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Using Action Research to Engage K-6 Teachers in Nature of Science Inquiry as Professional Development

Theresa A. Cullen · Valarie L. Akerson · Deborah L. Hanson

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Abstract Teachers are required to work with data on a daily basis to assess the effectiveness of their teaching strategies, but may not approach it as research. This paper presents a reflective discussion of how and when a professional development team used an action research project to help 12 K-6 teachers explore the effectiveness of reform based Nature of Science (NOS) teaching strategies in their classrooms. The team encouraged community development and provided "just in time" supports to scaffold the steps of the action research process for teachers. The discussion includes concerns they addressed and issues related to management and support of the professional development model. Evaluation results are shared to suggest how this approach can be improved in the future.

Keywords Nature of science · Action research · Professional development · K-6 · Inservice teachers

T. A. Cullen (✉)
Jeannine Rainbolt College of Education, University of Oklahoma,
303 Collings Hall, 820 Van Vleet Oval, Norman, OK 73069, USA
e-mail: tacullen@ou.edu

V. L. Akerson
Department of Curriculum and Instruction, Indiana University,
201 North Rose Avenue, Bloomington, IN 47405, USA
e-mail: vakerson@indiana.edu

D. L. Hanson
Hanover College, P.O. Box 890, Hanover, IN 47243, USA
e-mail: hanson@hanover.edu

Introduction

Sustained professional development improves teachers' abilities to teach science (Banilower et al. 2007), and recent research shows that professional development can improve teachers' conceptualizations of nature of science (NOS) to those in line with recommendations of national reforms (AAAS 1993; NRC 1996) as well as their abilities to explicitly teach NOS to their own elementary students (Akerson and Hanuscin 2007; Akerson et al. 2007). Engaging teachers in inquiry on their own practice through conducting action research studies promises to also provide a venue for helping teachers emphasize the very NOS aspects they are conceptualizing. Indeed, we have found that teachers who have been through professional development programs targeted at improving both their conceptions of NOS and their methods of teaching NOS to their students, desire strategies for knowing the influence of their instruction on their students' NOS views (Akerson et al. 2007). A perfect venue for them to explore the influence of their teaching on their students' views is through action research.

This paper describes a professional development program designed to help teachers conduct action research on their teaching of NOS. Thus, our research question became "How can we support teachers in their endeavors to design and carry out action research designed to track their students' understandings of NOS?" as the teachers investigated "How will we influence our students' understanding of NOS?"

Theoretical Framework and Literature Review

To frame our work we drew on prior research on professional development regarding improving elementary teachers' views and teaching of NOS, and use of action research as collaborative professional development (Capobianco 2007). We describe these areas below.

Professional Development and Nature of Science

NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman 1992). For the general public, NOS is considered an important part of scientific literacy (Hipkins et al. 2005; Muslu and Macarglu Akgul 2005). This component of scientific literacy is shown by NOS's inclusion in major reform documents, including *Science for all Americans* (Rutherford and Algren 1989, especially chapter one) and the position statement from National Science Teachers Association (NSTA 2000). These aspects include that (a) scientific knowledge is reliable and tentative, (b) there are shared characteristics of scientific approaches to science (e.g., scientific explanations are based on and tested against empirical observations) but no single scientific method exists, (c) development of scientific knowledge involves creativity, (d) observations and inferences are distinct skills used in scientific investigations, (e) there is always an element of subjectivity (theory-ladeness) in

scientific developments, and (f) social and cultural contexts influence the development of scientific knowledge. These aspects were the target of the current project because these are what the teachers were learning through the professional development in its first year (Akerson et al. 2007) and were incorporating into their teaching in following years.

To design our professional development program, we drew on prior literature that emphasized best practices in professional development. Hipkins et al. (2005) noted that most teachers have weak views of NOS, and yet are expected to teach about NOS. They noted that teachers are dissatisfied with the current curricula for teaching about NOS and are concerned that a focus on NOS may hurt the attainment of other science content by their students, and that new curricula that emphasize NOS must exist to teach NOS to K-12 students. This claim was based on teacher's concerns, but no strategies to address this concern were developed using empirical evidence.

Prior research on professional development seeking to improve elementary teachers' understandings of NOS and abilities to teach it effectively to their students has shown that it is essential to (a) explicitly teach NOS ideas (e.g., Sandoval 2003; Southerland et al. 2006), (b) support teachers in their classroom practices over time (e.g., Akerson and Abd-El-Khalick 2003; Akerson and Hanuscin 2007), and (c) provide time for teachers to collaboratively design lessons, share ideas, and provide feedback to one another (Akerson et al. 2007, 2009). Thus, as part of our 2-year program, we devoted the first year to teaching the participants about NOS and how to teach NOS (Akerson et al. 2007, 2009). The current paper describes how we designed activities to assist K-6 teachers in conducting action research on their NOS instruction to enable them to better assess their students' NOS understandings and the lessons learned by the professional development staff about this process.

Action Research as Collaborative Professional Development

Action research is a classroom-based study in which teachers investigate their own teaching situations. Feldman and Minstrell (2000) described teacher research as teachers inquiring into their own teaching in their own classrooms. The teacher designs a study, collects and analyzes data, and interprets and reports the results, paralleling scientific inquiry. Teacher research involves cycles of action followed by data collection, data assessment, reflection, and further action (Hopkins 1993). The study informs teaching practice, and develops a reflective practitioner (Hubbard and Power 1993). Action research encourages improvement of the quality of education, promoting change and encouraging participants to engage in further professional development (Mata-Segreda 2006). The questions investigated in classroom-focused research spring from what teachers see as problems that arise in their own classrooms, or strategies that they would like to try.

There is prior support for using teacher or action research as professional development. Van Zee (1998) used action research in science methods courses to improve her preservice teachers' science teaching. Waters-Adams and Nias (2003) used action research as a methodological tool for exploring the effect of teachers' understandings of NOS on teaching practice. They found action research allowed

the researchers to track teachers' understandings of NOS as well as their teaching practice, and allowed the researchers to discern relationships between teaching practice and NOS conceptions. The teachers in our program desired to know how their teaching influenced their students' views of NOS, and action research seemed the key to help them explore their teaching and their students' understandings.

The concept of scientific inquiry may be difficult for teachers to understand (Kielborn and Gilmer 1999). However, the idea of having teachers engage in inquiry is part of the *National Science Education Standards* (National Research Council 1996). In professional development standard C, it is recommended that teachers engage in inquiry, both educational and scientific (National Research Council 1996). Several studies have tried to engage teachers in summer workshops where they worked in a science lab (Barab and Hay 2001). However such studies engage teachers in formal science investigations; many elementary teachers in particular would find this uncomfortable and would not connect their pedagogical content knowledge (Shulman 1987) by engaging them outside of their professional domain—teaching. Varela et al. (2005) found that when engaged in a similar lab-based apprenticeship model, teachers struggled with how their lab work would translate into the classroom. They grappled with ethical concerns, student needs and prior knowledge and the lack of available curriculum that incorporated similar lab based skills. We engaged teachers in guided scientific inquiry in both summer sessions of the program (Akerson et al. 2007) to reinforce their roles in both educational and scientific inquiry (National Research Council 1996). We approached these skills from their area of expertise, teaching skills and a knowledge of their students. Highly qualified teachers are reflective practitioners who are constantly working to improve their practice using data (Seed 2008). Our study was designed to engage them in both scientific and educational inquiry to help them develop personally and as educators.

How Does Action Research Assist Teachers in Teaching NOS Aspects?

Because the primary goal of this professional development program was to improve teacher's understanding and teaching of NOS, one might ask why it was paired with action research. We sought to explore how action research helped our teachers to see relevancy of observation and inference by them having to explicitly practice teaching observation and inference and by recording student learning and analyzing their own assessments and classroom observations. We hoped this process would help teachers to see that empirical data does not always have to be formal experiments. The observations, classroom notes, and student work that they were collecting would allow them to better understand a phenomenon (student learning) and help them to form conclusions based on data. We knew from our previous data that many of the teachers struggled to let go of the idea of a formal scientific method, and we thought that the formative nature of action research would help teachers go beyond this formalized view (Akerson et al. 2007). We also hoped that action research would engage teachers in a research community and that they could learn from studies done by other teachers, write up their own studies, and present their findings at regional science teacher conferences. We thought action research

would help teachers see the subjective nature of science—in that teachers see how their experiences influence their questions, their observations, and their conclusions.

Method

To evaluate the effectiveness of the action research professional development model for NOS we used a variety of data sources and analyzed and triangulated the data using qualitative methods (Merriam 1998; Bogdan and Biklen 1998) to establish the effectiveness of our model and develop insights for future implementations. Given our research question "How can we support teachers in their endeavors to design and carry out action research designed to track their students' understandings of NOS?" our overall framework for our evaluation of the program was Kirkpatrick's (1994) levels of evaluation. Level 1 is reaction—or what did the participants think about the training? Level 2 is learning—did the participants learn a new skill or change an attitude? Level 3 is behavior—did they change how they taught? Level 4 is results—how has the training changed the participants' practices in the future? (Kirkpatrick 1994). In using this model, the lower levels are more easily measured, and many evaluations may only address on one or two of the levels. In our study, we addressed the first three levels in depth, leaving the fourth level as a follow-up study. To study Level 4 in a comprehensive way we would need to follow the teachers beyond the program to see if they continued to use data and incorporate NOS in their teaching.

Data Collection

To document the effectiveness of our program we collected several sources of data. First, we videotaped each summer and school year session. These videotaped sessions about which we also took detailed notes, were used to enable us to document the kinds of interactions that occurred during workshop sessions and to see how teachers' action research studies unfolded. They enabled us to determine what was going well, and what additional supports were needed. The professional development team also met regularly to discuss interactions with participants and plan future sessions. Notes were taken at these meetings. We made at least one classroom observation of each teacher, and collected copies of teachers' action research proposals, as well as student work and NOS assessments the teachers designed and implemented. We collected ten teachers' final written reports. At the final professional development session, 12 participants (some participants were absent) completed a survey about their experiences with action research (See Fig. 1). Approximately one-third of the participants (five) completed an interview to add depth and provide additional insights to their survey responses.

Data Analysis

Cullen and Akerson reviewed the data and compared analyses to ensure validity of interpretation. Notes of the videotaped sessions were reviewed and coded during

Action Research Survey

1. On a scale of 1 to 10, how would you rate your action research experience overall?
   1 2 3 4 5 6 7 8 9 10

2. List and describe three benefits to this action research experience:

a).
b).
c).

3. List and describe three drawbacks or negatives that you encountered using this action research:

a).
b).
c).

4. If you had to repeat this action research experience, what would you do differently?

5. What advice would you give to the professional development facilitators if we were to repeat this action research experience?

6. What advice would you give other teachers if they were going to conduct an action research study in their classroom?

7. How did the action research affect how you taught science?

8. What did you learn about your teaching and yourself from the action research project?

Fig. 1 Action research survey

which we sought emergent themes that enabled us to determine what was working well (such as the "Just In Time" Supports) and what more needed to be done to help the teachers (such as a session on data analysis and time for writing). Notes from classroom observations, teachers' proposals, and final reports were reviewed by the team to determine the effectiveness of teaching and assessment strategies implemented for NOS. Survey and interview responses were reviewed for emergent themes regarding teachers' experiences with action research. Data from different sources was compared to triangulate responses and ensure validity (Merriam 1998). These data were revisited in light of the Kirkpatrick framework (1994) to verify that we were collecting data about participants' reactions, learning and behavior related to NOS teaching and action research.

Participants

Teachers in this study had already been engaged in a year of professional development where they learned about NOS and inquiry and were encouraged to implement it in their classrooms. They had already completed a 2-week summer workshop, and seven school year workshops as part of the professional development program (Akerson et al. 2007). Seventeen teachers represented three school districts near a Midwestern university. One district was rural, another was a university community and the third was in a suburb to the university community. Teachers ranged in age and experience. One teacher has 30 years of experience, and two others had been in classroom less than 2 years. All teachers had developed informed

views of NOS by the end of the professional development. Their understandings were measured using the *Views of Nature of Science Form E* (VNOS-E) instrument (Lederman and Khishfe 2002) several times throughout the professional development program (beginning, after a summer workshop, again after one school year, and at the end of the program) and using qualitative methods to compare participant responses over the course of the professional development. To read more about the teachers' professional development and acquisition of NOS aspects please refer to Akerson et al. (2007, 2009).

Most teachers were inexperienced with research at the start of the program. The one common experiential thread within the group was that they had all been participants in our research program to evaluate the effectiveness of our professional development model. The researchers had been collecting data by interviewing, collecting surveys, and recording class discussions and presentations for over a year and had begun presenting some of the results. The researchers did not share specific results with the participants, but instead used some of our research as examples to illustrate how research could be conducted. For example, we explained how we had used responses to an end of summer survey to look for ways in which they had already met instructional goals and to identify areas that might still need to be addressed in school year workshops. In this way, the researchers took on multiple roles: researchers, professional developers, and modelers of research. There was trust present and though participants were nervous about action research they wanted to participate in group goals and had faith in the leadership of the professional development staff.

Action Research Design and Instruction

Next, we share the design decisions we made about the professional development workshop and the session arrangement that resulted. In order to indicate the data sources we used to make our decisions and our inferences about participant reactions, we have referred to the data in parentheses after the relevant statement(s).

Introduction of Action Research to the Participants

We worried that the introduction of the action research component might jeopardize the trust established. We recruited teachers to participate in a 2-year professional development about NOS and inquiry. They were told that it would include two summer sessions, monthly school year workshops, classroom supports, and a small stipend. We did not outline specific activities but promised teachers they would learn new ways of teaching science for their classrooms. The plans for action research were not introduced until the last school year session of the first academic year. The activities that were planned addressed the question: "Now that you have incorporated some of the teaching strategies to teach inquiry and NOS in your science instruction, how do you know if the kids are learning or not?" (workshop transcript). The facilitators planned to talk about research, but the participants naturally asserted the overall rationale for action research by discussing the need for

evidence of student learning. It is at this point that we began to discuss action research as a way to understand student learning and to inform oneself and other teachers. The teachers left with several action research examples they could read before the start of the summer session and think about their own projects.

There were pros and cons to waiting to introduce action research to the teachers. First, many teachers easily saw the connection and wanted to tell others about how their classrooms were changing with new techniques (interviews, workshop transcripts). Many had enjoyed presenting at a regional teachers' conference and were ready to take it a step further through research (interviews, workshop transcripts). However, by waiting to introduce action research, some teachers felt that it was a case of "bait and switch;" in fact, one teacher was overhead saying, "We didn't sign up for this." The teachers who had strong negative reactions were the teachers who dropped out during the second year (workshop transcripts).

Action Research Instruction

The instruction on how to conduct action research was designed with a few considerations in mind. Since teachers were anxious, we designed the activities to be straightforward and to include extensive scaffolding. We also chose not to go into depth on the analysis stages of research during the summer sessions. We decided that if a teacher could plan for data collection and had a general idea of how they would analyze it, we would cover analysis in greater depth in the school year workshops. Part of our plan included providing one-on-one and just-in-time support at each stage of the action research process.

The topics were broken up according to chapters in the book, *The Art of Classroom Inquiry: A Handbook for Teacher-Researchers* by Hubbard and Power (1993). This particular book was easy to read, had many relevant classroom examples and could be used as reference throughout the year. Each day, teachers were given a reading assignment from the book and examples from our own research experiences. Our goal was to present the process systematically, giving teachers time to think about different parts of the research process and then providing time in the second week for them to develop proposals of their own. The proposal provided the basic framework for a research paper so it could later be combined with results to develop a narrative of their research. Each day's activities were planned to help teachers to reach the goal and progressively build the proposal over 9 days. See Table 1 for how we presented topics over the 2-week period. While teachers were given some reading time, there was a clear expectation that teachers would read beyond workshop time.

Overview of Action Research

The overview of action research took 2 days of the summer workshop. The first day had a certain "sales" quality to it. We focused on why action research was important, what it could offer to the teachers, and why their voices should be included in the discussion of how elementary students learn science. The leader of the professional development team said about teachers, "People would rather listen

Table 1 Summer workshops on action research

Day	Topic	Activities/supports
1	Introduction	Overview of action research
		Time to read several book chapters and examples of action research by teachers
		Structured note-taking activity on teacher action research
		Discussion of the need for teacher input on K-6 science teaching and learning
		Formation of overall group research question
2	Overview of action research	Discussion of introductory chapters
		Jigsaw groups with teacher action research articles
3	Research design	Development of individual research questions
		Discussion of research questions as a group
	Break—curriculum day	
4	Thinking about data analysis	Develop an overall plan
5	Literature review	Making an argument based on past work
6	Library support	Structured note-taking on relevant research
7	Work day	One-on-one support for technology, library research, writing
8	Work day	Additional one-on-one and group support
9	Presentations	Presentations of research ideas and group feedback on ideas

to teachers, than me" i.e.… "That chick from the University says this, versus that *teacher* says this." Another professional developer shared, "Only you can communicate what goes on your own classroom. Action research lets you voice what you know to be true from your own practice." One of the teachers added, "and your principal will be happy" (workshop transcript).

As the first day progressed, the teachers began to warm up to the idea. In addition, two of the teachers had done action research in an earlier project and we asked them to speak about the value of the activity for them, what they learned from it, and how well supported they felt in the process. The faculty member talked about her collaborations with classroom teachers and the graduate students discussed how they were pursuing research in their dissertations (workshop transcript). These first person accounts were chosen to motivate teachers about action research and to help the teachers see how they could contribute to what is known about how elementary kids learn science.

After the introduction, we wanted the teachers to see how action research was possible, relevant to their practice, and would allow them to have a voice within the research community. We collected eleven articles that we thought would be useful to the teachers, six were examples of action research and five were about the practice of action research and tips for using it in your classroom. Given the abbreviated schedule of only nine summer afternoons to prepare them for action research, we felt that asking them to read all of the articles would be overwhelming and would work against our goals. Instead, we decided to use a jigsaw group

technique where discussion groups were comprised of members who each read different articles and summarized them for the group (Aronson and Patnoe 1997). This technique is especially effective for reducing large reading assignments and promoting participation by all group members.

Teachers were assigned to read one research article and one or two teaching practice articles. See Table 2 for the list of articles they read. Because many of these teachers did not regularly read these types of articles, we structured the activity so that each teacher could identify key points in the articles and fully participate in the next day's jigsaw group by using a note-taking guide (See Fig. 2). For the research articles, the guide helped them think about the how the teacher designed their research and for the practice pieces, it helped them identify key ideas about action research. The end of the first day included approximately 2 h for reading and note-taking.

On the second day we started the afternoon session with the jigsaw groups. Teachers were expected to have their notes but were also given focus questions to promote discussion. Each small group summarized their discussion encouraging synthesis and higher order processing of ideas (workshop transcript). This summary activity served as a great starting point to present an overview of fundamental ideas of action research. Using the articles, teachers now had examples of what kind of research was "doable" in an elementary setting. Teachers started to brainstorm out

Table 2 List of readings about NOS and action research for jigsaw

Readings about NOS and action research
Akins, A., & Akerson, V. L. (2002). Connecting science, social studies, and language arts: An interdisciplinary approach. *Educational Action Research, 10*, 479–497
Chandler, K. (1999). Working in her own context: A case study of one teacher researcher. *Language Arts, 77*, 27–33
Cox, A. M., & Craig, V. C. (1997). Teachers studying teaching and learning in their own classroom: Action research. *The Science Teacher, 69*, 50–53
Herr, K. (1999). Unearthing the unspeakable: When teacher research and political agendas collide. *Language Arts, 77*, 10–15
Hinchey, P. H., Adonizio, S., Demarco, H., & Fetchina, K. (1999). Sketching a self-portrait of skills instruction: Classroom research and accountability. *Language Arts, 77*, 19–26
Kutz, E. (1992). Teacher research: Myths and realities. *Language Arts, 69*, 193–197
Lederman, N. G., & Niess, M. L. (1997). Action research: Our actions may speak louder than our words. *School Science and Mathematics, 97*, 397–399
Liu, Z., & Akerson, V. L. (2002, May 31). Science and language links: A fourth grade intern's attempt to increase language skills through science. *Electronic Journal of Literacy Through Science, 1*, Article 4. Retrieved May 31, 2002, from http://sweeneyhall.sjsu.edu/ejlts/vol1
Nixon, D. T., & Akerson, V. L. (2004). Building bridges: Using science as a tool to teach reading and writing. *Educational Action Research, 12*, 197
Scott, P. H., & Driver, R. H. (1997). *Learning about science teaching: Perspectives from an action research project.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Chicago, IL
Winograd, K., & Evans, T. (1995). Preservice elementary teachers' perceptions of an action research assignment. *Action in Teacher Education, 17*, 13–22

Name_____

Action Research Article Name:

1. What does this article indicate are some advantages of action research projects? Disadvantages?

2. What does this article tell you that can help you in conducting your own action research project?

3. What examples from the article clarify the research issues and issues regarding using action research in your own classroom?

4. What barriers to successful research does the article identify and how does it suggest overcoming them?

5. Are there any references that the author referred to that seem like they might be applicable to our projects or might help us learn more about teacher research?

Overall Rating: 5 4 3 2 1 Why?

Fig. 2 Jigsaw note-taking guide used by participants

loud and think about the questions that they might have and how they could be developed in a meaningful way to inform their teaching (workshop transcript). We decided on an overall question "How will we influence our students' understanding of NOS?" We also discussed the first chapters of the book, on forming a research question. Throughout the presentation, we used examples from the articles that they read to help them make connections (workshop transcript).

The professional development team acknowledged that the second day asked a lot of the participants and could have been stressful for them (PD team notes). They were asked to read a lot, and to really grapple with the bigger picture of action research and what it would mean to their classroom. Teachers struggled to think about questions they naturally had and how those could relate to a research question. For example, one teacher shared:

> I never really understand how well students understood exactly what we were doing? So the assessment was an issue for me. We had a workshop kind of thing and the parents were coming. And I heard a student explaining the nature

> of science to a parent and it was just amazing. So I was so intrigued about how he explained it to another person who did not have an understanding of the tenet, and this person was an adult. So that is where I am really intrigued—something about how they explain it others. I don't really know how to go about it… (workshop transcript)

Teachers discussed their research questions in terms of day-to-day classroom life, using terms like "assessment" as they struggled to think about how they could approach these questions as research (workshop transcript).

The next day was spent talking about the research process as a whole. We presented information to them about how a research question matches the data that is collected to answer it. We again used the action research articles that teachers read to illustrate the different kind of data they might collect. We also used examples of our own research to model how a research idea became a research project with data and analysis. We introduced the idea of thinking about scope with the elementary grades. In our professional development research, we had been looking at how teachers were able to master an understanding of seven concepts related to NOS, but K-6 teachers might want to target student learning of one or two aspects. We used examples they had read to illustrate how scope was different for different grade levels. At this point teachers were asked to develop individual research questions that fit under the overall umbrella question we had developed (workshop transcript). We left instructional time for collaboration. Many of the teachers were able to talk about preliminary ideas and identify shared interests with other participants (workshop transcript). Pairs of teachers met with professional development staff to brainstorm ideas. These meetings helped us to see how many projects were developing and where teachers might need support. We began to notice two phenomena that we would not address until the school year. Some professional development staff members were consulted much more than others, so some groups were left waiting (workshop videos). Also, some of the teachers would ask the same questions to multiple staff members to obtain different opinions. It was not very efficient (PD team notes). See Table 3 for a listing of the action research topics generated by the teachers.

The next session started with teachers sharing research questions. Each pair or individual was asked to list their research question on a chart that was discussed with the entire group. The public discussion provided peer feedback and reaction to each research question. It allowed the teachers to show their classroom expertise and how they were able to plan for the needs of their students (workshop transcript). This sharing was helpful for the professional development staff to better manage questions and plan for support. For example, this discussion allowed us to develop a list of keywords to be used for journal searches for the upcoming library session.

Thinking About Data

We were able to use these research questions to focus on data sources. We had decided that going into a description of full data analysis would have been overwhelming for the participants in the short time of the professional development.

Table 3 Individual or small group action research questions

Grade level	Action research question
Kindergarten	How does the understanding of five elements of nature of science change for full day vs. half day Kindergarten students through our teaching?
1	What impact do the aspects of NOS have on students' beliefs, understandings, and enjoyment of science?
1	How can the use of picture books enhance children's understandings of Nature of Science in an inquiry-based science program?
2	Through explicit teaching, can second graders learn four elements of NOS aspects (observation and inference, tentativeness, creativity, and empirical)?
2 and 4	Does understanding the elements of NOS (observation/inference, tentativeness, empirical, and creativity) increase attention to detail in students' written applications?
4	How can explicit debriefing using literature support students learning concepts of Nature of Science when they are not explicitly discussed in the textbook?
4 and 5	What effect does NOS instruction have on students' self-efficacy in science?
4 and 5 split	Which of the seven NOS aspects are readily grasped, ready to be developed, and which, if any, are beyond understanding at the fourth and fifth grade level?
6	Will understanding NOS elements influence girls' attitudes toward science?
Special Ed	What can students who are considered "learning different" articulate about their understandings of NOS?
Special Ed	What can fifth grade students understand about NOS elements?

Instead, we presented a chapter on data analysis and encouraged them to think about it as a table or a matrix. We asked teachers to brainstorm what kind of data they already collect as assignments that would help to answer their research question. Instead of focusing on formal analysis procedures, we focused on what could be collected and a general idea of what it might tell a researcher. This activity allowed the teachers to talk about the special issues related to doing research at the elementary level. For example, a first grade teacher talked about how her students did not have the ability to write sentences (workshop transcripts). The kindergarten teachers talked about how their kids are scared to talk to adults at the beginning of the year. One of the teachers, at a highly internationally diverse school, discussed how she might need to adapt her plans for ELL students (workshop transcripts). These were valuable discussions and encouraged brainstorming creative ways to collect data.

Significant time was spent talking about data that could come from the teachers themselves. Teachers often write notes about what works or what does not work in a lesson. We suggested that they plan to take a few moments to be reflective and to record "data" on their observations whenever possible in a planning book (workshop transcripts). We continued this discussion on the following day where each teacher was asked to create a general plan including preliminary ideas about data analysis. Each teacher met with professional development staff for one-on-one feedback. The meetings helped the professional development team to identify future support needs. For example, several teachers planned to interview their students at the beginning and the end of the NOS lessons. This would require interview help.

Others wanted to develop a survey; they would need help adapting questions and analyzing the results (workshop transcripts, PD team notes).

After teachers had an overall research question and a general idea of the kind of data they would like to collect, we introduced library research. We employed the library staff to explain to the teachers what resources were available at the university and what they would have available to them at their schools. Teachers were given templates to guide their note-taking. This template was useful to teachers in summarizing resources, reducing the need to print many articles, and assisting them in writing up their proposals. For many of these teachers, it had been more than 10 years since they had taken a graduate course, so many were unfamiliar with current library techniques. The extra support of a note-taking guide was designed to reduce anxiety and help teachers to focus on the information they were seeking. See Fig. 3 for the library note-taking guide.

At the end the summer sessions we had each individual teacher or pair present their action research ideas to the group to celebrate and recognize their hard work. The professional development staff made efforts to look for commonalities in the projects and encouraged teachers to share ideas. The final product of the summer sessions was a research proposal with a short literature review, a plan for exploring NOS teaching practices, and a plan with a timeline for classroom data collection. It did not include a fully developed data analysis plan, which helped keep the summer projects manageable and allowed us to discuss analysis once they had collected some data. Each teacher created a proposal that was turned in, read by the head of the professional development team, and returned to them with comments at the first

Note-Taking Template for Research Articles for Lit Review

Author(s):		**Setting:**	
Title:		**Number of Students:**	
Journal Name:		**Grade Level:**	
Volume:		**Research Question(s):**	
Number:			
Pages:			
Summary of Study Findings:			

Notes on Connection to your Research Question or Other Articles.

Fig. 3 Library note-taking guide used by participants

school year session. These proposals were vital to the facilitation of these action research projects because they allowed the professional development team to assess needs and make plans for supports to be provided during the school year.

Lessons Learned from Summer and Plans for School Year Workshops

By the end of the summer session we realized there were some difficulties that were occurring for the teachers. Several of the teachers changed grade levels in June making it hard to implement planned research. In fact, one teacher's assignment changed from sixth grade, to third grade, and then finally to first grade over the course of 2 weeks (workshop transcripts; PD team notes). Not all teachers had access to their classrooms, so some noted missing resources in their proposals. Other teachers were scheduled to have student teachers in the fall, so their science planning was difficult. It became clear that our first school year workshop needed to focus on refining the plans for the reality of their classrooms (PD team notes). Throughout the school year, we found that the classrooms changed dramatically, and plans needed to be consistently revised and revisited, which is typical for action research in classroom settings. Creating an environment that was tolerant and supportive of this flux was important.

The professional development team found that it was difficult to support the teachers individually. Some teachers asked questions of every member of the professional development team, and others risked falling through the cracks because they worked more independently (PD team notes). Because each team member had different talents and interests, we decided to divide the teachers into support groups by facilitator. Meeting in groups created a smaller community where teachers could share ideas, commiserate, ask questions, get feedback and encourage each other to continue making progress throughout the school year.

School Year: Monthly Workshops and Supports

We planned the monthly school year workshops to continue to reinforce NOS teaching and to support the action research activities. We started the year by having teachers refine their action research plans. Many of the participants had planned pre/post measures as their assessments, so we wanted them to think about how they were going to measure learning and begin to get a baseline of their students' knowledge. We made time in each session to talk in small and large groups about what they were teaching and how they were collecting data. As the school year progressed, several teachers shared early results and trends they observed. They shared how they changed their teaching in response to these results. Much of the large group discussion in each session focused on NOS teaching as well as what they were learning about it from their research activities. They used NOS terms like observation and inference to explain what they were doing in their classrooms (workshop transcripts). As many teachers struggled with the idea of "the scientific method," (Akerson et al. 2007) the action research helped them to see inquiry was more fluid and direction is often informed by the empirical data that is collected throughout the process (workshop transcripts; interviews; survey responses). This

Table 4 School year workshops: year 2

Month	Morning session	Afternoon session
September	Action research plans, start-up for the school year	Action research group meeting
October	Goal setting/research work time	Action research work time
		Science standards
November	Density inquiries-floating and sinking	Action research work time
December	Planning for regional conference	Density inquiries-cartesian
	Buoyancy activities	Divers
January	Exploring standards	Action research work time
	Preparation for regional conference	Glitter tubes
February	Presentation for regional conference	Presentation for regional conference
March	Action research work time	Action research work time
April	Completion of survey instruments/data analysis	Action research work time
Summer	Additional individual meetings with project facilitators to complete data analysis and finish writing	

group sharing kept teachers motivated and working toward the action research goals (interviews; survey responses). The professional development team kept monthly summaries of teacher progress and met to discuss the teachers in their groups after each session to share insights and suggestions to improve their support. See Table 4 for school year session topics.

"Just in Time" Support

One of our keys to success of this program was the "just in time" research support we provided. Sometimes this support occurred at our monthly meetings but many times required one-on-one support in the teacher's classroom. The professional development team helped to administer surveys, interview students and train parents to do the same so that the assessments could continue beyond the professional development program. At each school year session, participants talked about their action research and discussed it as a group. We encouraged teachers to discuss their preliminary analyses and provided additional perspectives and techniques they could use. For many of the participants, they could envision how they wanted to assess their students, but had some difficulties in creating the materials they wanted. For example, the professional development team helped a first grade teacher create response stickers to allow emerging readers to communicate the NOS skills they were using (Akerson et al. 2010; PD team notes, teacher final report). Another teacher received assistance in creating charts and graphs thus freeing her to construct arguments and form conclusions (PD team notes, teacher final report). All of the teachers needed assistance with writing up their results. Most teachers were quite capable of the writing task, but many were intimidated by it (interviews, workshop transcripts, survey responses).

Beyond the Professional Development: Writing Up Results

Each of the teachers or teams worked with a member of the professional development team to write up results in the form of a book chapter. We started with revising their summer proposals, and then assisted them in reporting their results and summarizing their conclusions. Teacher reaction to the writing ranged from anxiety to excitement to be able to share results with others (interviews, workshop transcripts, survey responses). The final manuscripts were written after the professional development program was completed, mainly through the third summer. In hindsight, the process of writing was very difficult for many teachers, and more sessions would have benefitted everyone (PD team notes). Writing supports ranged from converting teacher oral reports into an outline, to editing preliminary drafts, to technical supports like scanning artifacts. Many teachers enjoyed the process of seeing their work turned into papers that they could share (interviews, survey responses, workshop transcripts). Many commented on how difficult it was to communicate their results in a short paper, and expressed a greater appreciation for the dissemination process (interviews, survey responses, workshop transcripts). The assistance provided by the professional development team helped the teachers to overcome their anxiety and the mechanics of writing. Much care was taken to maintain the teacher's voices and their perspective in their work. Once most of the teachers started on the writing task, they worked independently and asked for intermittent feedback (PD team notes). A summary of the projects and some examples of their artifacts can be found in Akerson et al. (2010).

Results

In this section we will describe our results using the Kirkpatrick framework to evaluate the effectiveness of our approach. We first measured Level 1, or teachers' reaction to the program. Teachers rated their overall action research experience on a scale of 1–10. The average was 6.82 (std dev 2.03). The highest rating was a 10 and the lowest was a 2 with both median and mode being 7. The lowest rating came from a participant who was very self-reflective and critical of her own teaching. She explained her rating by writing, "I realized how difficult it is to incorporate research into an already demanding schedule. I really didn't expect it to be so hard" (survey response).

For further insight into their reaction (Level 1), teachers were asked to discuss the benefits and drawbacks of performing action research in their classroom. The most common benefits included opportunities for self-reflection (7), validation of their classroom knowledge and competency (3), improved teaching and knowledge of strategies to promote student science learning (6), and opportunities to collaborate with peers (4). During the interviews three teachers explained the political benefits of doing action research. One explained in her interview that her action research helped her interact with her administrator through a professional development plan:

> So when I had my interview with him about my goals, then I was able to explain to him a little more about what we did in [the professional development program] and how I was using it in the classroom … He was very impressed, wanted to come down and see one of the lessons that I taught using, you know, the nature of science. (interview)

Other teachers thought that they could use their results to show the value of science when their district was stressing reading and math instruction. A teacher who worked in a pair explained:

> Well I think any kind of classroom action research is always positive because it makes you step back and take a look at what you're doing and how you're doing that and what's the affect on kids learning. In this particular case, we were trying to connect science and writing, we not only saw gains in science understanding, but we also saw gains in writing which is both personally rewarding but its also politically rewarding, because as you know there's not a lot of oomph in science right, its all reading and writing. (interview)

When it came to drawbacks related to the action research project, all 12 teachers talked about not having enough time to incorporate research or to write up their studies. Seven teachers talked about concerns they had about their data which included things like "Will I correctly analyze my data?" "Is the data valid?" and "Was I consistent in my collection?" (survey responses)

Teachers' reactions (Level 1) to the professional development continued when they suggested future workshops should include more time to write and more one-on-one support. The teachers seemed more comfortable offering advice to other teachers. The most common suggestion was to pick a topic that reflects what is already happening in the classroom or a topic that a teacher feels really passionate about (4). In an interview one teacher explained, "When we started this I wasn't sure how I was going to decide what to research, but then when it applied, anything that applies to me and my classroom is easier for me to do" (interview). The teachers stressed the importance of working with others (4), being organized (3) and not making the problem overcomplicated (3). In an interview one teacher shared:

> Don't stress out (laugh). It's not as bad as you think. It's not like you're getting a grade for doing it you know what I mean? It's more for you to help you first and your kids. … And then I also said incorporate it into your day as much as you can. Because I think that people do already but they don't realize its research, it actually is. (interview)

Participants were reflective and they explained to the researchers what they learned (Level 2) in direct comments and how they changed and planned to change their teaching behaviors (Level 3) in the future. Indeed, even the act of writing up their research results showed what they learned both from the program, and about their students' learning. Teachers shared how they were observing student learning in more meaningful ways. One teacher wrote, "I learned I can question and analyze students to help determine their thinking. However, I also learned that to truly understand another's comprehension is very elusive-yet exciting" (survey

response). Teachers shared how they would do things differently. Six of the teachers would plan differently including organizing the study and materials more carefully (3) and managing their time more effectively (3). These kind of changes showed that they were learning from the process and making changes to their teaching behaviors. Four of the teachers talked about how they would change or refine their methods or instruments. One said, "[I would] do initial testing of questionnaires to determine problems" (survey response). Others talked about redefining key terms in a 'kid-friendly' way so they could be sure that they students completely understood.

The third level of Kirkpatrick's model, behavior, is little more difficult to measure. Probably the most obvious measure of behavior is the completion rate of the action research studies and what they told us about what the students learned. Ten teachers completed the studies using their own time and support of the professional development team during the summer. Please refer to Akerson et al. (2010) for a summary of some of their projects. The measure of behavior (Level 3) is most relevant to the question about how action research changed their teaching and what teachers learned about themselves. All of the teachers reported they did change their teaching, but most comments were very specific such as "It helped me to focus on keeping NOS in my lessons" or on evaluation and reflection in general "I was constantly evaluating what I did and how I could improve" (survey responses). One teacher explained the process helped her understand NOS better when she said, "As I learned more what the nature of science really is, I felt a part of the science process—I like was involved in the same endeavor and thinking as Galileo and Einstein" (interview). Teachers also tracked student learning using their studies, and it was clear to see that all teachers who completed their action research studies showed measurable growth in their students' understandings of NOS elements that were appropriate for their grade levels (Akerson et al. 2010).

Conclusions

The data that we collected from the teachers offered us many exciting insights into the value of action research incorporated into a professional development program like ours on many different levels. Teachers' reaction (Level 1) to the action research was relatively positive. They identified benefits to doing action research that included improving their view of themselves as teachers and their abilities to advocate for themselves and their students within the school environment. They used their experience to help them reflect on their teaching, and to share those results with other teachers, administrators and in some cases parents. As with any professional development that encourages teachers to work outside their comfort zone, there were challenges for the teachers such as time constraints and questioning their own skill levels. We felt that the kinds of questions that they were asking helped us to see what they were learning (Level 2) and how they were changing their teaching behaviors (Level 3). These teachers were asking important questions about their data, instruments, collection techniques, analysis procedures, and teaching and assessing NOS with elementary students. They were fully engaged in the research process and even before developing a manuscript of their results, were

using their data to improve their teaching. This data suggests that action research can be a valuable tool to engage classroom teachers in inquiry and to promote NOS instruction and assessment, thus changing how they taught.

Teachers gave us additional insight into how their behavior (Level 3) changed. It was exciting to see the teachers share the positive results in their classroom and for many, see how the classroom inquiry was helpful to them in understanding NOS concepts. They showed their learning when they recognized that they were doing an inquiry on their own teaching that was similar, though not exact, to inquiries that scientists do to answer their research questions. Many of the teachers took our lead and used examples of their own inquiries to explain concepts related to nature of science to students. The action research projects continued to foster these teachers' development as science teaching leaders in their schools. Teachers presented action research studies at a local conference during the school year thus reinforcing their leadership role and motivating them to complete their work. This not only helped the teachers and their students but also enhanced the overall school environment. These kinds of changes to the school community may provide preliminary evidence for Level 4 (Results) changes.

The action research projects provided great opportunities for the professional development team to learn and change our facilitation behaviors, while staying connected with K-12 classrooms. We assisted teachers in interviewing students and observing their teaching practice at their request. This rapport helped teachers feel able to voice concerns over the research process, for example concerns over writing. This allowed the research team to address concerns early and often and provide appropriate support (e.g., templates, survey development, interview help) and adjust future sessions to actual classroom conditions. We also learned the importance of dividing teachers into groups to allow a small number of facilitators to efficiently support a much larger group of teachers in a challenging and complex task.

As with every project there were lessons learned that would be considered for future projects. The professional development/research team discussed at length when to introduce the idea of action research. The teachers who did not complete the action research project were many of those who had early objections. Could we have retained them if they had known the action research component from the start, or would they never have engaged in the professional development at all? Time, as with all professional development, was a factor. When planning future workshops, more time to allow ideas to develop might help to reduce their anxiety. The professional development team discussed that in a future program it might make sense to cancel one of the monthly workshops in lieu of one-on-one meetings mid-year in each teacher's classroom. This would take considerably more time but it would support teachers and provide an accurate report of each teacher's progress. While a bit anti-climatic to the group energy, having the final session be individual at the teachers' school might help teachers complete the project. Finally, to evaluate the program on all four levels of the Kirkpatrick (1994) model, it would be interesting to visit the teachers today and see how they are teaching NOS concepts and measuring their students' learning. The fact that 10 teachers completed their studies, and several went on to present their studies to fellow teachers and

administrators suggest that the action research projects had a transformative effect that extended beyond their classrooms.

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