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Kimberly Bilica
ojsadmin@journals.library.wisc.edu

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Kimberly Bilica
University of Texas-San Antonio

Introduction

Most reforms in science curriculum and assessment surface from formal studies headed by university researchers or science organizations. The professional development that results from such studies often takes the form of short-term, decontexualized workshops for teachers. Unfortunately, we do not hear enough from teachers who systematically study the changes taking place within their own classrooms. The need for conversation on science reform is especially evident at the elementary level where, according to a national science education survey, only 25% of elementary teachers reportedly felt "very well qualified to teach science" (NSTA, 2002, p. 6). This alarmingly low percentage provides strong evidence for the need to improve elementary science teaching.

In this paper, I will provide an example of how a team of four elementary and intermediate teachers of science made substantive changes in their classrooms based upon an action research study. First, I will discuss the connection between national science teaching standards and action research as a professional development. Next, I will describe how the teachers' action research study, findings, and challenges. Last, I'll describe the impact of the teachers' activity on science teaching and learning, from a local and global perspective.

Standards for Effective Science Teaching

Of all available sources on reform, the *National Science Education Standards [NSES]* (National Research Council, 1996) offers the most cohesive and relevant vision for the improvement of elementary science teaching. The *NSES* dedicates an entire chapter exclusively to standards that support the teaching of science (National Research Council, chap.3). This chapter is the first in a series of chapters on science reform, and its order of placement within the chapter sequence is not coincidental. According to the *NSES*, the Science Teaching Standards are presented first "to highlight the importance of teachers in science education" (p. 27).

The Teaching Standards focus on the relationships and interactions within classrooms and recognize that each classroom within each school has its own special needs and strengths. The *NSES* advocate for change that engages students and teachers in dynamic and interactive science experiences. Specifically, the Teaching Standards highlight the role that a teacher's enthusiasm and understanding of science has on student understanding and engagement in science.

Action Research as Professional Development

The Teaching Standards advocate for more collaboration between teachers that results in critical reflections on the practice of teaching

science. The *NSES* states that effective teaching "requires a sophisticated set of judgments about science, students, learning, and teaching. To develop these judgments, successful teachers must have the opportunity to work with colleagues to discuss, share, and increase their knowledge" (p. 37). Action research provides a systematic, pragmatic, and accessible means for teachers to reflect upon their teaching practice. According to Meyers & Rust (2003), action research is "the essential activity of a reflective teacher and …a viable means for teachers to identify how their practice is improving student achievement" (xvi). I believe that action research is a particularly good method to examine science teaching and learning, as it applies the features of science – questioning, collecting and analyzing evidence, and drawing conclusions – to the practice of teaching.

Action research is not a panacea. In most schools, teachers are under tremendous pressure to maintain their daily teaching and professional responsibilities. Rigorous state testing and accountability exacerbates the pressure. In short, the pace of teaching leaves little time for reflection; however, teachers and school administrators can design their school-based strategic plan so that it includes action research as part of their professional development goals. If the school promotes collegial collaboration and empirically centered critical reflection as part of its core strategy for achievement, action research is a natural fit.

Loucks-Horsley (1999b) describes quality professional development as helping teachers to understand subject matter, learners and learning, and teaching methods, not as discrete activities, but as holistic entities within the context of schools. These contexts are as varied as the children within classrooms, so "different teachers in different contexts need different professional learning opportunities" (Loucks-Horsley, 1999a). Action research expands traditional workshop-style professional development activities to be more inclusive, collaborative, and organic to understand the teaching-learning environment.

The Teachers' Journey

Meeting the Action Research Group

As an assistant professor of science education, I enthusiastically encourage the teachers in our science education program to challenge their own ideas about best practices in science teaching so that they are not merely reproducing other peoples' ideas but are leading the profession into the innovative, creative, and inspired science teaching. Aware of my interest in such practices, one of my university colleagues connected me with the action research group. The connection led to an invitation from the teachers to meet with them during one of their weekly meetings.

After only one meeting with the action research group, I knew that their journey would inspire other teachers to become teacher-researchers. My challenge was to find a way to share the teachers' story with others. With my prodding, we decided to write about their action research journey. The teachers were busy with their schoolwork, so I took the initiative to write their story with and for them. Over the course of an academic year, I met with the teachers as part of their Friday afternoon gathering. During many of these meetings, we sat and discussed their experiences so that we could properly process the journey for other readers. The teachers brought their journals and shared their methods, models, and findings from their studies. The next section of this paper describes the group's story as it was relayed and written during our Friday afternoon get-togethers.

Context for a Learning Community: How the Teachers Met

The four teachers involved in the group were veterans of the teaching profession with an average of 23 years of teaching experience. None of the teachers had any specific course-related science background; however each of them had an interest in scientific inquiry as a result of their shared experience as master teachers in a local systemic change grant. The teachers had extensively read the professional literature on inquiry and on action research, and, with the assistance of local experts,

designed their research study, which grew from their leadership roles in the grant. Over the period of an academic year, the teacher-researchers conducted the study in their respective classrooms and regularly shared their data, insights, and progress with one another during their Friday afternoon meetings.

The teachers' collaborative journey has its roots in the early 1990s when they were identified as master teachers and were invited to participate on a local systemic change project funded by the National Science Foundation (NSF). The goal of the funded project was to educate teachers in inquiry-based methods of science education through hands-on kits and advanced professional development. The four teachers were part of a larger group of leaders involved with planning and teaching for the NSF project.

The teachers were also full-time classroom teachers in a large, urban school district. The action research group included Norma, a program coordinator for an early childhood center; Jan, a special education resource teacher at a neighborhood school; Dianne, a 5/6th grade teacher at an arts magnet; and Judy, a Pre-K/K Montessori teacher. The teacher group represented four different schools and several different grade levels, but one important and binding commonality held them together: they were all interested in teaching and learning through inquiry.

As the teachers met with one another on a regular basis to work on the NSF project, their personal relationship grew. They shared questions and concerns about their classroom experiences, and they looked to one another for collegiality and intellectual stimulation. What they found through their conversations was that they had quite a few hunches about classroom practices, but they did not have any way to actually *know* if their hunches led to results. They wanted to identify a vehicle to systematically examine their hunches.

How Action Research Found Them

The vehicle surfaced when one of the teachers, Judy, was introduced to action research through a project with her student teacher. The student teacher was required to conduct a small action research study as part of a university course requirement, and Judy discovered that action research could provide a means to explore her own classroom hunches. With support from the NSF project administrators, the action research group formed and they began reading about action research, as they sought models to structure their journey.

As the teacher group studied action research, they recognizedd that action research could provide them with exactly what they wanted: a way to determine if their hunches about teaching science were correct. The group wanted to maintain a close connection between their research studies, their work with the NSF project, and their interests as classroom teachers; therefore, they collectively decided upon two guidelines for their study. First, they wanted to use authentic objects to stimulate student inquiry. Second, they wanted to write one common research question that could be studied in each of their very different teaching situations.

The first guideline, the wish to study inquiry with authentic objects, directly related to the work that the teachers performed as master teachers on the NSF grant. Authentic objects, as defined by the teachers, are the items that students find in the real world as opposed to models or representations that only imitate the real world items. The use of authentic objects was a natural extension of the NSF project because the teachers used real objects such as bones, feathers, and pelts in the professional development courses and kits designed for the grant. The action research teachers noted that authentic objects stimulated many questions for the teachers involved in the NSF project; they wondered if the objects could inspire their students to also ask questions. The teachers all agreed that inquiry through the use of authentic objects would be the focus of their action research project.

The second guideline for the project was to formulate a common question that they could each member could apply in their respective classrooms. By studying a common question,

they could take advantage of their common interests but still pursue those interests within their own classrooms, attending to the specific needs and abilities of their students. Because the teachers' classrooms – students, subject matter emphases, and grade levels - differed so markedly, the common question would provide them with common ground.

Deciding upon the question to study

Having established the guidelines for the study, the group then had to write their research question. From their reading on research methods, the teachers knew that their research question was one of the most important decisions for their study, as it would be the driving element in their data collection and analysis. However, the quest to formulate a good research question proved difficult.

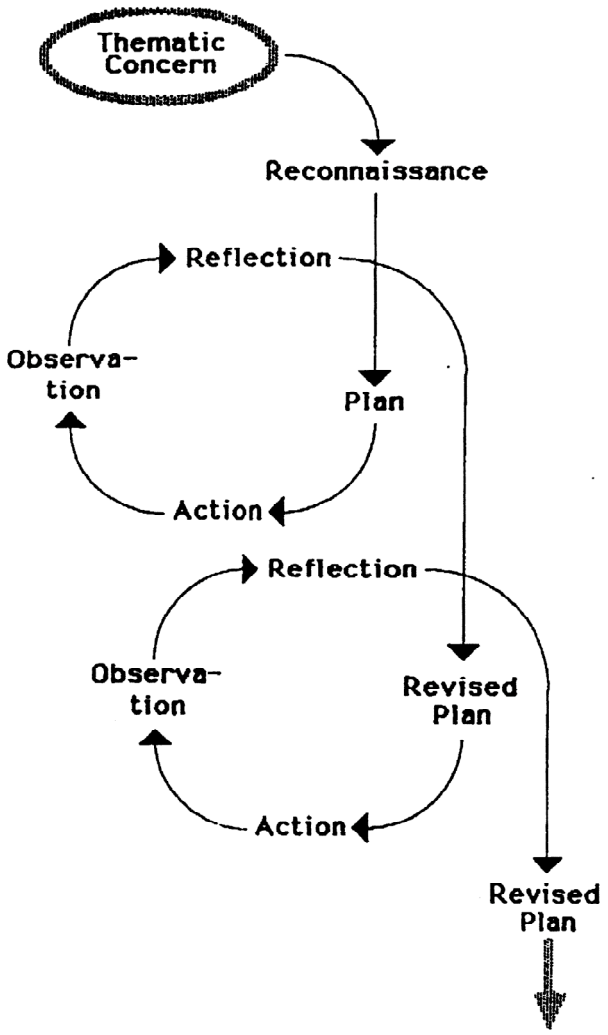
The teachers developed several questions on their own, carefully considered each of them, but had some difficulty isolating one specific research question that met the demands of research and incorporated the guidelines that the group had established for themselves. After several weeks of frustrating attempts to write their question, they realized that they needed some expert assistance. The teachers found that expertise in a local high school principal who had also was an expert on action research (Battaglia, 1997). With Dr. Battaglia's mentorship, the teachers, through much more discussion and deliberation, were able to identify a question. They decided to ask: "In what ways might I promote inquiry using authentic objects as elements of surprise?"

Identifying an Action Research Model

Dr. Battaglia guided the group through the question-development process, but she also taught the teachers that the research question is only one step in designing an action research study. Because research demands systematic and purposeful planning, the group needed a research model or what they called a roadmap for their journey. With Dr. Battaglia's help, the group decided to use the Action Research Spiral Model (Kemmis & McTaggart, 1988) to structure their action research. The AR Spiral Model is an iterative, ongoing, reflective action research model with several distinct phases (Figure 1).

Figure 1

The Action Research Spiral[8]



Over the course of the group's yearlong study, the teachers moved through several iterations of the AR Spiral Model. The model is not something that tethered the action research; rather, it sequenced the experience so that as the teachers became more deeply involved in data collection and analysis, planning, and revisiting the study naturally flowed from the model. The model did not rigidly determine the flow, but the model buoyed the experience so that the teachers were able to describe their journey from its beginning to its eventual close.

In the end, the model provided initial scaffolding for their experience, but as the teachers moved more deeply into their study, asking serially more focused questions, the faded from the forefront of their activity.

Data Collection & Analysis

Like any other research project, the study required the collection of substantial amounts of data. For this, the teachers relied heavily upon the use of journals. The teachers had been using journals to record ideas as they related to their work with the NSF project. Now, with the action research project, their journals' value expanded. The teachers used the pre-bound composition books to record data so that their data could be kept in an orderly space that was sequentially bound. The data took the form of written observations and reflections during class, after class, or during the regular Friday afternoon meetings. The data included student responses to the skulls and other authentic objects, student quotes, and the teacher's personal reflections. In much the same way that scientific researchers use laboratory journals, the teachers' journals contained a cohesive record of evidence related to their research journey.

The teachers did not follow any prescribed format for the analysis of their data; however, they did meet on a weekly basis to share their data, discuss the meaning, compare their students' reactions, and to digest the meaning of the data. Therefore, their analysis was authentic and closely related to their professional practice. The teachers discovered whether their hunches led to expected results or new questions.

Results of the Study

From my interpretation of their work together, the teachers made three iterations through the action research spiral (Figure 1). The first iteration, called *reconnaissance* provided them with insights that defined the next iteration. At each turn, the teachers made new insights into their original research question, devised strategies, and shared the outcome of their strategies in their weekly group meeting. The following describes the teachers' results at each phase of their study.

The first spiral: Teaching children that "It's okay to wonder."

The teachers started their action research project by conducting a reconnaissance study. A reconnaissance is defined by Merriam Webster's Online Dictionary as a "preliminary survey to gain information" (Merriam-Webster, 2005), and in the case of the teachers' action research, the reconnaissance gave them the chance to gather baseline data for future action. The reconnaissance plan was based upon the shared research question; it required teachers to place a real mammal skull somewhere in their classrooms and allow the students to explore the object on their own without any provocation.

Following the reconnaissance portion of their study, the teachers recognized that their particular classroom routines and procedures influenced students' abilities to engage in inquiry. The teachers had hoped that by placing the skulls in the classroom without any fanfare, the students would show some spontaneous excitement about the object. The teachers were surprised to find that some of their students had unexpected reactions to the mammal skulls.

Jan, a special education resource teacher, placed a skull in her classroom during reconnaissance and was surprised when her students completely ignored the skull. She had hoped that her resource room students would find this object fascinating, and they would be drawn to it immediately. This did not seem to be the case. Jan realized that because her students had a routine to follow every time they entered the classroom (attendance, and so on), they needed her permission to deviate from their routine.

Jan decided to ask students questions in order to permit them to engage with the authentic object. She asked the students, "What do you notice? What do you think about it? What do you want to know?" By asking these questions, Jan invited the students into the inquiry process, and they were full of questions and

observations. Jan learned an important lesson from her reconnaissance: that by asking a few inviting questions, she was able to give her students permission to participate in the inquiry. Jan said, "I had to let them know that it is okay to wonder."

Dianne, a grades 5/6 teacher in a magnet program, also had an important realization during her reconnaissance study. She found out that her students had been taught to be skeptical of spontaneous learning events. Like her research colleagues, Dianne placed the skull in her classroom and anticipated many questions from her students. The children did have questions, but they were not the kind of questions that Dianne had expected. Dianne described the students' questions as having the purpose of deciphering her intentions for bringing the skull to their classroom. The students were convinced that Dianne had ulterior motives for bringing the skull to class. For example, some of the students asked if the skull (of a small mammal with large teeth) might have something to do with Groundhog Day because is was February.

Dianne realized that the natural curiosity that we expect of young children had been tempered by a school culture that teaches children to figure out what the teacher wants or what the activity is supposed to mean. The students had come to believe that every lesson has a single, simple answer, and it was their job to get that answer right away. Dianne had to teach her savvy students how to re-engage their own curiosity and to explore the object with a fresh and open mind.

The second spiral: Powerful questions/powerful thinking

Dianne and Jan's reconnaissance experiences, among others, helped lead their action research into the next iteration of the Action Research Spiral. The reconnaissance phase offered insight into the role of inquiry in a classroom, and it heightened the teachers' awareness of the need to teach children how to openly examine, explore, question, and share their ideas. For the next phase of their action research study, the teacher-researchers refined their question, localizing on their own teaching practices. Their revised research question was, "How can we help children to engage freely in inquiry with authentic objects?"

The move from a traditional classroom setting, where the teacher asks the questions and the students supplies the answer, to an inquiry classroom, where the questions come from student explorations can be quite difficult. Based upon the data collected in the reconnaissance phase of their journey, the teachers noted that children typically ask simple questions, such as "Is it real?" or "Is it a dinosaur?" These types of questions are closed-ended, simple requests for information. The teachers realized that they had to find a way to encourage the children to ask different types of questions. They called these new questions *powerful* because they are based in wonderment and reveal children's understanding of an object.

In order to become better inquiry teachers, the action research group had to develop a strategy to elicit powerful questions from their students. They found that by asking open-ended questions, the students supplied rich responses, which helped them to better understand what students thought about objects. Some of the open-ended questions that the teacher research group used in the second iteration of their study were:

- What do you see?
- What do you think about these objects?
- Tell me about them.
- Draw one.

Is there one object that you would like to find out more about?

The teachers noted that they need to learn to ask *powerful questions* as part of their own teaching. According to the teachers, powerful questions in teaching are questions that are investigable and promote inquiry. The teachers learned to recognize when they were asking powerful questions and how these questions led to students' abilities to ask their own powerful questions.

As a program coordinator for a pre-K center, Norma included several of her pre-K teachers in their study of children's questions. Norma found that the teachers who were using inquiry with authentic objects were excited about their students' growing ability to ask powerful questions – and their own ability to recognize these types of questions in their own talk. With the teachers' new understanding of powerful questions, Norma saw an increase in the number of teachers who were creating new learning environments that engrossed children in an explorations that led to powerful questions.

The third spiral: Shedding the role of All Powerful Giver of Information

When the teachers first began their action research journey, they were focused on what they could learn about how their students respond to inquiry. By the third iteration of their study, they found themselves rethinking their own roles in their classrooms. In traditional, teacher-centered classrooms, the teacher is the authority or as the group explained the "All Powerful Giver of Information." The teacher does most of the talking and the students do the listening. The teacher's role changes when the students learn to engage in their own inquiries. In an inquiry classroom, the students ask the questions, and the teacher must become a better listener and observer.

Judy, a pre-K/K Montessori classroom teacher shared how her thoughts changed when she shifted from activities that reflect teacher-centered perspectives to activities that reflected child-centered perspectives. She taught herself to notice when her students asked similar questions about the authentic objects in her classroom; she also started to listen when the same question re-emerged during classroom investigations. When she saw that the kids' questions were leading in a certain direction, she could facilitate their inquiry so that the children were guided toward an answer. By listening to the children's conversations with one another during investigations, she could encourage them into deeper investigations by merely supplying the appropriate tools at teachable moments rather than trying to script false experiences for children to blindly follow.

In one instance, Judy heard her students asking questions about the details of a skull that she had placed in the classroom. Hearing their conversation, as unobtrusively as possible, Judy gathered some magnifying glasses and rulers and placed them near the skull for the students to use. By listening, she was able to provide the tools that the students needed to continue their quest without interrupting their exploration.

As a result of this third iteration in their action research study, the teachers learned to trust their students to ask the right questions at the right time. By listening and observing the students as they engaged in inquiry, the teachers were able to help students develop their own understanding of science in a way that fit their specific learning needs. Listening to the conversations between students was as important to the inquiry process as the dialogue between students and teachers.

Summary of Study: I Used to Think and Now I Know

As veteran teachers, the action research group described the process of action research as "both humbling and professionally challenging." They learned about teaching scientific inquiry with authentic objects, their students' responses to inquiry, and the contexts that framed these experiences. They learned as much, if not more, about their own teaching beliefs and philosophies. The teachers summed up their thoughts on action research as follows: "We hope that other teachers are inspired to begin their own action research journey that will certainly help to turn their own powerful questions into classroom action."

Discussion

The teachers' research experience directly influenced their own teaching practice, and I contend that the importance of these experiences extends far beyond the walls of the four teachers' classrooms. Their project has important implications for all of us who are involved in the improvement of science

teaching. The action research teachers showed that, given the opportunity, teachers can use scientific inquiry both as a means to teach our students about science and as a vehicle to improve our own science teaching practice. Possibly without realizing what they had accomplished, these four teachers had transformed the vision of the *National Science Education Standards* into reality. Through their action research project, they were able to illustrate how their own systematic questioning had real and credible effects on science teaching and learning.

The teachers also came to their own, deeper understanding about themselves as teachers of science; their description of personal transformation impressed me as one of the most important effects of their work together. The action research group helped me to see how science teaching can be radically improved thorough the direct action of teachers who take risks, ask themselves questions, and recognize the value of research. I would like to highlight three themes that surfaced. These teachers are individuals who learned to (a) take risks in their practice, (b) become reflectively critical of their own teaching, and (c) use inquiry as a method to learn more about their own teaching as well as a method to engage students in science. The teachers truly challenged the traditions of the teaching profession in ways that led them to reshape and redefine what it means to be a good teacher of science.

Taking Risks

Change, by its very nature, can be a process rife with risk. In the case of the action research group, the teachers had to overcome cultural barriers inherent to the teaching profession. Before embarking on their study, the teachers had to reconcile their desire to learn their practice with the unspoken barrier that precludes teachers from asking questions about teaching. Barth (1990) describes this dilemma as a crisis of competition, in which no teacher can be seen as more expert than another and in which questioning one's practice is considered professionally damaging. Such a cultural tradition flies in the face of an underlying tenet of teaching: to instill a life-long love for learning. The teachers involved in the action research project modeled their vision for how teaching can be enriched by active questioning and reflection. Their work demonstrates the value of life long learning.

A related risk emerges from the culture of autonomy and isolation in teaching. Marsh (1999) speaks of this isolation: "The teacher does her most important work – the development of pedagogical style and curriculum – alone, without validation or insight from peers or superiors" (p. 186). In order to participate in their action research, the teachers had to develop a community that could overcome the force of autonomy present in school culture. Their participation in the professional development courses outside of the classroom likely contributed to their ability to develop a strong community.

The four teachers developed strong collegial relationships that were characterized by friendship as well as intellectual networking. The four aptly refered to themselves as their own, personal learning community. The fact that the four teachers knew one another through the NSF grant and were actively engaged in professional leadership activities outside of their regular school responsibilities likely had a tremendous impact on their growth as an action research team. As stated earlier, one of the obstacles that teachers face when considering action research is time. Because the teachers were already meeting regularly and valued their conversations about matters within and beyond their own classrooms, the context for the study was already set. Further, they were comfortable sharing with one another, as they regularly confronted challenging questions. Collaboration defined the teachers' experience; they found that sharing produced even more insights about their pedagogical practices, and they were able to see the similarities and differences between their students, classroom practices, and personal teaching beliefs.

Reflecting on One's Practice

The teachers involved in the action research project were expert teachers who knew the field of teaching, knew students, and knew schools.

All four were master teachers who had important leadership roles and were represented within their school district. Yet, these teachers were forthcoming enough to recognize that they could learn *more* about their teaching practice. The teachers clearly demonstrated how their action research required them to think deeply and to critically reflect upon their own teaching. In their description of their interest in action research, the teachers stated that they wanted to "go beyond the talk" and to "take action" in their classrooms. Such a deep examination into one's teaching, regardless of the potential risk, is the type of reflective practice promoted by the *National Science Education Standards*. The teachers in the action research study were so curious about the use of scientific inquiry that they were willing to examine themselves – and their students - through a metaphorical magnifying glass.

As a vital part of their study, the teachers reached into professional literature on teaching and learning. In doing so, they reaffirmed that teaching is an intellectual activity. When I first met them, they shared several books and articles that had influenced their thinking. These resources included a multitude of research articles and several books, such as *Nurturing Inquiry* (Pearce, 1999), *Primary Science: Taking the Plunge* (Harlen, 2001), and *Science Notebooks: Writing About Inquiry* (Campbell & Fulton, 2003). The literature fed their research and fueled their action research journey, and I admit that I regularly incorporate bits of this literature into my own teaching and research.

Using Science to Improve Science Teaching

Often considered a peripheral content area in elementary grades, science holds a low post in the hierarchy of pre-K-6 curricular structure. This phenomenon is exacerbated by the current trend to make elementary teachers accountable for basic math and reading skills to the disregard of other disciplines, such as science, social studies, and the arts. These action research teachers bridged this chasm by including science as an integral part of their interdisciplinary lessons.

The *National Science Education Standards* highlight how a teacher's prior perception of science as a subject directly influences their actions in the classroom. The action research teachers illustrated how science can be taught in a manner that reflects the standards-based vision and at the same time supports other subject areas. For example, Judy's pre-k class produced a play about their inquiry experiences with the authentic objects. The ability to draw interdisciplinary connections between science, the arts, and writing reflects Judy's understanding of science as a integral part of a child's learning experience.

The *National Science Education Standards* also advocate for a more authentic, engaging science experience for all students – and for teachers. According to the standards, "Teachers are models for the students they teach. A teacher who engages in inquiry with students models the skills needed for inquiry. Teachers who exhibit enthusiasm and interest and who speak to the power and beauty of scientific understanding instill in their students some of those same attitudes toward science" (NRC, 1996, p. 37). The action research process that the teachers modeled the value of authentic inquiry by planning engaging inquiry lessons using authentic objects and by participating in those inquiries with their students. However, the action research teachers also took inquiry to a higher level. They used inquiry to enhance their own professional growth.

Clearly, one of the most striking features of the teachers' action research project was that the teachers used inquiry to meta-analyze the effectiveness of their teaching. In other words, the teachers "walked the talk" of scientific inquiry by engaging in their own action research. Although it is unlikely that their students were immediately aware of the action research, the students benefited from the understanding that each teacher gleaned from their own action research project. The teachers developed a more holistic understanding of the value of questioning and data gathering, and

they, in turn, used this knowledge to enrich their classroom lessons.

To conclude, the success of the action research group can be attributed to a multitude of factors, but the most substantial credit goes to the four teachers who carved out time to be with one another to share, support, and question their own practice. By taking risks and inquiring deeply into their teaching, the teachers demonstrated the type of long-lasting, substantive change that is described in the literature on quality professional development (Loucks-Horsley, 1999b). Most importantly, the teachers showed each of us that change does not have to emerge from an outside agency because teachers already own what they need to improve science teaching. It's just a matter of taking action.

References

Barth, R. S. (1990). Improving schools from within: Teachers, parents, and principals can make the difference. San Francisco: Jossey-Bass Publishers.

Battaglia, C. F. (1997). Creating a reflective teaching community: Action research squared. Unpublished doctoral dissertation, State University of New York at Buffalo, Buffalo, NY.

Campbell, B. and L. Fulton (2003). Science Notebooks: Writing about Inquiry. Portsmouth, NH, Heinemann.

Harlen, W. (2001). Primary Science: Taking the Plunge 2nd Ed. Portsmouth, NH, Heinemann.

Kemmis, S. & McTaggart, R. (1988). The action research planner (3rd ed). Victoria, Austalia: Deakin University Press.

Loucks-Horsley, S. (1999a). Bookends hold a decade of ideas. Journal of Staff Development, 20(2), 49.

Loucks-Horsley, S. (1999b). Research on professional development for teachers of mathematics and science: the state of the scene. School Science and Mathematics, 99(5), 258-271.

Marsh, M. S. (1999). Life inside a school: Implications for reform in the 21st century, Yearbook (Vol. 1999, pp. 185-202): Association for Supervision and Curriculum Development.

Meyers, E. and F. Rust. (2003). Taking Action with Teacher Research. Portsmouth, NH, Heinemann.

Merriam-Webster Online. Retrieved August 12, 2005 from http://www.m-w.com/.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

National Science Teachers Association. (2002). National survey provides snapshot of K-12 science classrooms. NSTA Reports!, 13(4), 1, 6, & 15.

Pearce, C. (1999). Nurturing inquiry: Real science for the elementary classroom. Portsmouth, NY, Heinemann.