom observations it was noted that teachers were indeed collecting student ideas of science content prior to instruction, using charts to record student responses in a way similar to that which was modeled in the workshop. Teachers also had instituted the use of science journals in their classrooms. No teachers were observed using checklists to monitor and assess students as they worked on science investigations. Thus, strategies that were modeled within the teachers' own classrooms were more likely to be adopted (science journals, charts) than strategies that were merely shared in workshops (assessment checklists).

Strategies for adapting curricula to be inquiry-based. "Curricula" in terms of our project, refers to content-specific materials used by teachers in their own classrooms. Through adapting existing curricula (including textbook activities) to be more inquiry-based, teachers are able to increase their content and pedagogical knowledge, and reflect on their teaching. Understanding the *Indiana Academic Standards for Science* (ISBOE, 2000), modeled after the *National Science Education Standards* (NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993), and how these addressed inquiry and the nature of science were a key part of this endeavor, as was the extended time necessary to time to complete the adaptations necessary to align lessons with these standards. As such, a series of workshop sessions was devoted to preparing teachers for this task and working to adapt their curricula.

> To help teachers develop strategies for adapting their existing lessons and text series to be inquiry-based and allow for emphasis of NOS elements, facilitators guided participants through the process using an activity based on *Parachutes* developed by the Institute for Inquiry (Exploratorium, n.d.). Teachers first generated a list of characteristics of inquiry and what they considered to be "good" science lessons (see Table 1). The inclusion of "the scientific process" as a criterion for a good science lesson was a further indication of teachers' early perception of inquiry. When pushed to clarify her meaning of this criteria, the

> teacher participant listed the steps of the hypothetico-deductive model or "scientific method." The use of such terminology suggests a dichotomy between *the* "scientific method" and all other methods or "non-scientific methods," effectively excluding non-experimental designs from importance in the construction of scientific knowledge.

Next, they participated in a "cookbook" activity involving parachutes (Harlen, 2000). Having discussed and critiqued the experience according to their criteria, the teachers divided into two teams, which were each guided by a facilitator as they revised the lesson to better reflect characteristics of inquiry and their criteria. When finished, the two groups presented their adapted lesson plans and provided feedback to each other. Because the teachers had not included an emphasis on NOS in their original list of criteria, the facilitators next solicited teachers' ideas about whether and how each of the six target NOS aspects could be illustrated by the adapted lessons. At this stage in their development, this task required support and prompting by the facilitators, as teachers did not readily recognize opportunities for emphasizing NOS within the inquiries they had designed.

<u>Looking at where inquiry and NOS fit into our curricula</u>. The final workshop of the first year was facilitated by a guest speaker considered an expert on NOS and inquiry. The facilitator spent the first half of the session reviewing NOS elements through activities and discussions, and the remainder of the session brainstorming with participants and sharing examples of how NOS and inquiry could fit into the participants' regular curricula. In the first example, teachers were given a drawing of a fossil and were asked to create a drawing of what they thought the live organism might have looked like, based on what they'd been given. The participants described their drawings, and then interpreted how what they had done was like what scientists do. The facilitator noted that this kind of activity—creating an explanation from the evidence—can be used with students to negate the existence of one single scientific method because the teachers, as would scientists, approached the activity with a mindset of solving the problem; none of their solutions had involved "the scientific method." The facilitator noted that people with different mindsets, or background knowledge, may have somewhat different interpretations that are all consistent with the data.

Amy raised the question of whether teachers should use the terms we used to describe the elements of NOS with elementary students. The workshop facilitator indicated that as long as students understood the meanings of the terms and concepts behind the terms it was not necessary, nor probably important, to use the labels of the focus elements. He noted that he did not even call what he was teaching "Nature of Science" to high school students, but he used some form of the words to describe what scientists do when they are doing their work. Amy noted that the fossil activity could be a good example of observation and inference, and she would feel comfortable using those terms with her first graders, but maybe the terms "tentativeness" or "empirical" would be beyond their grasp. The facilitator agreed, and reiterated that the teachers could choose to focus on NOS ideas that they deemed appropriate for their own students, but that were consistent with current NOS definitions. Later observations in teachers' classrooms revealed that one such strategy they employed was to simply ask students to relate the classroom investigation to "what scientists do."

Analysis of dialogue from this workshop, the participants were beginning to demonstrate their own understanding of NOS in terms of wrestling with ways to use NOS in conjunction with their current curricula that were appropriate for their students. The facilitator noted that "The inquiry focus can also allow you to infuse NOS in your lessons. NOS should not be thought of as an add-on, but integrated within your content, as a way of helping students understand how scientists develop knowledge." Teachers' questions indicated a personal concern (Loucks-Horsley, 1996) for how the strategies would work in their own classrooms, yet considering how they would these strategies for use in their own situations indicated a movement to the stage of consequence, or noting how to refine a strategy to have more impact on their students.

Transition to the New School Year

As the first semester of the project ended project staff and teacher participants met during the summer to plan for the upcoming academic year. It was decided that workshops would begin with curriculum adaptation activities, followed by a workshop on using children's literature to support NOS understandings of elementary students, another full day of curriculum adaptation (that included planning for a presentation of their work by the teachers at a science teachers convention), and a half day session exploring methods for obtaining and using inexpensive materials for science, concluding with a session to debrief and assess the successes of the program, as well as determine what other kinds of support might be desired by the teachers. The support provided to individual teachers is discussed in their profiles.

Modifying existing curricula to focus on inquiry and NOS. Though many curricular materials bear the label "inquiry," upon closer inspection what may be claimed to be inquiry falls short of the vision of inquiry put forth by the *National Standards* (NRC, 1996). Hoping to find inquiry activities appropriate for her kindergarten students, Kerry purchased a science inquiry activity book with her own money. However, she found these "inquiry" based activities still fell short of what she hoped to accomplish in her classroom. Indeed, this was the case with the district-adopted text series used by the teachers, which Judy recognized contained an inaccurate use of the term "inference," one of our target NOS elements. As such, teachers found it necessary to adapt materials for use in the classroom, and an important function of this professional development program was to provide them with the time and means for accomplishing this goal.

During this session, the teachers utilized their resources from previous workshops, including their list of NOS target elements, and their own teacher-generated list of strategies for adapting activities to be inquiry-based. Project facilitators provided one-on-one assistance in adapting their curricula to an inquiry focus, and pointed out opportunities for including an emphasis on NOS elements in the curricula. From a research perspective, it is important to note that at this stage, the teachers tended to focus on inquiry and the distinction between observation and inference as an element of NOS. The work they began would be continued on their own, and then again with staff at a later workshop.

Using children's literature to emphasize NOS elements. An outside facilitator with expertise in children's literature led this fall 2002 workshop, sharing her own experiences using literature to teach NOS to elementary students. Participants were treated to many different children's literature books, and both the facilitator and the teachers generated ways to use particular books with children to emphasize elements of NOS, such as observation and inference, tentativeness, and subjectivity. For example, the book *Seven Blind Mice (*Young, 1992) was used to highlight how scientists draw inferences from observations. *The Three Pigs* (Wiesner, 2001) was used to provide teachers with a way to introduce the concept of "fair tests" and multiple methods to their students as they design ways to test the strength of air blowing (wind). *Something From Nothing* (Gilman, 1993) was used to introduce the theme of form and function, and to launch an inquiry investigation into the form and function of paper “whirly-birds.” Though initially hesitant, with some prompting teachers were able to describe potential inquiries their own students could conduct by developing testable questions that could be answered by manipulating the form of the whirly-birds, and were able to accurately identify aspects of NOS which were illustrated by the activities. Though they appeared unsure of their abilities to implement inquiry and NOS, they were growing in their knowledge of both.

For Kerry, in particular, this workshop served as an important link between her classroom practice and the new ideas she learned in the workshop. As the teacher participants initially indicated they feel more comfortable teaching language arts than science, it intuitively follows that literature would provide a scaffold for implementing NOS instruction. Changes in Kerry’s teaching following this workshop are described in more detail in her profile.

<u>Modifying existing curricula to focus on inquiry and NOS- second session.</u> This workshop was a continuation of activity begun in previous curriculum adaptation sessions. An additional task during the session consisted of summarizing and sharing the efforts teachers had undertaken to adapt their lessons for use in their classroom. Through this social interaction, teachers were able to share successes and challenges, and offer support to colleagues through ideas and strategies that had worked for them. Teachers discussed learning issues, rather than personal or management issues, indicating they were generally operating at the consequence stage of CBAM (Loucks-Horsley, 1996). For example, teachers compared students’ abilities to distinguish between observation and inference at their respective grade levels, noting common misconceptions and difficulties students encountered.

Another purpose for this discussion was preparation for a presentation to be given by the teachers at the upcoming Hoosier Association of Science Teachers, Inc. (HASTI) annual conference. During the presentation, they would be sharing strategies they developed for teaching inquiry and NOS through “before and after” examples of their lesson adaptations. The teachers each described a lesson from their text, critiquing it and explaining how they adapted the lesson to be more inquiry-based. It was at this point in the program that teachers began publicly mentioning strategies for emphasizing NOS to their students. They wanted to be certain that they shared these strategies with teachers at the conference. The strategies they shared, summarized in Table 2, were a good indicator of what they had learned in the professional development thus far; the aspects of the lessons teachers focused on in their critique were those which were consistent with their growing understanding of NOS. This suggests that while the teachers might not fully be able to articulate their ideas, this tacit knowledge was expressed in their desire to teach effectively to their students. Through the act of planning and teaching NOS to their students, their own NOS understandings were growing. The act of teaching was an impetus to the deliberation between the sometimes contradictory ideas they held about NOS aspects.

<u>Results</u>

Through a review of data from the first year of the project, including teachers’ VNOS-B, and classroom observations, individual profiles were developed for each of the teachers. These profiles show the influence of the professional development program on teachers’ conceptions and practice. Table 2 provides an overview of the general changes in the teachers’ views.

Table2. Change in views of nature of science

Teacher	*Pre-participation Views*	*Post Participation Views—Year Three*
• Kathy	• Science is absolute, black and white • Science never changes • Scientists use one method	• Science is tentative, but robust • Scientists' background knowledge affects their interpretation of data
Andrea	• Science is truth found through empirical methods • Many people agree on scientific truth	• Scientists create knowledge through empirical means and their own background knowledge • Scientists use many methods to develop knowledge • Science is tentative but robust
Melissa	• Laws are proven, and theories can change	• Scientists' backgrounds influence data interpretation • Scientists create knowledge empirically • Theories explain laws • Laws don't change

Student understandings of NOS and inquiry. One gauge of how successful teachers' instructional attempts to integrate inquiry and NOS in their teaching is the influence on students' conceptions. The interviews focused on students' conceptions of nature of science and inquiry, using a modified VNOS for each grade level. Students generally held naïve views of most of the NOS elements at the beginning of the school year, and as would be expected, students of a higher grade level improved their views at a larger percentage. The changes in each grade level students' views will be discussed in the profile sections for each teacher. Table 3 shows an overview of the change in view by grade level and aspect. It should be noted that the conception of the relationship between theory and law was not measured for these elementary students, nor was it emphasized by the teachers.

Table 3. Number of students with adequate NOS ideas pre and post instruction by grade level

Grade	Empirical		Observation and Inference		Creative and Imaginative		Tentative		Sociocultural		Subjective	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
K	0	4	7	7	3	5	0	1	0	1	0	1
1	0	2	4	6	3	5	1	5	2	3	2	3
5	1	2	3	3	1	3	3	3	2	2	2	2
6	1	3	5	5	0	3	2	3	0	2	0	2

Total number of students interviewed:
K—15 (2 classes)
1—8 (1 class)
5—5 (5/6 split)
6—5 (5/6 split)

Learning to teach NOS and inquiry in kindergarten: The Veteran Novice. After 29 years of teaching Kindergarten, Kerry still retains her enthusiasm and love for teaching, despite the fact that she now finds herself more tired at the end of the day than she used to get. She enjoys teaching reading and using literature in her classroom. She teaches science, though it is the subject about which she says she has the least confidence, and she often uses children's literature in addition to hands-on activities to meet curricular objectives. She finds science teaching hard to accomplish at times because kindergarten is half-day, and her schedule is divided into chunks of time she feels are too short for conducting an entire science lesson.

She views science at the primary level as building a foundation for future science learning and a way to get students interested in learning in general. She often selects topics based on student interest, even if they are not featured in her curricula, however she notes it is difficult to find science materials that are developmentally appropriate for her kindergarten students. She is concerned whether she is doing this "thing called science teaching" right, and is open to learning more about how to improve her practice.

At the start of the project, Kerry exhibited naïve views of many of the target aspect of NOS; though she grasped that scientific claims require evidence and data (empirical NOS), she viewed science as "truth." This conception of scientific knowledge as "black and white," which she retained throughout the first year of the project, made it difficult for her to integrate an understanding of the subjective NOS. Despite this conception, she retained the view that theories and laws can change with evidence (tentative NOS), claiming that theories, though durable, change, while laws do not. Prior to participation though she acknowledged scientists use creativity, in the sense of developing different ideas for investigations, she felt that "…experiments are all leading to [the same] result—theory, law, or principle…" This belief is reflected in her practice; she views science as "a way to help children ask questions… and explore," however, her goal for students during exploration was to find the "right answer" on their own, rather than her telling them. However, she concluded the professional development program believing that creativity is also involved in interpreting data, and in making predictions.

In addition to attending the monthly workshops, Kerry invited project staff to teach a model lesson which focused on inquiry and NOS within the content of dinosaurs. Within that lesson on fossils as evidence for "dinosaurs," an example of guided inquiry, the practice of providing students with open-ended questions was modeled. Additionally, the distinction between observation and inference was highlighted. It was after viewing this lesson that Kerry began to demonstrate a more informed conception of the distinction between observation and inference. This support, as well as attending the workshops, had a noticeable impact on Kerry's classroom practice, as delineated below.

In the third year of the project, Kerry became intensely involved with revising her curriculum to an inquiry focus. Kerry spent most of the third year workshops bringing in her curricula, and with support from project staff, restructuring the lessons to an inquiry focus. To do the revisions she read the lesson and figured out what was the main point. She then raised a question that would help her students think about the main point, and then guided them toward an inquiry that helped them explore that idea. She has authored a paper describing the change in her teaching (Hollinger & Akerson, in press).

During initial observation of her teaching, it was apparent that while Kerry's science activities were "hands-on," they would not be considered "inquiry." Nor did she use the activities to illustrate aspects of NOS to her students. For example, in an activity on movement, Kerry read a book about motion, and then students were asked to look around the room and outside the window to identify examples of things that moved. In contrast, after the first year of the project, Kerry exhibited several changes in her practice. The same lesson was revised by Kerry to emphasize the role of "pushes and pulls" as forces that contribute to movement. Students were asked for their ideas of why things move, and responded in ways that the teacher then led them to describe as "things that move on their own" and "things that require the addition of a force in the way of push and pull." They were then asked to take a toy car and some ramps, and explore the influence of different surfaces (i.e., carpet, linoleum, cement) on the cars' abilities to travel a greater distance. Students were asked to design these investigations on their own, and in the debriefing of the activity they were asked to share their conclusions, as well as the evidence on which their conclusions were based. They were then asked to discuss how this activity was "like what scientists do." Kerry spent an entire day of the Kindergarten (2 ½ hours) on this lesson, to allows students to explore and come to reasonable evidence based conclusions, as well as to discuss NOS elements. Most noticeably, she incorporated the formative assessment strategy of charting students' ideas prior to the start of a lesson or activity. "I'm approaching [science teaching] from a different angle. I like introducing science in a new way—finding out what they already know and want to know. Our assumptions aren't always true. Kids are pointing me in the direction I need to go."

Kerry also found a way to build on her strength, children's literature, through strategies shared in one of the workshops. Following the technique modeled by the children's literature workshop facilitator, Kerry used the book *Seven Blind Mice* (Young, 1992) to share with her students how scientists used data, and put the data together to create an explanation of a phenomenon. Though she had frequently used literature with her classes, this was her first explicit emphasis of NOS with her students. As suggested by the facilitator of a first year workshop, she did not use the word "empirical" with her Kindergartners, but rather emphasized "data" and "evidence" as a way scientists both learn and make explanations about the world. The internalization of ideas presented throughout the professional development was apparent in her approach. Though she already brought with her a wealth of knowledge for teaching kindergarteners, Kerry has obviously made tremendous growth in teaching science as inquiry, and in emphasizing NOS in each of her science lessons.

Though Kerry did emphasize NOS elements specifically, her Kindergarteners did not seem to make particular growth in their understandings. The biggest change was for the empirical NOS, where no students recognized that scientists used evidence to make claims, but at the conclusion of the year four of the 15 students interviewed recognized the role of empirical data. It must be noted that students of this grade level were difficult to interview—many of the transcripts simply consisted of "no response" to questions, and for the "no response" categories we considered inadequate views.

Three students, however, did have improved views of the creative and imaginative NOS, believing that "scientists imagine how scientists must have died" and "imagine other things to find out about dinosaurs." One student said scientists "think it out in their heads" to figure out about science. The other students either could not or would not define their views about the creative and imaginative NOS.

Learning to teach NOS and inquiry in first grade: Learning to Know What My Students Know. . Amy has five years of teaching experience, all at the first grade level. She enjoys teaching reading and writing, and comments that she would enjoy teaching science (which she considers her "weak area") more without the constraints of limited time and supplies. Amy is responsible for teaching science to all classes at the first grade level, and often finds the 30 minute sessions during which the other classes visit her room insufficient for achieving her goals. As a primary teacher, her first and foremost goal is encouraging curiosity and enthusiasm, which she views as secondary to knowledge through rote memorization. These goals are apparent in her assessment practices in science, which reflect participation and affective, rather than cognitive, outcomes. She feels that her text series often serves as a barrier for accomplishing teaching goals. She experiences several tensions in her teaching, including negotiating addressing individual students' misconceptions within whole-class instruction and giving priority to students' ideas while accomplishing her own instructional "agenda."

Amy's initial NOS conceptions were a mixture of adequate and naïve views, which were often held in contradiction. While she had a grasp of the subjective nature of science and acknowledged the impossibility of a science without bias, she simultaneously held an absolute view of science, in which "truth" is discovered through empirical means. She defined scientific knowledge as that which "many people hold true. It's tested and the same results come out." However, she could not fully reconcile the role of subjectivity in creating a tentative body of knowledge. Rather than let go of her view of science as achieving absolute and unchanging truths, she reconciled this with a seemingly informed conception of the socio-cultural embeddedness of science, and resorted to a relativistic view. In describing what separates science from other disciplines, she commented, "…it's really taken as—at least in Western cultures—it's taken as *truth*." Thus, in her view what is considered is "truth" might vary by culture. These views were interesting, given her perspective on students' knowledge of science: "I'm not necessarily looking for something specific—and they're not WRONG; you know, in science—or at least the science things I have them do." She allowed her students to find their own, often different answers, though she believed science gave one "right" answer. At the conclusion of the project Amy held the view that personal perspectives, coupled with prior knowledge, influences interpretation of data.

In addition to participating in the monthly workshops, Amy was visited by the project director early in the first year, who modeled how to launch an inquiry investigation and introduce the distinction between observation and inference, while students studied pillbugs in the classroom. Student journals were utilized as a tool for gathering and recording students' ideas prior to and following the investigation to document changes in their conceptions. Students drew pictures of how they imagined pillbugs to look, then after observing them more closely using hand lenses, they again drew pictures. Responses were recorded on chart paper during a class discussion in which students shared their observations, and during which *inference* was introduced as an interpretation of the observations. Amy readily incorporated the use of observation and inference charts, as well as student journals, into her teaching practice.

Initial observations of Amy's teaching revealed a reliance on the text, and a commitment to providing some degree of hands-on activity for students in each science lesson. For example, after a discussion of weather, students ventured outdoors to read the temperature on individual thermometers, and then were asked to make a comparison to the temperatures they recorded indoors. This lesson, as well as others in her text series, was not inquiry-based but activity based. However, during the first year of the program, Amy made attempts to incorporate both inquiry and NOS into her science teaching. For example, as part of a unit on plants, Amy provided seeds for students to plant, and then asked them what type of plant the seeds might grow into. The use of an open-ended question, the answer to which students did not know in advance, was her initial attempt to use inquiry in her classroom. Students revised their predictions about the type of plant as they observed and made inferences over the course of the investigation. While this situation lent itself to explicit instruction regarding the tentative nature of science, Amy did not take advantage of this opportunity, perhaps due to her own uninformed view of this aspect of NOS. However, she was successful in highlighting the distinction between observation and inference using two of the modeled strategies—individual student journals and whole-class charting of observations and inferences. For Amy, modeling was an effective strategy for helping her develop her teaching strategies. As she commented, "it made me realize that a lot of what I'm doing [can be] inquiry."

However, during the final year of the project Amy made good strides in emphasizing NOS elements. She explicitly taught her students about various NOS elements, and had them illustrate posters to show their understandings of the ideas. She hung these on the wall, and observations of her science instruction that year showed that at the conclusion of her science lessons she had students indicate which NOS elements from the posters were apparent in the lesson. Thus, she explicitly emphasized NOS throughout the final year of the project.

Amy's students improved in their understandings of several aspects of NOS. However, like the Kindergartners, there was no aspect where most students in the class held adequate views, though students in her class held a higher percentage of adequate views considering only 8 students were interviewed. Post instruction, five of her students held adequate views of observation and inference, the creative and imaginative NOS, and the tentative NOS. These were the same students across the elements, indicating that these students may have been more developmentally ready to attain more informed ideas. Regarding observation and inference, these students believed that scientists used bones, fossils, and old dinosaur eggs they have found as evidence that dinosaurs existed. Others without informed views retained the "seeing is believing" idea, noting that scientists had seen dinosaurs.

In terms of the creative and imaginative NOS, one student claimed that "scientists have to imagine what happened after they study and research-they have to imagine what the research didn't tell them but almost told them." Others (3) claimed that scientists have to use their imaginations to figure out stuff. Two students who retained erroneous views claimed that scientists could not use their imaginations because they would be wrong because imagination is "not real."

Concerning views of the tentative NOS, one student held the view that" new tools in the future would help scientists get more information." Another claimed they may simply "change what they study." Two others held more of the view that scientists "aren't exactly sure, just kind of sure" so they might change their ideas. These are definitely ideas that move toward appropriate NOS views, particularly in light of the emphasis in Mary's classroom.

Learning to teach NOS and inquiry in sixth grade: Mary's story. Mary taught in a 6^{th} grade self-contained classroom, and in the third year of the project taught a 5-6 split class. As a relatively new teacher, she was enthusiastic and eager to develop a repertoire of teaching ideas and strategies. . She tended to rely on the adopted text series to plan science lessons during her first year of participation, but found this text insufficient for accomplishing her goals. Mary decided to join the project during the second year as a way to improve her knowledge and skills for teaching science. Data relating to her conceptions and teaching practice is limited to the two years of her participation.

Based on her initial responses to the VNOS-B, Mary appeared to have adequate views of many of the target aspects of NOS. She explained the subjective NOS, stating that "scientists' backgrounds influence how they interpret data." She was similarly able to describe the tentative NOS, and how theories can change with new evidence. However, she held an incomplete understanding of the tentative nature of science because she believed while theories could change, laws could be proven. At the conclusion of the project she retained her informed views, and held a better view of the role of indirect evidence in making claims.

Because her own conception of observation and inference was adequate, this seemed an appropriate starting point for modeling how to make NOS explicit to her own students. At Mary's invitation, the project director visited her classroom and taught a 45 minute activity ("tricky tracks") (add citation) which highlighted the distinction between observation and inference using students' own ideas about a presented scenario. The students were given an organizer to categorize their responses as "observation" or "inference." Subsequent observations of Mary's teaching revealed she continued to use this organizer during investigations of other content, and has made efforts to reinforce students' conceptions of this distinction. An additional impact on Mary's practice became evident after the workshops on modifying curricula; though not a part of the project during the workshop *Strategies for Adapting Curricula to be Inquiry-based*, Mary was able to learn from her peers and with assistance from the project staff transform "cookbook" text activities to mini-inquiries. A successful strategy for her was to enable students to brainstorm variables involved in the cookbook activity, then design inquiries to investigate the effects of those variables on the outcome of the new investigation. Mary also described the changes in her science instruction as a result of the professional development program in a paper (Rooney & Hanuscin, in press).

The fifth and sixth grade students in Mary's class made some interesting changes in their NOS views. They seemed to be more capable of attaining these NOS conceptions, and there did not seem to be much difference between the levels they were capable of attaining, possibly because they are not that different developmentally and they participated in the same course activities that explicitly emphasized NOS. Students in Mary's class held better ideas of the empirical NOS, creative and imaginative NOS, and tentative NOS, while they retained their adequate views of the distinction between observation and inference.

For example, all students agreed that scientists know about dinosaurs because they made inferences from data such as bones, DNA, and footprints. Empirically, students began to describe studies, or experiments scientists need to do to provide evidence for their claims. Regarding creativity and imagination, the students began to recognize the role imagination and creativity play in the development of scientific claims. For example, students said:

> They imagine how the experiment will turn out, what the evidence means (6^{th}, post)
>
> They imagine what the evidence means, like if they see a bone they say “oh yeah, this is probably from a T-Rex—I’ve seen those before. (6^{th}, post)
>
> They have to imagine to figure out their complicated work (5^{th} , post)

Students in Mary’s class also had improved ideas of the tentative nature of science. Most agreed that scientific claims could change. They described the reasons for scientists changing their ideas as:

> They figure out new things to study and new answers to things. They are not positive, so they could change (5^{th}, post).
>
> They are never sure because evidence never proves anything. They will find new things that represent their ideas. (6^{th} post)
>
> Students in Mary’s class did have improved views of these aspects of NOS.

Discussion

The results of our study provide insight into teachers’ conceptions of NOS and inquiry and those strategies which were effective in helping teachers improve their understandings and practice of teaching inquiry and NOS. Following Bell and Gilbert’s teacher development model that indicates three components of development must be present we focused on teachers’ personal, social, and professional development. All participants claimed they were insecure about teaching science, yet also displayed a commitment to improving their science teaching, an important first step in their *personal development*. Teachers also participated in the *social development* component of that model, by engaging in discourse with peers regarding their practice. Furthermore, support from project staff and colleagues provided *professional development*, offering new ideas and strategies to address their needs. However, it is necessary to discern which specific aspects of our program were effective, and what can be improved to support these teachers (and others like them).

At the start of the project, all teachers held inadequate views of the target elements of NOS. While their viewpoints improved in many areas, there is evidence that these viewpoints are still developing, and indeed, are still not adequate in all areas, nor integrated into a coherent view of

NOS, particularly of the distinction between theory and law, and the tentative nature of scientific laws. Many contradictory views were initially held simultaneously by the teachers. However, sustained professional development improved their views. One particularly strong idea that has finally tumbled from the teachers' conceptions is the belief in a single scientific method. Amy even spent time gathering evidence that there is no single scientific method to convince her physicist husband to change his view. Providing teachers the necessary extended period of time over which to articulate, challenge, and revise their NOS conceptions was a strength of our program, and allowed to teachers to revise their ideas and use them in their own teaching.

Related to their change in conceptions was teachers' awareness of NOS as an important instructional objective for science. As described by Lederman (1999), internalization of this importance is a factor that facilitates the relationship between teachers understanding of NOS and their classroom practice. Initially teachers lacked abilities to define NOS, and consequently a belief that it was important to teach. The project staff prompted them at each workshop to focus on NOS as part of the activity, such as when teachers were asked to describe how their inquiry activity helped illustrate aspects of NOS. However, as found by Akerson and Abd-El-Khalick (2003) even internalizing the importance of, and being motivated to teach NOS is not enough to ensure that experienced teachers explicitly include NOS in their instruction. It was necessary to support these teachers in their efforts to teach NOS to their students. By the second year of the project teachers did not need prompting—they readily mentioned including how they were addressing NOS elements in their own lessons for their Hoosier Association for Science Teaching, Inc (HASTI) presentation, for example. Their willingness to share their own NOS teaching strategies with other teachers illustrates how far they have come in one year.

In contrast, teachers more readily internalized the importance of inquiry as an instructional objective than they did NOS, and as such, were more immediate in their attempts to integrate this into their practice. Without this prior commitment to inquiry it is unlikely that teachers would have been able to emphasize NOS, given that their text series promoted a view contradictory to many of the target aspects through a "cookbook" approach to science. Again, a success of the program was in allowing teachers time to reflect on and question their ideas about inquiry. As Kerry stated:

> I enjoyed the part… that was more hands-on, that gave me some concrete things that I could do in the classroom--- BUT, I think I wouldn't have been so gung-ho about that part if I hadn't done the beginning part and just thinking about what inquiry is and why we teach it.

All teachers implemented some form of inquiry, whether structured or guided, (Colburn, 2000) into their science teaching, either providing students with questions and asking them to design ways to answer these questions (as in the case of the primary teachers) or asking students to identify variables that could be manipulated to conduct further investigations about phenomena already investigated through a more structured means. Students experienced more autonomy in conducting science investigations than in the first year. They were asked open-ended questions for which they needed to design investigations to answer the questions. Moreover, the teachers showed more of a commitment to building on their students' prior knowledge. In most lessons we observed students were asked for their prior knowledge about a topic, which was recorded in writing either by the teacher, or by the students themselves in science journals. These student ideas served as aids in helping teachers plan future lessons to improve student understandings, such as when Kerry asked students to describe what influences how fast a car can move, and then asked students to explore their ideas by having toy cars move from ramps on different surfaces.

While all aspects of the project influenced teachers to various extents, individual support to teachers was a critical element of teachers' social development. As Amy explained:

> …feeling like there was… having the support there—that I could ask you guys, and talking about it with other educators, I think is really, really helpful and motivating for a teacher—for me.

Having the project staff teach model inquiry lessons while emphasizing elements of NOS seemed to be the most influential component of the professional development thus far identified as a trigger for teachers to emphasize NOS in their classrooms, and is in line with previous studies and recommendations (Akerson & Abd-El-Khalick, 2003; Loucks-Horsley, et al 1996). It is particularly difficult for teachers who do not have experience conducting science inquiries to adequately conceptualize and teach scientific inquiry (Kielborn & Gilmer, 1999), and it has also been found difficult for elementary teachers to explicitly teach NOS to their students, even when they show a commitment to do so (Akerson & Abd-El-Khalick, 2003). Viewing the modeled lessons enabled the teachers to see how these types of lessons "worked" with their own students. All teachers began using observation and inference charts, as modeled in their classrooms, in various ways with their own grade level of students. Additionally, teachers who saw the use of student science journals modeled in their classrooms continued to use them as well with their students.

Needless to say it would be difficult to model effective instruction of all NOS aspects in all teachers' classrooms. The teachers requested a "guide" or packet of NOS activities which they could use with their students. Development of curricula that illustrates ways for teachers to explicitly teach NOS elements within inquiry lessons, coupled with professional development, would go a long way in supporting teachers in their endeavors. Such curricula could be used as a scaffold to help teachers envision explicit NOS instruction within inquiry lessons. However, simply providing curricula without professional development would be antithetical to what we have proposed through our program, and could result in a form of "activitymania" (Nelson & Moscovici, 1998).

Though the teachers do have a better focus on inquiry and NOS, there are still constraints preventing them from teaching as science as outlined by reforms. For example, when they were unsure of how to approach an activity they initially simply presented the lesson as suggested in the teacher's manual of their text series. Invariably these activities were not inquiry focused, and did not explicitly emphasize any NOS elements. This practice was a barrier to their continued professional development. In the second year of the program, however, they became much better at adapting their lessons, and by the third year of the program this barrier really did not exist. Other constraints mentioned consistently by the teachers include the lack of time and materials for science teaching. While some solutions were offered during the project, such as providing classroom volunteers from the university to collect and organize materials, teachers did not take advantage of these opportunities. The additional task of management of volunteers perhaps made this a less than desirable solution.

For Kerry, there was a perceived constraint that the school day (half day kindergarten, scheduling of specials such as art, music, and PE, and library visits) made it difficult for her to teach science because of the smaller segments of time available for instruction. However, she has made some adjustments to her schedule that allow her to teach lengthy periods of science in her classroom. Several times a month she now schedules a day for science during which the whole 2 ½ hour class day is devoted to science explorations with her students.

One key feature of the program that enabled substantial teaching change to take place was providing teachers with time in terms of the length of the program and release time to explore ideas. Another feature was the collaborative nature of the relationship between the project staff and the teachers, as well as the collaboration among the teachers themselves. We negotiated goals for each work day, and worked toward those goals, while maintaining an emphasis on the nature of scientific inquiry. One of the main features that helped with the success of the program was providing individualized on-site teaching support to the teachers. We were able to model lessons in their classrooms, as well as provide feedback on lessons they taught, and help with lesson planning and assessment ideas.

The influence on students' NOS views was negligible, at least as measured through the interviews, on Kindergartner's views, yet more substantial on the first graders' and particularly fifth and sixth grade student views. This differential attainment in views, despite similar explicit NOS instruction, could be simply explained through raising the question of "when are students developmentally ready to conceptualize the aspects of NOS emphasized in the reforms?" For instance, are Kindergarten students really ready to understand the tentative NOS when they are still trying to figure out what it means to be at school? Another question is whether the one-on one interviews using our instrument was the best way to understand young students' NOS views. Many of the kindergartners simply did not respond to the questions. We are unsure of whether they did not understand the questions, or just did not know the answers. However, it is apparent that the explicit emphasis on NOS elements worked for the first grade and fifth and sixth grade students, whose responses became more elaborate and in-line with reform recommendations at the conclusion of the school year. These results provide further evidence that explicit reflective instruction can be effective for not only changing teachers' views, but also children's NOS views.

References

2000 National Survey of Science and Mathematics Education. (2002, April 26). Retrieved April 26, 2002, from http://2000survey.horizon-research.com/

Abd-El-Khalick, F. S., & Akerson, V. L. (under review). Learning about nature of science as conceptual change: Factors that mediate the development of preservice elementary teachers' views of nature of science. *Science Education.*

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (1998, April). *Improving science teachers' conceptions of the nature of science: A critical review of the literature.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA.

Akerson, V.L., Abd-El-Khalick, F. S., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37,* 295-317.

Akerson, V. L., & Abd-El-Khalick, F. S. (under review). A fourth grade teacher's attempts to teach nature of science elements: A year long case study. *Journal of Research in Science Teaching.*

American Association for the Advancement of Science (1990). *Science for All Americans.* New York: Oxford University Press.

American Association for the Advancement of Science (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Atwater, M. M., Gardener, C., & Kight, C. R. (1991). Beliefs and attitudes of urban primary teachers toward physical science and teaching physical science. *Journal of Elementary Science Teaching, 3*(1) 3-11.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: W. H. Freeman.

Bell, B., & Gilbert, J. (1996). *Teacher development: A model from science education. London: Falmer Press.*

Bogdan, R. C., & Biklen, S. K. (1998). *Qualitative research for education (3rd ed.).* Boston: Allyn & Bacon.

Brown, J. S., Collins, A., & Duguid, P. (1986). Situated cognition and the culture of learning. *Educational Researcher, 17* (1), 32-42.

Carspecken, P. F. (1996). Critical ethnography in educational research: A theoretical and practical guide. NY: Routledge.

Colburn, A. (2000, March). *An inquiry primer.* Science Scope.

Cox, C. A., & Carpenter, J. R. (1989). Improving attitudes toward teaching science and reducing science anxiety through increasing confidence in science ability in inservice elementary school teachers. *Journal of Elementary Science Education, 1* (2), 14-34.

DeBoer, G. E. (1991). A history of ideas in science education: Implications for practice. New York: Teachers College Press.

Dickinson, Burns, Hagen, & Locker (1997). Becoming better primary science teachers: A description of our journey. *Journal of Science Teacher Education, 8,* 295-311.

Duschl, R. A. (1990). *Restructuring science education.* New York: Teachers College Press.

Exploratorium: Museum of Science, Art, and Human Perception: (n.d.) *Institute for Inquiry: Parachutes Activity*. Retrieved January 15, 2002 from http://www.exploratorium.edu/IFI/activities/parachutes/parachutes.html

Gilman, P. (1993). *Something from nothing.* New York: Scholastic.

Harmon, H. L. (2001). *Attracting and retaining teachers in rural areas.* Paper presented at the Annual Meeting of the American Association of Colleges for teacher Education, Dallas, TX.

Harlen, W. (2000). *The teaching of science in primary schools, 3rd Edition.* London: David Fulton Publishers.

Henriques, L. (1998). *Maximizing the impact of your in-service: Designing the inservice and selecting the participants.* Paper presented at the Annual Meeting of the Association for the Education of Teachers of Science, Minneapolis, MN.

Indiana Department of Education (2000). *Indiana's academic standards, Teachers' Edition.* Indiana.

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

Lederman, N. G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching, 29,* 331-359.

Lederman, N.G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of* *science in science education: Rationales and strategies* (pp. 83-126). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Loucks-Horsley, S. (1996). Professional development for science education: A critical and immediate challenge. In R. Bybee (Ed) National standards and the science curriculum. Dubuque, IA: Kendall/Hunt.

Loucks-Horsley, S., Hewson, P. W., & Love, N. (1998). Designing professional development for teachers of science and mathematics. Thousand Oaks, CA: Corwin Press.

Luft, J. A., & Pizzini, E. L. (1998). The demonstration classroom in-service: Changes in the classroom. Science Education, 82, 147-162.

McComas, W. (1996). Ten myths of science: Reexamining what we think we know about the nature of science. *School Science and Mathematics, 96,* 10-16.

National Research Council. (1996). National science education standards. Washington DC: National Academy Press.

National Research Council (2000). Inquiry and the national science education standards: A guide for teaching and learning. Washington DC: National Academy Press.

Perkes, V. A. (1975). Relationships between a teacher's background and sensed adequacy to teach elementary science. *Journal of Research in Science Teaching, 12,* 85-88.

Schoeneberger, M., & Russell, T. (1986). Elementary science as a little added frill: A report of two case studies. *Science Education, 70,* 519-538.

Schwartz, R. S., Lederman, N. G., & Thompson, R. (2001, March). *Grade nine students' views of nature of science and scientific inquiry: The effects of an inquiry-enthusiast's approach to teaching science as inquiry.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, St. Louis, MO.

Schwartz, R. S., & Lederman, N. G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39,* 205-236.

Schwartz, R. S., & Crawford, B. A. (2003). *Critical elements for teaching about nature of science in the context of authentic scientific inquiry: Practical guidelines for science teacher educators.* Paper presented at the annual meeting of the Association for the Education of Teachers in Science, St. Louis, MO.

Taylor, S. J., & Bogdan, R. (1984). *Introduction to qualitative research methods: The search for meanings.* New York: John Wiley & Sons.

Tilgner, P. J. (1990). Avoiding science in the elementary school. *Science Education, 74,* 421-431.

Tobin, K. (2000). Interpretive research in science education. In A. Kelly and R. Lesh (Eds.) *Handbook of research design in mathematics and science education.* Mahweh, New Jersey: Lawrence Erlbaum.

Welch, W.W., Klopfer, L.E., & Aikenhead, G.E (1981). The role of inquiry in science education: Analysis and recommendations. *Science Education* 65:33-50.

Wiesner, D. (2001). *The three pigs.* Houghton Mifflin.

Willis, J. (1991). *Earthmobiles as explained by Professor Xargle.* New York: Dutton

Young, E. (1992). *Seven blind mice.* New York: Scholastic.

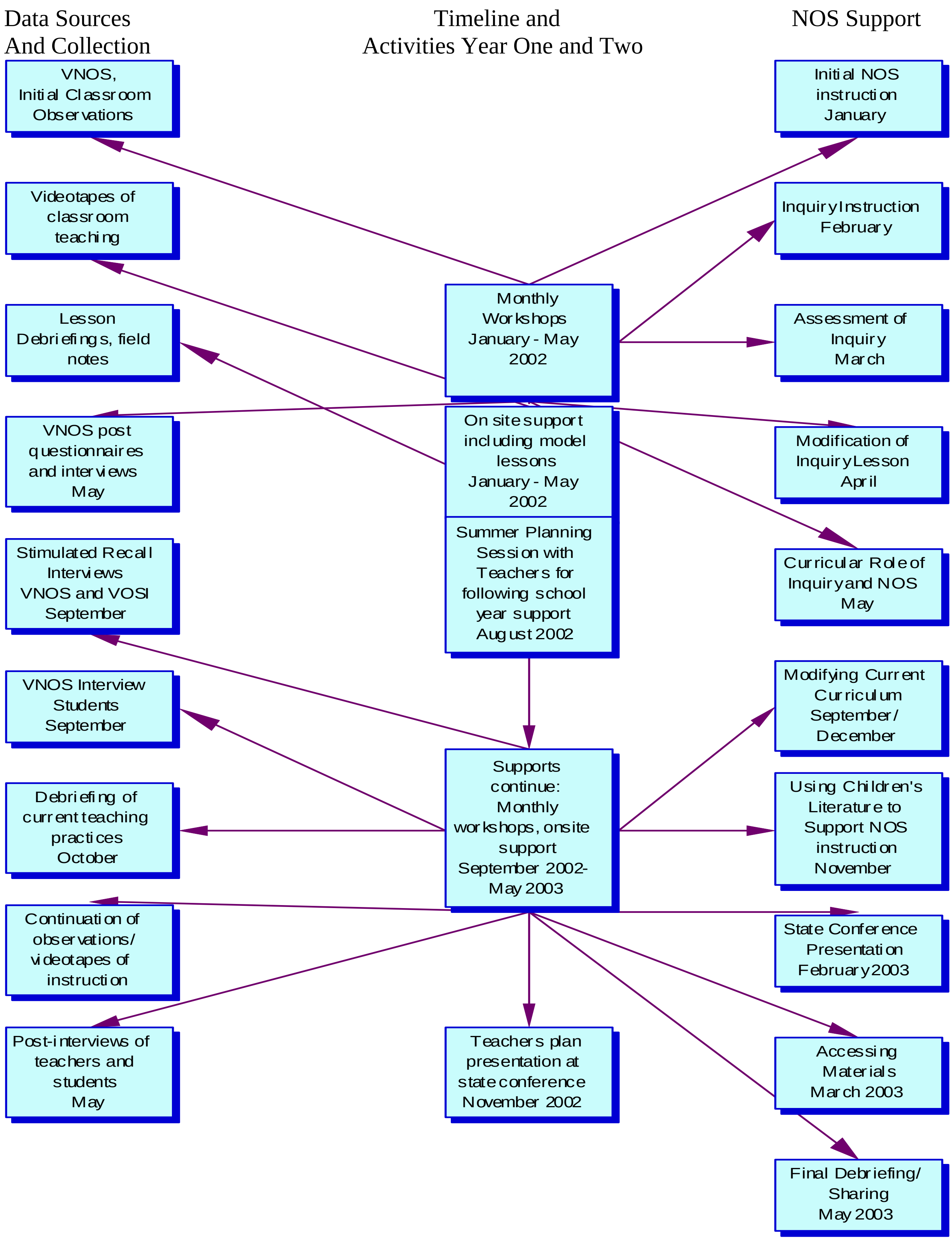

Figure 1. Overview of the study

Table 1. Initial list generated by teachers as they evaluated activities

Criteria of a “good” science lesson
• Provides students with “hands-on” experience • Topic is at an appropriate level for the students • Includes the scientific process • Uses materials that are easy to obtain/use • Starts with a question • Allows students to complete the activity in different ways • Allows students sufficient time to fully explore the concepts of the lesson • Sparks student interest • Relates to students’ everyday lives

Table 2. Illustration of how various teachers adapted their lessons

Grade Level/ Topic and Focus	Original Lesson (featured in text series)	Lesson Adaptation (revised by teacher)
Kindergarten: Push and Pulls Lesson focus was to help students recognize how things move	Lesson begins with pre-determined step-by-step activity, followed by a question Materials were only used by one child at a time (taking turns) Narrow range of experience (only two surfaces) Little chance for in-depth exploration	Students asked question, and how they might go about answering it Enough materials provided for every child to be engaged (selecting and testing multiple surfaces) Students discussed inferences based on what they observed during their investigations (nature of science)
First Grade: Magnets Lesson focus is to help students note what is magnetic and what is not.	Lesson begins with teacher TELLING students information prior to any investigation or discussion of prior knowledge Poster book is read, and students are asked to repeat information told previously by the teacher Students then verify what they've been told and what they've read	What do we know about magnets?" chart generated Students investigate magnets on their own to test their ideas Chart made of students' observations and inferences from the investigations Revisit chart of "What we know…" and change ideas that were wrong, add ideas that are new
Sixth Grade: Weather Lesson focus was a cookbook activity to have students explore weather	Step by Step cookbook activity Main skill used is following directions 15 minute time frame	Students identified and manipulated variables within the experiment Skill focus on making observations and inferences Exploration engaged students for over 45 minutes.