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The Influence of a Teacher Research Experience on Elementary Teachers' Thinking and Instruction

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Abstract

The purpose of this study was to investigate whether and how elementary teachers' thinking and instruction changed as a result of a teacher research experience. Each teacher worked with a scientist conducting research for a period of six weeks. Data in the form of classroom observations and interviews was collected before and after the research experience. Also, document analysis of journals kept during the research experience was conducted. Case studies for three elementary teachers describe the specific changes to thinking and instruction that resulted from the research experience and how such changes differed between beginning and experienced elementary teachers.

Creating opportunities for elementary teachers to develop knowledge of science teaching is an important goal of educators (NRC, 1996). Often unrecognized for their role in science education, elementary teachers may become responsible for delivering more hours of science than high school teachers if national reforms result in mandatory science instruction in the early grades. Previous research indicates, however, that elementary teachers' content preparation in science is often inadequate (Tolman & Campbell, 1991). Moreover, unlike undergraduate science majors and secondary science teachers, elementary teachers are rarely given the opportunity to work with scientists to learn how science is conducted. In order to address these deficiencies in the preparation of elementary teachers, several forms of professional development have been explored by educators. These have included programs that focus on elementary teachers' analysis of video cases (Tippins, Nichols, & Dana, 1999), their use of collaborative inquiry (van Zee, Lay, & Roberts, 2003), and their science teaching self-efficacy (Duran & Duran, 2005). Few, however, have examined the impact of the research experience model on elementary teachers' thinking and instruction. The purpose of this study, therefore, was to explore how a research experience influenced the thinking and practice of science for three elementary teachers.

Theoretical Framework

Research experiences generally refer to contexts in which teachers interact with scientists in conducting scientific investigations. According to Kardash (2000), research experiences epitomize the cognitive apprenticeship model. Grounded in the theory of situated cognition and social constructivism, cognitive apprenticeships foster the development of thinking and knowledge that is necessary to a particular context by allowing individuals to develop within that context (Anderson, Reder, & Simon, 1996; Brown, Collins, & Duguid, 1989; Lave, 1997). Cognitive apprenticeships are assumed to promote enculturation in several ways: individuals learn within a community of practice often guided by an expert; the activity is authentic or real-world; and learning is an active and constructive process in which individuals appropriate the practices, use of tools, and identities required for participation (Brown et al., 1989; Garrison, 1995; Greeno, Collins, & Resnick, 1996; Rogoff, 1990).

Thus, in the case of research experiences, teachers actively participate within a scientific community in order to acquire the skills and knowledge relevant to the practice of science. Immersion in a science research facility provides teachers with new science content and knowledge of science processes. Also, teachers becoming students again places them in the unique situation of experiencing how their students learn science, since teachers are experiencing science as an activity in conjunction with a body of knowledge (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). This is an underlying assumption upon which all features of the research experience are developed. As part of reform efforts portrayed in the *National Science Education Standards*, "All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry" (NRC, 1996, p. 59). The standards support teachers learning science content by participating in real-world research and then incorporating newfound content and processes into their teaching. Furthermore, the standards recommend and support commitment by all stakeholders, especially the scientific community, to enhancement of classroom science. This partnership between teachers and scientists is further strengthened by the fact that teachers become the link between the scientific community and students, parents, and the general public.

Teachers must not only appropriate science skills and knowledge; they must find ways to translate this learning into what they do in their classrooms. Hashweh (2003) recently outlined components in teacher professional development necessary to the process of accommodative change, or changes to thinking and practice. Many of these components can be found in research experiences: intrinsically motivated learners, critical reflection of prior beliefs, active construction of new knowledge through inquiry, and a social climate conducive to collaboration and discourse. Additionally, research experiences provide the participants with an opportunity for extended professional development. Supovitz and Turner (2002) have indicated that professional development activities that are longer than four weeks are more likely to promote change in teachers' practices than activities of shorter duration. Schwartz, Lederman, and Crawford (2004) suggest that research experiences provide an authentic inquiry context in which contemporary views of the nature of science (NOS) can be successfully promoted as well.

Outcomes of research experiences have been documented for undergraduates, preservice science teachers, and secondary teachers. Undergraduates participating in research experiences perceived themselves to have increased their research skills, including their abilities to formulate hypotheses, design experiments, and interpret data (Kardash, 2000). In the case of preservice teachers, the benefits of participation in a research experience included an increased understanding of the scientific method and how science is conducted, an ability to communicate what scientists actually do, changes in pedagogical practices, and new professional networks (Raphael, Tobias, & Greenberg, 1999). Content knowledge increased among secondary science teachers as a result of the experience, while beliefs about the nature of science and self-efficacy showed no change (Buck, 2003).

Although research experiences have been explored by previous researchers, none have examined how a research experience influences elementary teachers' thinking and practice. As previously mentioned, teachers have the unique task of *translating* their research experience into classroom practices. That is, through their interactions with scientists, teachers may experience new ways of thinking about and conducting science, but they must then take the additional step of fostering changes to their instruction.

Research Questions

To explore the influence of a research experience on elementary teachers' thinking and instruction, the following question was examined: How, if at all, do elementary teachers change their thinking about science and their pedagogical practices as a result of an extended research experience?

The Context

The participants in this study took part in the National Science Foundation funded Research Experiences for Teachers (RET) program at a national laboratory in the southeast. The research experience involved inservice teachers working with research scientists on a variety of projects located at the laboratory. Teachers were put in teams, usually one experienced teacher and one teacher in years one through five of her or his career. Teachers were then assigned a scientist with whom to work for six weeks. All participants were required to present their research in a formal public presentation at the end of the program. Research projects were negotiated between the teachers and scientists. This resulted in a wide range of projects from assisting in ongoing research to special projects designed just for the teachers.

Based on the Loucks-Horsley et al. (2003) model, goals for the program were set and included features that aligned with the context of the research experience. Current research on teachers' knowledge and degree of change (Hashweh, 2003) and on teachers' understandings of the nature of science (Schwartz et al., 2004) provided additional considerations for the features of the research experience. These included weekly sessions on writing in science, content lectures, workshops, online journaling, peer mentoring, and share fairs. Teachers were also required to participate in a final showcase of lesson plans, manipulatives for the classroom, unit plans, or equipment designed for the grade level they teach. Final products reflected individual research experiences in physics, chemistry, geochemistry, and optical microscopy.

Participants

A total of 11 teachers participated in the 2005 program: six elementary, two middle school, two high school, and one preservice. Of the six elementary teachers available for this study, one was eliminated because she was participating in the RET for a second year; another was ruled out because of her school's distance from the program site; and a third teacher participated midway through the study but had to drop out because her school made the change to a science resource teacher for all elementary students, and she was reassigned to teach language arts.

Participation was voluntary in both the summer research program and the study. The three elementary teachers who participated in the study are described below.

Allison: Allison teaches fifth grade. She has just completed her second year of teaching in an elementary school that alternates science and social studies, although science has become a priority due to statewide high stakes testing. She has attended several science workshops and one graduate course in science methods. Teaching is Allison's second career. Allison pursued a master's degree in order to obtain her teaching certificate. Her experience at the laboratory was one that closely mirrored the research her mentor was conducting. Having read an article on levitating a water droplet, Allison's mentor gave her the task of replicating the experiment described in the published article. Interestingly, Allison and her partner were unable to get the same results, and their mentor was delighted with their efforts since he could not replicate the experiment either (a fact he did not share until the end of the six-week experience).

Jason: Jason teaches fourth grade and has done so for four years. He is hard working and is constantly striving to find new strategies and materials for his class. In his school, science alternates with social studies. Every other week, there must be 250 minutes of either science or social studies instruction, always at the end of the day. When asked about science courses he has taken, Jason stated, "Well, I started off in college as a nursing major. I was prenursing and ran into the brick wall of chemistry, and that was a difficult class. I actually started going in another direction, and I ended up getting my undergraduate degree in history as opposed to nursing. As far as science, mostly high school biology, etc. The RET experience was the first major science instruction I've gotten in probably the last five years or so." Jason's research examined the effects of irradiation on food. His mentor designed the project with Jason and his teammate.

Melissa: Melissa teaches talented and gifted fifth grade students. Although her teaching assignment has remained relatively stable at her current school, teaching writing has been added to her math and science duties. Her vision of an ideal class is one in which many questions are asked by her and by the students. Melissa has taught for 17 years and has made science a professional development priority, having attended many workshops and short institutes (one to two weeks) on astronomy. Melissa is very comfortable with astronomy content and was hoping her experience at the lab would be astronomy-related; however, her project involved the use of an environmental chamber to determine the physiological effects of second hand smoke (environmental tobacco smoke) on volunteer subjects. Unlike Allison and Jason, Melissa participated in ongoing research.

Design and Procedures

A multiple case study design was employed, and a variety of qualitative procedures were used to acquire evidence for answering the research questions (Yin, 2003). The study was conducted in three stages: (1) pre-program, (2) program, and (3) post-program.

Pre-Program

- Four pre-program classroom observations with each teacher
- Semi-structured, open-ended interview with each teacher

Program

- Weekly structured online journals

Post-Program

- Four post-program classroom observations with each teacher
- Semi-structured, open-ended interview with each teacher

Prior to gathering data, we developed protocols for recording observations and conducting interviews. Several methods were used to ensure researcher consistency and quality of data. Each researcher compiled his or her observation notes, and interview audiotapes were transcribed for analysis. Coding of the data was done following the guidelines set forth by Constas (1992), and a variety of tactics were used to derive themes, make comparisons, and draw conclusions among the three cases (Miles & Huberman, 1994). We independently analyzed case studies for themes. We then worked together to distinguish between observation and interpretation, outline confirming and disconfirming evidence, and corroborate themes.

Data Sources

Observations. Teachers were contacted via e-mail and asked to provide days and times that they would like a researcher to make an observation. The first set of observations was conducted during the last six weeks of the 2004-2005 academic school year. State-wide achievement tests had been completed. Observations of each teacher's classroom practice were recorded in field notes by one of two researchers. Each teacher was visited four times (twice by each researcher) before participation and four times (twice by each researcher) after participation. Since there was no well-defined standard for outcomes of a research experience, researchers recorded observations for science methods (activities, inquiry, experiments, etc.), science content, communication (description of scientists, nature of science, expectations for success, etc.), and teacher/student-centered instructional approaches. Observation field notes were transcribed after classroom visits.

Semi-Structured Interviews. Interviews were conducted both before and after participation in the research experience. Each interview lasted approximately one hour. The interviews consisted of open-ended questions that required elementary teachers to reflect on their teaching methods; use of vocabulary; views about the nature of science; comfort with science content; and use of experiments, activities, and science journals. In both sets of interviews, researchers asked identical questions with the exception of the post interview, which included questions about their perceptions of the research experience on their thinking and practice. Interviews were conducted by the researchers.

Online Journals. Journals were kept by each teacher during the research experience. All teachers received a new set of questions each week that were intended to guide their thinking as they moved through the experience. Questions related to knowledge of scientific process, the nature of science, content knowledge, and translating the research experience into practice. Teachers were provided as much time as they liked to make journal entries. Entries varied in length from three sentences to full pages. Participants made two entries per week for six weeks.

In order to provide the reader with an indication of the amount of data collected by each method and for each participant, we provide total word counts in the following table.

Total Word Counts for Method x Participant

	Participants		
Method	**Allison**	**Jason**	**Melissa**
Observations	5,542	8,162	10,715
Interviews	11,285	11,596	9,509
Online Journals	1,504	1,921	1,978
Total Words	18,331	21,679	22,202

Findings

The major emphases of this article are to examine how the research experience influenced thinking and practice for three elementary teachers, to describe differences among the teachers, and to outline implications for further study. A case report was generated for each elementary teacher and is presented below in the form of a pre-/post-research experience case narrative. Within and across case analyses are presented in the discussion section. Pseudonyms were assigned to protect teachers' and scientists' anonymity and to give them a sense of security.

Case Report: Allison

Profile. During our pre-experience interview with Allison, she indicated that her "heart starts racing" when she thinks of teaching science. She described a view of teaching science in which science takes more effort than other subjects. Allison believed this view derived from her lack of content knowledge. She was concerned that she did not have enough knowledge of the concepts that state standards required her to teach. To meet this challenge, Allison said that she routinely gathered information from the Internet before developing her lessons in order to understand the concepts she would be teaching. Interestingly, Allison emphasized that she was primarily concerned with her students being able to recognize words and terms when they arrived at middle school rather than with their understanding of the concepts. This perspective was driven, in part, by a county-wide program to infuse vocabulary in all content areas and by mandated preparation for high stakes testing. She later added that she was very concerned about the writing process and how it was being taught in her school. For this reason, she said she had each student keep a science notebook. The notebook was used to answer textbook questions that were directly related to classroom activities. In addition, she believed that she did not have the "right equipment" with which to teach science, equating science with activities involving instruments and materials.

Prior to the research experience, Allison was observed making heavy use of the textbook. She frequently used the textbook to guide her instruction; she read aloud from it and referred to it when working with students. This observation was corroborated by statements made by Allison during her pre-experience interview. Allison said she felt compelled to follow the textbook because it was aligned with state standards and statewide tests. She mentioned that as a new teacher, she was relieved to have a structure upon which to base her instruction. Allison suggested that her *students* did not use the textbook because there were not enough books for everyone and because she believed it was "unfun" for them to read about something from the book.

Although the textbook appeared to drive Allison's instruction, science-related activities were observed in her classroom prior to the research experience. Project-oriented science played a central role in her classroom. The projects did not necessarily involve "doing science" but often had a science theme. For example, Allison had her students create an ocean creatures mural and Earth Day posters. On other occasions, students were divided into groups, or teams, and sat in clusters of desks arranged to accommodate group work. Students appeared to enjoy working together and looked forward to "science time" as Allison called it. It was clear that, while students sat together, they did not always work together, reach consensus on issues, or create group products. On one occasion, students went in groups from station to station where they participated in activities that exemplified Newton's laws of motion. At one station, for example, students blew up a balloon and then let it go. They later answered textbook questions about what they observed. According to statements made in the first interview, Allison suggested that students considered anything that they did in science that did not involve the textbook as an "experiment," and our pre-experience observations provided evidence that she did little to dispel this idea.

Allison was enthusiastic about providing meaningful science experiences for her students. Although she struggled in her description of inquiry-based science activities during her pre-experience interview, Allison said she wanted her students doing them. According to Allison, most of her strategies and instructional approaches are based on what she experienced in school and what she had learned from her parents who are both teachers. Allison indicated that much of the value she places on "curiosity" comes from the fact that her parents were "always asking questions." She had strong ideas about what is and is not effective instruction, although it was difficult for her to articulate. For example, on the topic of her students' content knowledge, she stated, "I expect them to be curious and be engaged and be able to participate in discussion about it whether they know the right answer or not . . . I hand them the ball and they're able to go with it."

When asked in the pre-experience interview to describe how science is conducted in her class, Allison said she recognized that it is unrealistic to think that students can get meaningful results after only one or two days of an activity or after making only a few observations. According to Allison, collecting, recording, and graphing data require a great deal of follow-up, and she felt it was difficult to find the necessary amount of time for students to make sense of these activities. At the same time, she stated that "being okay with elaborating . . . not being afraid of time constraints" is part of using experiments in the classroom. One example of an activity Allison considered a success because it did *not* work was discussed at the time of an early observation and during the interview. Allison found an activity on the Internet that involved students' working with acids and bases. Students were trying to figure out why a baggie would explode if baking soda and vinegar were added. Students expected the baggie to "blow up" and were asked to figure out why. When the bags did not burst, students discussed the variables and hypothesized that it would "work" with smaller baggies, and it did. While Allison identified the science learning as acids and bases, it was clear from her description that students were learning about experimental design, although Allison made no explicit statements about the methodology.

The research experience changed Allison's thinking and practice in a number of important ways. When asked in the post-research interview about how the research experience influenced her, Allison stated, "I have a lot more curiosity for science . . . I felt like last year if I had rated my interest in science on a 1 through 10, it would have been 5 or 6. I feel like it's definitely a 9 or 10 now." Allison's interest, in turn, influenced her instructional goals: "I expect them [students] to be curious . . . that they keep asking themselves . . . that they leave curious, that is my main goal." She went on to say, "I've grown more confident." She then described how this confidence allowed her to give students more control in their investigations, decreased her own need to have things "work out," and allowed her to "devote more energy" and time to science in her classroom. Allison pointed to a time during her research experience when her mentoring scientist had provided guidance to her and her teammate but had left the work up to them. Allison reflected on that experience and how it affected how she structured activity for her students.

Following the experience, we observed students conducting science experiments in Allison's classroom. Allison stated that the research experience had given her the confidence to have her students conduct more experiments than she had allotted time for during the previous year. Allison suggested during her post-experience interview that her research experience gave her the confidence to go outside of her comfort zone. More importantly, according to Allison, the experiments did not have to work out. Allison related, "But being okay with it not working, and its okay to let them [the students] figure out how it works. It's the beauty of what should we do next, or what is going to make this work?" Allison elaborated on the idea about science working: "I always tell them, 'Scientists make a living every day having to run into dead ends . . . There are people that spend years and years, a lifetime of work and they still haven't figured out the answer to it . . . ' You know I always use the idea of cancer or diseases we're trying to cure. And people have devoted their whole lifetime running into dead ends. 'Do we want them to stop doing that?'" Allison became open to activities not working the way she might expect them to. She even asked students to help figure out why they did not work by designing tests. Allison appeared to believe that an experiment should have a right answer, if one could only determine how to arrive at it; however, this view may have stemmed from her particular research experience that involved replicating the results of a published experiment. In her research placement, Allison was attempting to recreate a procedure to levitate a water droplet reported in a science journal. After six weeks of experimentation, help from her mentor, and keeping a record of successes and failures, Allison suggested that it was not the end result that was of greatest importance but the path that she followed to get to that result. Allison found that setting up an experiment and comparing her findings with published results provided her with a new understanding of scientific work: "It is not enough to teach students 'the process'. You have to share with them that . . . things in science are just like life; they don't always work out. You are *continually* going through 'the process.'" Allison referred to this as the "never ending cycle of inquiry and discovery that makes science so exciting."

Allison moved from a belief that "science is fun" to the idea that curiosity can create excitement for science. During initial observations and the first interview, Allison mentioned that the textbook was "unfun." She was unable to reconcile her vision of a science textbook as boring with her instruction, which she thought was supposed to be fun. Prior to the research experience, Allison believed that building a science vocabulary would help her students recognize terms when they moved on to the more content-oriented middle school curriculum. During the summer experience, Allison recorded in her journal several collegial conversations that confirmed her belief that engendering curiosity in her students, rather than having them recognize random words that they may not have understood, would promote success in middle school. In observations conducted after the summer research experience, Allison was still using the textbook as a resource for content and as a source of hands-on activities; however, the goal of science, for Allison, had shifted to finding answers to one's own questions. Allison was consistent in her belief that children's curiosity should drive their science work, but her post-experience observations and interview support the fact that she was practicing this belief with confidence.

During initial observations, the first interview, and throughout her summer journaling, Allison talked and wrote a great deal about the responsibility she had to "bring back" better science instruction to her fifth grade team. She mentioned her experience frequently and believed that she was now doing more than the other teachers. Allison was extremely proud of conducting a comet activity with the entire fifth grade, something she said she would not have done before the experience. In response to a question about the kinds of challenges that arose when conducting experiments, Allison responded, "Just getting your hands on things and I would say nine out of ten teachers are discouraged because of the collecting of resources to do them and problems that arise, of course." She indicated in this same interview that this was why she decided to do the activity with the entire grade level, so that all students could enjoy the experience.

Pre-experience observations gave some indication that students were writing in conjunction with their science activities; however, there appeared to be no system other than a vague mention of science notebooks. After her experience, Allison's students had begun science journals to keep a record of their class work, observations made outside of school, nature drawings, and current issues in science. She was very proud of their journals and showed us several samples that represented a willingness on her part to let each child determine how to represent his or her own learning. According to Allison, a change from science notebooks to science journals was a direct result of weekly writing sessions that occurred during the experience. During the pre-experience observations, Allison frequently had students put worksheets, works in progress, or answers to textbook questions in a science notebook. Following the experience, students in Allison's class were observed making entries in science journals, which were more reflective and included students' interpretations of science activities and new questions that resulted from classroom experiences and discussions. During one of our post-experience observations, students shared nature journals in which they wrote about certain schoolyard locations, how the observations compared with their preconceived ideas about what they were likely to find, and new questions that arose.

Following the research experience, a significant change was observed in Allison's efforts to communicate the activity of science and scientific work to her students. Allison took time to describe how scientists think and made multiple references to what scientists do. For example, she talked about how scientists ask questions and collect information to answer their questions. This conversation was a direct result of her experience with her scientist mentor. She used instructional time to address the importance of science, relate science to her students' daily lives, and provide students with a variety of scientific tools (e.g., microscopes, hand lenses, measurement tools) in an effort to present a full picture of what scientists do in real-world science laboratories. On one occasion after the experience, students were observed making presentations about science careers. Students described what "they" studied and how it was important to everyone. During another observation, Allison asked students whether they thought scientists had a role in developing the tennis shoes that they wore. She challenged her students to come up with questions that might be asked by scientists about tennis shoes and what kind of scientists might answer those questions.

Case Report: Jason

Profile. Several things were clear from observations of Jason's classroom practices. Jason used the textbook as a source of information. Either he or his students read aloud from it at some point during each lesson. The textbook also drove the activities and flow of instruction. Each of Jason's science lessons covered many concepts. The overhead projector played a major role in his instruction, and it was used for a variety of tasks, almost like a second instructor. For Jason, the textbook was a tool that, if used properly, would result in student learning and effective teacher practice. According to statements made by Jason during his pre-research interview, science should be fun and should be "like art" — engaging and apart from the regular curriculum. For Jason, science was to be used as a reward "that follows things that aren't as much fun, like regular math and multiplication facts." Science activities were in some cases indistinguishable from art activities until Jason asked the key question; then it was clear what he expected from his students.

For Jason, questions were a central theme to his science instruction. During the pre-research interview, Jason suggested that when doing science, "it all starts with questions." He also believed it was important to create an atmosphere in which students felt free to ask questions. Consequently, when they did science, there were many questions, and students seemed free to make comments and discuss what they were doing. There were several interesting things at play regarding Jason's beliefs about science and how science is conducted. The vocabulary of science was important to Jason since he admitted that he was not as comfortable teaching science as he was other subjects. He was happy being a learner with the children. He equated doing activities from the book with "experiments." He described experimentation as "playing with stuff and then completing a task, then coming up with alternate ways of completing the task." Interestingly, Jason stated strongly that students can develop their own theories, but he believed theories are associated with "famous people in science." Jason recognized that he needed a strategy to help students answer the many questions he encouraged. He also noted that he would like them to "ask questions with a hypothesis," although he had difficulty describing the significance of having one.

An example from pre-research observations of how Jason implemented a science lesson that covered a number of concepts involved a small group, problem-solving activity in which students worked on lighting a light bulb. The activity was described for students in their textbooks, and step-by-step instructions were provided. Each group of students was given a "kit" that contained a battery, battery holder, a small light bulb, and one wire. Prior to completing the activity, students were asked to draw how they thought "lighting a light bulb worked." Jason was observed putting a diagram on the board while students worked. One student asked whether he could get a flashlight because he thought that would hold the secret to figuring it out, but Jason replied that he thought that would be cheating. The student then drew what he thought the inside of a flashlight looked like, and he then went on to light the bulb. During this observation, Jason described the activity as an "experiment," although the textbook titled it an "activity."

At the mid-point of his summer experience, Jason's journal entries revealed that he began to question his use of the words *law, hypothesis,* and *theory*. He also reflected in his journal about whether his techniques for dealing with student-generated questions were effective. Jason worried about this because many of the students' parents were scientists or mathematicians, and he was intimidated by them. He recorded in his journal at the end of week four of his summer experience that it was "okay not to answer them [student questions] because scientists are okay with this."

Following the research experience, Jason stated in his interview, "I notice I do a lot more science in the classroom with the kids . . . In the two years prior [to the research experience], I've seen science as something I need to do, but now I see it as something that can really engage my students." When asked to quantify the change in the amount of science he teaches, Jason responded, "I'd say I was doing 75% social studies and 25% science. I'd say this year I'm doing 25% social studies and 75% science." This statement was corroborated by another teacher at Jason's school who in a passing conversation indicated that Jason had been teaching much more science since his research experience.

Jason was also observed communicating to his students what scientists do following his research experience. When asked about this in his post-research interview, Jason indicated, "I try as much as possible to say, 'This is how scientists do it in the real world.'" Jason's instructional goals in science became more focused. "I want them to be able to use science to problem solve, and especially the scientific method, in trying to figure things out and think critically," he said. He added, "I don't want them to be intimidated when they come across science in middle school. I want them to think back to elementary school and be like 'Oh yeah, I remember doing this. Science is fun!'" Following the experience, Jason still wanted science to be something that his students enjoyed, but he also wanted them to think of science as "something that helps explain the world around them."

Beginning a lesson with a question remained central to Jason's approach. He stated in his interview, "I think when we start with a question, it spirals into more questions. When I was working with Harold this summer, we started with a question, and by the end of it, we realized we had more questions than we started with. So I guess I see my role as a facilitator of questions." He went on to add . . .

> I guess I saw science as more concrete than what I got through the RET experience. I always thought, or at least until this summer, of a scientist as someone who goes in with a very specific question. But to find out that scientists go in maybe having an idea, not even a question, and coming up with more questions, not necessarily coming up with an answer, that surprised me. That was something I didn't know happens in the scientific community.

Jason suggested that his instruction was moving in this direction and that he sought science materials that provided his students with "a real-life problem that they have to use science to solve . . . Sometimes there is not always the specific, right answer."

After the research experience, Jason indicated in his interview that he felt more "comfortable and confident" with the questions his students asked of him. Having communicated to his students his research experience, they came to see him as "an expert," although he acknowledged he was not. He also felt more comfortable with the idea that his students might not always have an answer to their problem but that they could go on to develop an experiment to find the answer together. Further changes to Jason's thinking about how to conduct science were evident from his final interview:

> That's the way science should be conducted, coming into it with an open mind, not saying if I do this there, this is what will happen. I know that a lot of times you get a recipe for a science experiment, and if you do all these things you're supposed to, you put in A, you put in B, you're supposed to get C. What if you don't get C? Well, I want them to know that science is more than just a recipe . . . I'm not going into an experiment saying "you need to do this and this, and you'll get this," because that is just feeding them as opposed to letting them experiment on their own.

He reflects, "You know, I think last year I was probably more willingly to just give them an answer, kind of like a top-down management style for teaching . . . like all knowledge must flow from your teacher. No, I learn from you guys. You guys learn from each other." When asked what prompted this change, Jason concludes that he made this change in his thinking after working with a scientist and his lab partner: "It was the type of situation where we were all learning from each other."

The research experience provided Jason with what he called an "authentic experience." He suggested that although the scientific method was a "concrete process," science in the classroom should not be limited to "recipes." Although Jason was sure experiments would be an important component of his science instruction, most of the instruction we observed both before and after the experience involved students in science activities, rather than science experiments. After the research experience, Jason continued to draw no distinction between a science experiment and a science activity, and he felt the two terms could be used interchangeably. Following the research experience, when asked to describe what an experiment was, Jason answered, "I see it as starting with a question or an idea and using things around us, usually hands-on activities to solve that question or idea." Jason added that an "experiment" he had done with his students prior to his research experience resulted in unrealistic numbers. He went on to say that it was not until after his research experience that he recognized the need for his students to repeat their "experiment several times" in order to control for error.

Jason identified specific strategies that he thought would enhance his instruction. He mentioned specifically that he would have students graph their findings and display them on the overhead projector, which is exactly what he did during one post-experience observation. During that observation, however, Jason appeared to revert to his belief that there was a "right answer." In fact, he manipulated the data so that the graph matched what he thought it should look like.

Case Report: Melissa

Profile. Evidence gathered from our first interview with Melissa suggested that she was well versed in the language of science inquiry and the goals set forth by the *National Science Education Standards*. In describing how science was conducted at her school, she stated that her school has an "open inquiry mindset" and suggested that teachers there are "high quality." Melissa stated that she did not use a textbook because she could not find one that she really liked; therefore, she frequently used the Internet to obtain science content and often pulled up web pages during class to present content to students.

Pre-research observations indicated that Melissa used a variety of effective practices in her teaching. She often began by explicitly stating what the day's goals would be. She then asked students what they already knew about a topic or asked them to recall information from a prior lesson. In this regard, identifying prior knowledge and misconceptions was an important aspect of her teaching. She stated in her pre-research interview "My challenge is to find out what they know is correct and what is incorrect and build on that. You want to start with misconceptions that your children may have." Melissa also indicated, "I always have for my kids some type of model that they can put their hands on to demonstrate whatever concept we are doing."

In order to facilitate her students' acquisition of knowledge, we observed Melissa using a variety of model building activities with her students prior to her research experience. Students worked with one another in small groups to build models of bridges and the ocean floor. When providing students with a new concept, Melissa ensured that they received multiple examples. Students often worked in small groups to make observations, gather data, and perform calculations. She stated during her pre-research interview, "The students are the scientists. It's not me. It's them. They are the ones doing the experiments. They are the ones who are engaged and are participating in something. They have to go through the whole process, and they are the ones who have to interact with one another." During our four observations, however, we recorded students making observations and taking measurements, but we observed no experiments and little inquiry. Furthermore, Melissa had no illusions about the type of science she was conducting during our observations, referring several times to what she was doing as a science activity. At one point, she came by to explicitly state to the researcher that what she was doing was different from an experiment, as if to suggest experiments are good science, but she was not doing them. Melissa's statements about one goal of her instruction being "exposure to information" and her corresponding use of compare and contrast activities, seemed to serve as the primary instructional focus during our visits to her classroom. Although our observations were spread over a period of six weeks, Melissa's practices may have been affected by the dynamics of the school year, or it may have been that our sampling technique led to few observations of inquiry and experimentation in a classroom otherwise dominated by them.

Melissa expected her students to have an attitude of questioning. Prior to her experience, she stated during her interview that one of her roles as a science teacher was to " . . . teach them to think like a scientist, which is to go through the scientific process, through asking questions, experimentation, conclusions, you know, the scientific process." Melissa elaborated on the process she liked to use:

> I like to start with something that really throws them. That they are really going to get interested in, and it might be a basic concept, like in physics, you know, just about motion and how motion works. And I usually set out lots of experiments for them to do, and when I do inquiry-based science, it is not completely free inquiry, but it is guided inquiry. In other words, I know where I want them to go, but I also want them to have the freedom to experiment without any judgment.

She described a communication pattern that she often used when talking with her students: "It is ok to be wrong. That we are not looking for you to always be right, so I want you to feel free to not always be right, or not know the answer, but it is about your thought processes." As Melissa puts it, "I expect them to have good science. By that I mean that it is factually based and it is not hokey science."

During her pre-experience interview, Melissa stated that scientific theory "is what you can prove through measurement and observation and a lot of experimentation." She laughed as she reflected on her own choice of words, "I shouldn't have used that word [prove]." She continued, "Sometime down the road, we will change the way we will look at that because we can measure it more accurately, or we can get information that we didn't have before." When asked about truths in science, Melissa responded, "As a scientist, truth is something that is measurable, observable, you know something they have experimented with. That becomes your truth." Melissa wanted her students to have a similar view. She wanted her students to know that scientific knowledge "isn't always absolute, that sometimes things will change." Melissa commented on how a child's epistemological framework often serves as an obstacle to science instruction: "It is a hard thing for kids to grasp because they want to make everything an ultimate truth. Children are geared toward the right or wrong answer; whereas, in science it is about the question and then the process to get there. Sometimes you get there and sometimes you don't." Melissa stated that she regularly tells her students, "One test is no test."

Melissa indicated that she expected only her content knowledge to change during her research experience; however, during her first week, she recorded in her journal: "I am impressed with the care and methodology of scientists who do research. This is different from the classroom experience, in that it is methodical and time consuming . . . I will make time to include this aspect of 'real' science." Melissa noted other changes to her thinking in her journal:

> One thing that impressed me and the way that I think about science is when Mark explained that science is about a way of thinking and slowing down and addressing a problem in a factual, thoughtful process. I think about how my students so often use their feelings, rather than the scientific process. It will be a good example, conveying what happened in this lab to my students. Scientific reasoning perhaps can be taught by using examples and nonexamples.

One notable change during her experience was how Melissa's view of the purpose of experiments and their relationship to scientific knowledge had begun to shift, although it retained an element of imprecision. Prior to her experience Melissa stated . . .

> As a scientist, truth is always something that is measurable, observable, you know, something that they have experimented with. That becomes your truth. So you kind of have to put your beliefs at the door when you walk into a science room. It doesn't really matter what you believe or what you think is true. It is what you can prove through measurement and observation and a lot of experimentation.

During her experience, however, she wrote the following in her journal:

> So often we think the experiment is the end all, when in reality, it might be but probably won't. But science is never that simple. As we conducted our experiments, so many things went wrong! When I come back to my class this fall, I will never again teach a lesson with the results as a gospel fact. If they had been done over and over, like in a lab situation, the results would be somewhat different.

Melissa recorded in her journal that her thinking was once again changed when she tried to make sense out of an answer her mentor scientist had given her:

> Jerry sees himself [as a] scientist, in order to stay objective in the field. Wow, what an interesting idea! Now how does that apply to teaching science? In order to do real science, I am piecing together the idea that one must be a free thinker, who sees the good of the society that he or she serves. So often, we get into the ethical issues . . . and yet, to some degree, a scientist must find the balance of his or her own personal belief system and the unbiased view that he or she must take in order to do pure research. Wow, what a challenge for the classroom and conveying that to the kids I teach.

During the last week of her research experience, Melissa commented . . .

> I feel my approach to science has been changed in little, but significant ways. First, I will take away a more careful approach to the experiments I do with my children. Science takes time. Secondly, I have found that all the "answers" are not always at one's fingertips. Most of the scientists just have little snapshots of the truth and discoveries they work with. I will hopefully be able to model this with my students.

Several months after the research experience ended and Melissa had returned to the classroom, she was asked in a post-experience interview the following question: "How do you think the research experience changed your thinking or practice?" Melissa immediately stated . . .

> Definitely one thing that hit me and I carried to the classroom . . . is that science takes a lot of time. A lot of times, we rush to conclusions or we like to put science in a little box. In order to do science well, and I told my kids this, it takes a lot of time. Do things small. I find out that people might do research on one tiny little thing that might take them years. And so, I try to practice that in my classroom. I want my kids to experience what it's like to methodically go through the process. It's a real revelation. It's not that I didn't know it before; I just never experienced it, like you would if you work along a scientist.

This statement corresponded with our post observations. Melissa engaged her students in an investigation of the seasons that spanned several weeks.

Melissa had also changed the extent to which students used science journals in her classroom. For Melissa, journals became an important log for the recording of scientific data, and students were observed during each of our post-visits recording data in their journals. Melissa described the importance of keeping detailed records: "I told them that scientists are always writing everything down, so as you're working, I want you to write things down because you're going to forget stuff and you're going to want to go back and compare it. I can't begin to tell you how much documentation, documentation, documentation a scientist does. So we need to start writing things down and being able to see how we think or how things have changed." Prior to the research experience, Melissa's students used journals to respond to teacher questions. At the time of the last observation, students not only used the journals to answer questions but to record their own questions and understandings. There was an effort to revisit prior drawings, answers, and observations; students were given time to "correct" their drawings and answer their own questions.

Discussion

Our case studies provide an in-depth examination of how three elementary teachers' practice and thinking shifted as a result of the research experience. Case analyses suggest several themes of interest: teacher self-efficacy, views of the Nature of Science (NOS), perceptions of the purpose of science teaching and learning, and distinguishing activities from science experiments.

Teacher Self-Efficacy

Prior to participating in the research experience, Allison and Jason, the beginning elementary teachers, taught science infrequently. When they did teach science, lessons were structured primarily from their textbooks. Allison tended to create experiences for students based on her own comfort with the writing process. Jason wanted science to be "fun" and tended to build his science lessons around art activities. Following the experience, both Allison and Jason increased the amount of science that they taught and felt more confident in doing so. Allison was willing to devote more time and energy to teaching science and even felt a responsibility to the rest of her fifth grade team. She took opportunities to include other teachers' students in her science teaching when possible. Jason greatly increased the amount of science he conducted in his classroom by inverting the percentage of time he spent between science and social studies. He also felt more confident in allowing his teaching to be guided by questions, and he shifted from a "top-down management style" to a more student-centered approach to teaching.

Views of the Nature of Science

Several changes in the way that Allison, Jason, and Melissa viewed the nature of science were identified. Allison's view shifted from simply seeing science as materials and tools to perceiving science as a continual process. She suggested that one might spend a lifetime on a particular question. Her statements, however, suggested that there was a right answer to be gained as a result of the scientific process; it was just a matter of finding the right way to arrive at it. Jason, on the other hand, suggested that there was not always a right answer, but during his teaching, we observed him acting upon a belief in a "right answer" by manipulating data to achieve one.

Subtle changes were also captured in Melissa's thinking. The importance of meticulous attention to detail in setting up experiments to ensure valid results was an important outcome for her, one that she felt would be important for students to know and practice. After the experience, she chose to demonstrate to students that sometimes science is a long-term process. She did this by providing them with an investigation that spanned nearly four weeks. Throughout this investigation, students were required to make repeated observations, record data, and draw conclusions at the end. Melissa's notion of how scientific investigations produce "truth" seemed to shift, as well. Prior to the experience, Melissa held truth to be something that "you can prove through measurement, observation, and a lot of experimentation." The research experience provided her an opportunity to accommodate new meanings around scientific processes and the results derived from them. While Melissa stated prior to the experience that "one test is no test!," she seemed to limit this idea to taking measurements. During her experience, Melissa came to a realization that this principle applied to the experiment itself. Melissa stated she would no longer take the results of only one experiment to be "the end all" nor would she "teach a lesson with the results as a gospel fact." What her post-experience language revealed is that the laboratory experience provided her with an opportunity to mediate her thinking and served as a context in which she continued to construct meaning around the concept of replication and its role in the development of scientific knowledge.

Perceptions of the Purpose of Science Teaching and Learning

Before the experience, Allison and Jason rarely discussed what scientists actually do and did little to relate the work of scientists to their students' lives. Allison had stated that her students would "not become scientists." During her experience, Allison developed an understanding of the role communication plays in science and planned to have her students communicate with another participant's class on a joint project, in which students could collect and share information from different locations. Also, Allison's communications about science shifted. Her position changed from one of not believing her students would become scientists to actively communicating to her students that they are scientists. She drew parallels to classroom science and the students' lives by having them critically think about scientists' involvement with everyday objects such as their tennis shoes. She also discussed with students a variety of science careers. Jason and Allison discussed the importance of modeling scientific thinking and fostering in their students an enjoyment of science, two activities that their scientists had done regularly with them. Melissa wanted her students to know that science "takes a lot of time" and provided them with opportunities for extended investigations. Moreover, Melissa hoped to find ways to convey to her students the balance between personal belief systems and the "unbiased view" that a researcher must take.

Distinguishing Activities from Science Experiments

Both of the beginning elementary teachers in our study were puzzled during their pre-experience interviews when asked about how they distinguished between scientific experiments and science activities. The difficulty for Allison and Jason in distinguishing between experiments and activities remained even after the experience. It appears that Jason and Allison may think of experiments as synonymous with investigations. This suggests that participation in a research experience alone may not produce shifts in how teachers define their classroom science practices.

Implications for Further Research

The research experience presents a unique opportunity for elementary teachers to situate their learning within a scientific community. Although educators have assumed that the research experience model has an influence on teachers' thinking and practice, there has been little evidence to support such assumptions. Our preliminary investigation into the influence of a research experience on elementary teachers' thinking and practice suggests both positive outcomes as well as areas for improved teacher learning.

The research experience model as a form of cognitive apprenticeship offers a powerful learning context. Future studies should investigate how individuals construct an understanding of scientific concepts (e.g., theory, replication, and experiment) as they participate in a research experience. Also of key interest is exploring how teachers develop an understanding of the relationship between scientific methods and what claims can be made about findings from such methods. Specific attention should be given to such misconceptions as "right answers" and the inability to distinguish between various scientific and classroom practices. Additional research should examine how specific program features, such as teacher discussion groups and collaboration within teams, impact these dynamics of translation and ultimately influence elementary teachers' pedagogy.

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