Journal of Elementary Science Education, Vol. 18, No. 1 (Spring 2006), pp. 15-31.

Elementary Preservice Teachers Learning to Teach Science in Science Museums and Nature Centers: A Novel Program's Impact on Science Knowledge, Science Pedagogy, and Confidence Teaching

Maura Lobos Jung
Karen L. Tonso
Wayne State University

This ethnographic research examined two out-of-school science practica where preservice elementary teachers learned to teach science. We wondered what teachers learned about science and teaching science, how their sense of themselves as science teachers changed, and how such settings might contribute to reform in science education to promote greater scientific literacy. Preservice teachers had positive experiences; found the practica non-threatening; learned hands-on, inquiry-based teaching practices and some science; and developed confidence in their ability to teach. Practicing teachers from earlier practica carried what they learned into their classrooms. We explore implications for incorporating such sites in elementary teacher education programs and suggest further research.

Introduction

Calls for K-6 students with better science knowledge continue to influence how we think about preparing teachers for teaching science in elementary schools, yet surprisingly, little variation exists in the design of science teacher preparation programs from institution to institution (Anderson & Mitchener, 1994). Of interest to us is the potential for teacher preparation in science museums and nature centers—places with extensive teaching materials from the real world for hands-on activities, experts with deep science understandings, and opportunities for repetitive teaching, all of which hold promise for learning to manage hands-on science activities and to develop reflective practice (Chin & Tuan, 2000; Falk & Dierking, 2000; Swift, 1999). In an earlier time, science education programs primarily focused on transmitting knowledge, even though content alone was (and is) not enough for a teacher to adequately teach science (Anderson & Mitchener, 1994). For over a decade, the importance of practica to learning to teach science has been well-established (e.g., Cannon, 1999; Mason, 1989). In fact, linking science methods with a practicum reaps benefits. For instance, in a three-year project studying the science efficacy of two groups of preservice teachers, Crowther and Cannon (1999) found that order mattered: "[H]aving the methods first cut down on many problems such as understanding lesson planning, hands-on teaching

methodologies, and general understandings of developmentally appropriate science lessons" (p. 16), and after their methods classes "[teacher education] students had . . . more in-depth answers to the questions and seemed to get more out of the science practicum" (p. 15). Though most practica occur in schools, we wonder about the potential of offering practica in out-of-school science learning communities. Such sites are suggested not as a replacement for in-school practica, but as places where different opportunities might exist that enable learning useful teaching skills consonant with becoming a mature science educator. In order to systematically consider the potential of out-of-school sites for learning to *teach* science, our research used an ethnographic approach to examine a practicum where preservice elementary teachers are learning to teach science at two out-of-school science settings. In particular, we wondered what teachers learned about science and teaching science, how their sense of themselves as science teachers changed, and to what extent such settings might contribute to reform in science education to promote greater scientific literacy.

Conceptual Framework

Science education reform made scientific literacy its main goal (e.g., AAAS, 1998; Ahlgren & Rutherford, 1993; Aldridge, 1992; NRC, 1996; NSTA, 2000), but some argued that "though the vision of scientific literacy reflected in reform proposals is broad, progressive, and inclusive, it is being implemented in narrow and conventional ways" (Eisenhart, Finkel, & Marion, 1996, p. 261). We will argue that out-of-school sites of science practice provide robust opportunities to learn science and should inform science education. As innovative sites of science teacher preparation, out-of-school science settings must account for concerns raised by science education research. In *Making Science Make Sense*, the Bayer Corporation (2004) reported that in elementary education classrooms, science continues to be taught less often than other subjects, though teachers use more hands-on activities to teach science now than they did a decade ago. Their report also states that teachers continue to feel ill-prepared to teach science and wished they had had more science teaching preparation. In fact, the Bayer Corporation study found that science was perceived and treated as a second-tier subject both in classrooms and in teacher education programs. Many College of Education deans surveyed said that elementary education programs should require more elementary teacher-education classes in science. Anderson and Mitchener (1994) drew our attention to some aspects of science education needing reform with their focus on the lack of adequate preparation for and interest in teaching science (especially among elementary teachers), issues they cited as central reasons for science not being taught and, ultimately, students' poor showings in science. Researchers, trying to explain why elementary teachers avoid teaching science, noted that teachers have scientific misunderstandings (Butts, Koballa, & Elliott, 1997), a lack of formal reasoning ability (Anderson & Mitchener, 1994), naïve views about science (Abd-El-Khalick & BouJaoude, 1997), or a superficial understanding of concepts and processes (Ginns & Watters, 1995). Furthermore, inadequate science knowledge can lead to negative attitudes toward science and the teaching of it (Butts et al., 1997), which contributes to these teachers avoiding teaching science in their own classrooms (Caton, Brewer, & Manning, 1997; Ramey-Gassert, Shroyer, & Staver, 1996). In fact, factors such as low science teaching self-efficacy, negative attitudes toward science, and science anxiety are related (Ramey-Gassert & Shroyer, 1992) and directly affect teachers choosing to teach elementary science or not. Reforming

science teaching is further complicated when teachers' own school-related experiences influence their thinking about how to educate children, operate schools, and prepare teachers, whether or not these opinions are consistent with research (Akerson & Reinkens, 2002; Harwell, 2000; Tosun, 2000).

Several authors suggested ways in which preservice teachers could be better prepared to teach science. Preservice teachers, for instance, need adequate and accurate science content and pedagogy instruction, especially since elementary students have an early interest in science that diminishes as they progress through school (Ginns & Watters, 1995). Wilson (1996) promoted improving the teaching of science with inquiry-based, hands-on activities *early* in preservice field experiences, allowing preservice teachers to practice presenting science information, to use science materials, and to learn to manage equipment, as well as to observe educators who model these teaching practices and reflect on their own practices. Similarly, Ramey-Gassert et al. (1996) suggested that science learning occurs in an environment that promotes cooperative learning, collegial support, an inviting and noncompetitive atmosphere, and links to current societal issues. Preservice teachers need to actually "see" science at work to internalize science and understand the extent to which it is a part of our everyday lives (Lederman, 1999).

Also, the structure of preservice teachers' preparation impacts their future science teaching experiences once in the classroom. Wilson and Berne (1999) expressed concern with teacher preparation programs whose mandatory and voluntary aspects are "patched" together into a "curriculum" of methods courses and subject-matter courses taught in different departments. When there is little coordination between the two, preservice teachers must synthesize science content with methods courses, which can lead to disjointed information. Science methods courses are sometimes criticized for their lack of rigor; for a duplication of materials covered in other classes; for incorporating more than one subject (such as science and math); and for being organized haphazardly, diluted in content, or otherwise inadequate (Anderson & Mitchener, 1994). Furthermore, even when teachers have science majors or minors, they might only be knowledgeable in a narrow area of science, though elementary teachers will be expected to teach in all science areas (Lenton & Turner, 1999).

Thus, support for using out-of-school science settings for educating preservice teachers developed (Chin, 2004; Falk & Dierking, 2000; Hofstein & Rosenfeld, 1996; Kelly, 2000). Such sites provide opportunities to manipulate real objects and engage visitors in active participation, thus countering concerns that elementary classrooms diminish curiosity with an emphasis on rote learning (Ramey-Gassert, Walberg, & Walberg, 1994, p. 345). Advocates of teacher preparation in out-of-school science settings recommended forming a partnership or collaboration among these alternative science settings and universities (Chesebrough, 1994), sharing methodologies (Bailey, 1998), and providing preservice teacher training for using the outdoors (Ferry, 1995a, 1995b). According to Paris (1997), "Universities can increase their service learning by involving undergraduates in school outreach programs. Museums have creative educational staff members and physical resources that can augment school curricula if teachers have access to them and are shown how to incorporate the materials" (p. 26).

Though an increasingly expansive literature about students' learning in out-of-school sites is emerging (which is beyond the scope of this article), there have been relatively few studies about *teacher preparation* at these sites (Chin, 2004; Chin & Tuan, 2000); however, those studies that exist suggest the potential to positively impact elementary science teaching. Neathery (1998) studied the

out-of-school learning experiences of twenty public and private elementary (K-6) school teachers who had varying amounts of teaching experience. Each teacher was given a learning experience at sites such as SeaWorld, EPCOT, Discovery Island, and a wildlife refuge. Neathery found that teachers responded favorably to this experience, especially learning "valuable knowledge to use in developing their science lesson plans" (p. 42). In a small study in Taiwan, researchers found that including museum resources in science methods courses helped preservice teachers learn to teach science, and such resources were later incorporated into their own teaching (Chin, 2004; Chin & Tuan, 2000). In an internship program between a science museum and a school where practicing teachers took advantage of an opportunity for training in the museum, participating teachers later conducted more science activities with their students than did teachers who did not participate (David & Matthews, 1995). A small-scale preservice teacher preparation program between a university and a field study (nature) center revealed that attendees of the program felt the program benefited them, increasing their science knowledge and confidence in their science teaching ability, even after working only eight hours there (Ferry, 1995b). Increasing classroom use of science activities and greater teaching confidence also might improve student learning since involving students in hands-on activities significantly helps them to understand scientific concepts (David & Matthews, 1995; Jacobson & Lind, 1992). Thus, promising results for teacher education in out-of-school science settings suggest the potential of such preparation (Chin, 2004).

Alternative settings, such as natural history and science museums and nature centers, seem likely to promote active engagement in real and simulated science activities. Preservice teachers have the opportunity to interact with science educators who have deep-seated science expertise, to learn to use collections of scientific materials and the outdoors, and to engage in hands-on activities and learn science concepts themselves as they teach these to students at the sites. Also, such science settings have the potential to cultivate the wonder of discovery, which might help students appreciate the excitement and relevance of science. Because the number of science museums is growing faster than other types, some researchers suggest that science museums, and we argue other similar sites, could serve as change agents for reform (e.g., St. John, 1990). Thus, educating teachers in out-of-school science settings shows promise and deserves more attention. The research reported in this article studied a practicum where preservice elementary teachers learned to teach science at two out-of-school science settings. In particular, the authors looked into the following:

- What teachers learned about science and teaching science
- How their sense of themselves as science teachers changed
- To what extent such settings might contribute to reform in science education to promote greater scientific literacy

Description of Science Teaching Practica Studied

Since the late 1970s, "Midwestern" University has required its undergraduate preservice teachers who were enrolled in science methods to concurrently obtain science teaching experience in the ungraded practicum that we studied. Here, preservice teachers earn full credit by completing the required number of science teaching hours. Like other teacher preparation programs, this requirement developed out of a desire to enhance the science backgrounds of elementary

teachers and to better prepare preservice teachers to teach science. Though the specifics of the science teaching requirement evolved since conception, students are currently required either to teach science a minimum of 15 hours accompanied by several alternative written assignments or to teach approximately 30 hours without additional assignments. Most of the preservice teachers studied chose to teach the full complement of hours, or close to it, in lieu of completing alternative assignments. On the first day of their science methods class, preservice teachers heard presentations from science museum and nature center staff, after which they selected a place to gain science teaching experience: one of the two out-of-school sites or finding their own situations. Most preservice teachers chose to learn to teach science at the science museum or nature center, places where visitors expect lively, vibrant, and engaging lessons.

Prior to teaching at the out-of-school science sites, preservice teachers received a detailed lesson plan for the activity or lesson they would be teaching as well as training from museum and nature center staff. As state content standards evolved, lessons at both sites explicitly addressed them. The two sites differ. At the science museum, preservice teachers learned 45-minute lessons/activities, which they presented to students in grades 4 to 6 from area school districts who came to the museum for a full-day or weeklong museum experience. After training from scientists and museum educator specialists, preservice teachers worked in pairs or in groups of three and divided the teaching responsibilities or took turns teaching as visiting elementary students rotated through science lessons or activities. Children received a sampling of various programs on a variety of science topics such as light and color, geology, motion, and water purification. Typically, on a given day each week, the same lesson was consecutively taught three times. Ultimately, each preservice teacher learned only two 45-minute lessons—one for the first half of the semester and another for the second half.

At a nature center serving K-12 students in a large suburban school district, preservice teachers learned prepared activities embedded in two-hour lessons taught to visiting classes; these lessons augmented students' in-school science curriculum. The lessons have a science-research or process-skills focus with an outdoor component. After receiving their training from experienced nature center staff, preservice teachers taught all or parts of the lessons under the guidance of the staff. Preservice teachers worked individually or with other preservice teachers as they instructed small groups of students. Lesson topics varied by grade level; for example, Kindergarten students focused on animal classification, fifth graders studied ecosystems, and sixth graders explored people's impact on the environment. The number of times a lesson or activity was taught by a preservice teacher depended on the teaching schedule selected for the semester. Each preservice teacher learned from two to four different grade-level programs that incorporated many experiments and an outdoor component. At these practicum sites, studying learning to teach science required a methodology that allowed seeing the sites from the participants' viewpoints.

Methodology and Data Collection

An ethnographic methodology, the mainstay of cultural anthropology research (Denzin, 1997), provided a systematic way to study the everyday world from the vantage point of participants. Using this approach allowed studying the teaching of preservice teachers as they taught as well as learning about their teaching and about their sense of themselves as science teachers during interviews. In addition,

a quasi-longitudinal piece examined the ways that teaching in the out-of-school sites influenced teachers' classroom practices.

Though ethnographic data are typically qualitative, it is not unusual to incorporate quantitative data to enhance research findings (LeCompte & Schensul, 1997). Our data collection strategies included observations, individual and group interviews, and a survey. Data came from two primary sources: 24 preservice teachers teaching at the sites and 42 practicing teachers who had taught there. Eight preservice teachers (four at each site) were observed teaching over the course of a semester and were interviewed at the beginning and end of their teaching experience. Except for one preservice teacher who was observed three times, five or six two-hour observations of each preservice teacher occurred throughout the semester, taking place about every other week. Handwritten field notes were later typed up into expanded accounts (Spradley, 1980). A focused group interview with 16 preservice teachers was conducted at the two science teaching sites (7 at the science museum and 9 at the nature center). Forty-two practicing teachers (30 from the science museum and 12 from the nature center) participated in an anonymous online survey, and 13 of these teachers agreed to individual interviews (8 from the science museum and 5 from the nature center).

Qualitative data analysis was utilized in the ethnographic interpretive tradition (Spradley, 1980) to search for and identify patterns in the data. In particular, semantic domains—those preserving participants' sense of the situation or their meanings—emerged though careful readings of data and preserved patterns of sameness. A taxonomic analysis was begun by gathering common domains across participants and locating subdomains; this was completed by working out relationships between domains. Finally, systematic searches for patterns of difference (componential analysis) completed the analysis. Careful, repeated readings of the data to rule out competing hypotheses or conjectures was the final step in the analysis. Rigor was built into the study through triangulation of methods and sources, persistent observation of teachers (four or more times each), prolonged engagement (Jung's experiences in the region as a K-12 science educator, a frequent participant at both sites, and a teacher educator made her presence less likely to disrupt the settings), member checks, and by keeping a researcher journal in which conjectures could be noted and later corroborated through fieldwork (Lincoln & Guba, 1985).

Findings

As the sites selected for science learning and teaching practice, the out-of-school locations provided opportunities that enhanced preservice teachers' skills. In what follows, we describe teachers' characterization of their teaching experiences and the climate of the sites, the use of appropriate teaching practices and other teaching strategies learned, teachers' science learning, and the ways different aspects of their experiences ultimately influenced teachers' confidence to teach science.

Positive Experiences in a Nonthreatening Environment

Preservice and practicing teachers had positive experiences in science teaching at the science museum and nature centers. For example, during an interview, Sidney, a preservice teacher commented,

I have had a very positive experience at [the science museum]. I never taught science in an atmosphere such as that. And I really like it a lot. I'm actually thinking about continuing there and teaching. . . . I see kids so excited about what they're learning because we do fun things that make them excited about what we're actually teaching. I've had a very positive experience. I think I'm a stronger science teacher in my actual K-5 teaching because of [the program].

Likewise, two teacher-education focus group participants (Janet and May) found their science teaching experiences were consistently good, unlike other teaching field experiences where the quality was inconsistent. Janet felt "way more involved than in some of the other fields. I feel like I'm doing so much more [than in my other fields]." A (science major) practicing teacher said she did not gain as much as she would have wanted from the science teaching experience, but "had a very positive experience at [the science museum]." "I think it's an excellent program" (practicing teacher Patricia). Practicing teachers' online survey responses (to item #14) also reflected positive out-of-school science teaching experiences with over 80% rating them as good, very good, or excellent (not poor or fair).

The out-of-school sites provided a nonthreatening climate that preservice teachers found conducive to teaching. In each of the out-of-school science teaching experiences, preservice teachers primarily team-taught and thus supported one another. They noted that they sometimes felt inhibited during traditional classroom teaching experiences because they felt they had to please the classroom teacher. They did not feel as though they had to please anyone at the out-of-school sites and could experiment with finding their own teaching style. Ungraded credit received for merely completing the required number of science teaching hours also contributed to feeling less pressure. As Amy put it,

This one [science museum] is entirely different because it's nice, the fact that I don't have a teacher in the room. And I'm able to, I obviously jump in and do it myself instead of sitting back and checking papers and smiling and leading the pledge or something. Where in my other fields, I was new and I had certain things to do. And I don't want to say I was afraid to volunteer, . . . you can jump in, because it's just expected and I like that. But in my other fields, . . . I wanted a good review, so I didn't want to tick off the teacher, so I would just do what they wanted.

Ultimately, by observing science learning in the nonthreatening teaching environment and being involved through interacting with objects and displays, preservice teachers were actually able to "see" science at work, which helped them to internalize science and understand it as part of their (and their students') everyday lives (Lederman, 1999).

Science Knowledge

Though not seen as a major benefit, all participants reported gaining scientific knowledge, but the extent to which this was the case varied. For instance, preservice teachers with science majors or minors reported science knowledge behind all other benefits gained from the science teaching experiences, even though some made notable gains. Several non-science preservice teachers were observed struggling with the content of lessons. On five different occasions, two preservice teachers were observed consistently avoiding teaching one part of a lesson and later told the researcher this was due to not understanding one of the

concepts. In separate instances, three other preservice teachers were observed delivering too little information to students, making the science taught not fully accurate. Also, possibly signaling a decided lack of science preparation, focus group participant Yvonne said she felt that out-of-school science sites "increased it [her science knowledge] 10 times at least." We wondered if preservice teachers' sense that they had learned science might have stemmed from learning lessons or parts of the lessons very well, thus conflating learning a prepared lesson with learning science. The variation in gains in scientific knowledge might be related to the program's structure, which limited preservice teachers' access to new science knowledge. For instance, preservice teachers taught a limited number of lessons, and the nature of the sites' lessons were designed either to be a "science sampler" or to augment a school district's science curriculum.

Hands-On Teaching and Learning

The main benefit gained by participants was seeing and experiencing hands-on science teaching. In several cases, teaching at the out-of-school sites was the first time participants had seen hands-on teaching (Tina), and this led directly to their appreciation for these methods:

> *[The out-of-school site] impressed upon me that [having kids just sit and listen] is not the way to [teach science]. I just saw the advantage of hands-on, kids involved, manipulation, being able to actually handle these parts and make something from it using their imagination. That was probably the biggest thing I tried to take back [to my own classroom]. (Griffon)*

Participants reported feeling more comfortable using hands-on activities and experiments, becoming convinced that teaching in a hands-on fashion was the best teaching practice for science (Lillian, Suzanne). Practicing teachers said they incorporated hands-on methods into their own teaching in a fashion similar to that experienced at their out-of-school setting:

> *I think [the science teaching experience] has been interesting because I never was really too exposed to teaching science at all or really I don't remember seeing it taught very much in any of my fields either. (Katherine)*

For most participants, having the opportunity to work with artifacts, animal mounts and skins, science supplies, and the outdoors was a novelty, which facilitated learning to teach via hands-on activities.

Learning Additional Teaching Strategies

In addition to learning how to teach using hands-on strategies, teachers reported other facets of the out-of-school sites that contributed to developing their own teaching strategies. First, preservice teachers reported having more opportunities for actual teaching than in other traditional teaching experiences (comparing teaching science out of school with teaching of all subjects in schools). Janet, a preservice teacher in a focus group interview, said, "I feel way more involved [in this teaching experience] than in some of the other fields." Others corroborated:

I totally agree with that. I feel that I'm in charge, and I'm the teacher instead of sometimes in the fields when you don't get any teaching, or hardly any teaching, because some teachers are very controlling and they just make you staple and do random things. I feel I am actually the teacher in a class, so it's very positive. (Sidney)

I would agree with what everyone has said. I think that it's really, I think it's been my first experience where you are really the teacher. . . . You have to do everything on your own. . . . So you're really doing it all. It's really more like real teaching. (Laura)

Second, teaching science at the out-of-school sites connected ideas learned in methods classes to actual teaching, as practicing teacher Ivan noted: "Well, it really solidified, really made real, made concrete the idea of constructivist teaching. And having the children construct the knowledge that they are actually using to build that view up in what they're doing." He gave an example of a lesson where students took the temperature of water over time. He mentioned that learning to take the temperature by just doing it was a good thing and reiterated, "Some things are best learned just by doing them." Among practicing teachers, Tammy remarked on learning to apply the scientific process to experiments; Suzanne said, "but hands-on, demonstrations, not only lecturing, of course in elementary that's definitely not the way to go anyway, but, just making sure the kids have things to do to help them learn"; and Lillian noted, "A lot of what I got from the experience was to go about how to teach what I already knew about science as well as those new concepts. So different ways of teaching it I think was my greatest benefit from the experience." When asked to specify what influence, if any, the science field had on their classroom teaching, one teacher participant wrote, "I have much better timing in regards to conducting experiments. I have a better quality small-group collaboration system. I place a heavier stress on the scientific process than on the specific concept" (online survey question #7). Another wrote, "I did my student teaching in science and it (the out-of-school site) influenced me by seeing the value of having science classes outdoors" (online survey question #7).

Third, preservice teachers taught lessons to students from different grades. This was especially true at the nature center, which served a wider span of grades. This gave preservice teachers opportunities to learn about developmental stages in children and appropriate practices for different groups of children. Finally, unlike conventional classes in which curriculum marches on, out-of-school settings explicitly provided the opportunity for students to teach the same lesson several times—repetition preservice students found more effective if it occurred within the same day. This repetition provided students with enough practice to comfortably master the lesson. Education students were observed remembering more about the lesson, and they had smoother deliveries after teaching the same lesson at the second rotation of classes than the first, which helped to build their confidence. Such repetition provided opportunities for these preservice teachers to learn reflective practice, which was systematically supported by on-site science educators.

Confidence to Teach Science

Teaching science ultimately led to preservice and practicing teachers becoming more confident to teach. As one preservice teacher noted,

I have found that probably the biggest impact that my time [at the out-of-school science site] has had is in my confidence that I feel. I'm much more capable with my classroom

management to get up in front of a large group of students and maintain control and get their attention and part [of my science lesson] is going outside, so I really had to work on keeping everyone together. Another thing is that it's made me more excited about science. I'm not as afraid of it as I think I was before. I feel more excited about being able to do fun things with the kids with them doing science eventually when, you know, you have your own classroom. It's made me want to be like an outside educator. I love taking the kids outside, and they get so excited. And it's just so much fun. (Laura)

In fact, certain aspects of teaching in these settings contributed to preservice teachers' confidence: observing other teachers at work, seeing children engaged in hands-on activities, teaching younger students, working with science materials, and having the opportunity to teach the same lesson repeatedly (Table 1). When looking at elements that enhanced confidence, a pattern or series of "steps" to becoming confident to teach science emerged. Memorizing the lesson flow and content does not necessarily have to occur before teaching the lesson for the first time; in fact, it could occur during teaching.

Table 1. Sequence of Experiences Promoting Confidence to Teach Science

Experience	Description
Observing hands-on instruction	*Practicing* teachers in the study stated boldly that seeing children engaged in hands-on activities made concepts much easier for children and themselves to grasp in a much more interesting fashion. *Preservice and practicing teachers* reported that seeing experiments and activities modeled helped make them more confident to teach science.
Memorizing lesson flow and content	*Preservice teachers* committed the flow of the lesson to memory and solidified enough science knowledge to present the lesson fluently and to answer basic questions.
Doing teaching	Without a sense of the lesson, in their words "being thrown into the teaching," *preservice teachers* reported feeling nervous and often forgetting parts of the lesson. Some even felt they had to make up information to fill in the silences. Once information and the flow of the lesson were memorized and the first teaching occurred, nervousness went away.
Repeating teaching	*Preservice and practicing teachers* reported that teaching the same lesson multiple times permitted them to feel more confident to teach. Ideally, the first repetition should occur within a short time period, preferably the same day, with others over a limited period of time (about 3 to 5 weeks).

Feeling confident after having had the science teaching experience manifested affectively and behaviorally in both preservice and practicing teachers. Most preservice and practicing teachers reported feeling more confident; some said

they felt like experts (affective manifestation). Teachers who had science teaching experiences at out-of-school settings reported teaching using hands-on activities and experiments (behavioral manifestation).

Feeling confident to teach science after having out-of-school science teaching experiences was not necessarily linked to science teaching expertise, however. In fact, not all participants fully recognized the objectives contained in the lessons they taught or the value of some teaching methods. Some teacher participants perceived the teaching experience in a more concrete or literal way. One poignant example concerned a practicing teacher who decided she could not use anything from her science teaching experiences because the grade level of students at the out-of-school site differed from her classroom. She could not identify either underlying methods or techniques used, or adapt an activity to the grade level she currently taught. Conversely, other practicing teachers saw their science teaching experience more holistically. These teachers gleaned methods, techniques, and strategies from the experience in addition to learning to teach using hands-on activities. One practicing teacher, who was not teaching science, said he learned that taking children outdoors added value and interest to lessons, as did learning by doing (Ivan). He felt that methods and techniques could be transferred across content areas. This reinforces what Crowther and Cannon (1999) found to be true: the importance of teachers possessing underlying teaching fundamentals to benefit from practica. It also suggests that explicitly making such links remains important.

Discussion of Findings

Our study illustrates that out-of-school institutions benefit preservice teachers by providing them with positive science teaching experiences—exposure to and practice with hands-on, inquiry-based science lessons and other teaching strategies, in a nonthreatening environment, that build confidence in teaching science. In fact, in the classroom, teachers taught science using the methods learned in their out-of-school field experiences. As such, the out-of-school settings we studied provide a model program meeting elementary science professional development criteria, especially NSTA's (1996) requirement that "activities should involve teachers in the learning of science and pedagogy through inquiry, and integrate knowledge of science, learning, and pedagogy."

In particular, the out-of-school sites studied provided *some* aspects of good teacher preparation. First, carefully organized lessons conveyed science expertise from professional science educators to preservice teachers. To a limited degree, this enhanced the science knowledge of preservice teachers, as suggested by researchers (Bailey, 1998; Ginns & Watters, 1995). Second, with professional science educators available for consultation, preservice teachers' science misconceptions could usually be corrected, an issue raised by Ramey-Gassert et al. (1996). Third, preservice teachers gained practice using inquiry-based, hands-on science teaching, which had been notably absent at their in-school practica to date, and most practicing teachers incorporated such activities in their classrooms, answering Wilson's call (1996). Fourth, preservice teachers did not feel threatened, since science educators at the sites had little power over teachers' futures, an unanticipated finding. Though collegiality per se may not have developed (as called for by Ramey-Gassert et al., 1996), there was an air of cooperation between experts at the sites and preservice teachers (and among preservice teachers), which contributed to teachers' confidence. Fifth, preservice teachers learned about

classroom resources that they could begin to gather, resources Wilson (1996), Ramey-Gassert et al. (1994), and Tirunarayanan (1997) found important, and about out-of-school science-learning opportunities for their students that could augment science lessons in schools (as suggested by Paris, 1997). Sixth, out-of-school settings explicitly allowed preservice teachers to teach the same lesson several times and to diverse groups, repetition that not only provided them with enough practice to master the lesson but also contributed to their confidence and initiated reflective practice (Baird, Fensham, Gunstone, & White, 1991; Chin, 2004; Chin & Tuan, 2000; Swift, 1999). Finally, the sites brought science to life for preservice teachers (Lederman, 1999), which improved the chances that they would help their students make such connections.

Nonetheless, some aspects of science teaching could not be modeled or attempted at these sites. For instance, as currently structured—and this is a partial list—the range of science knowledge and activities taught was quite limited for an individual preservice teacher. Also, not having full control of a classroom *over time* limited the extent to which preservice teachers could develop (1) understandings about individual students that influence decisionmaking about teaching, (2) classroom and time management skills, (3) meaningful lessons that convey science ideas to children, (4) skill in moving between different subjects, and (5) questioning techniques. Thus, the out-of-school sites provided robust opportunities that began the process of becoming a science teacher, as intended in the program structure at Midwestern University.

Implications for Teacher Education

The sites studied illustrate one way to incorporate new approaches to teaching science through institutionalized collaborations between a university and out-of-school science sites. This collaboration sought to improve children's science literacy, which was an important goal because children at the elementary level need a solid foundation upon which to build subsequent science understandings that are central to life in today's society (Darling-Hammond, 1996). Several aspects of the sites we studied add to growing evidence for using out-of-school science settings for educating preservice teachers (Cox-Petersen & Pfaffinger, 1998; Katz & McGinnis, 1999). We believe these experiences could be stronger if they explicitly coordinate academic science content, teaching methods, and teaching practice (which did not always happen at our sites) because this provides for much-needed synthesis across often-disjoint areas (Anderson & Mitchener, 1994). Also, when incorporated in teacher preparation programs, out-of-school practica lessons should attend to state-level mandates for content standards (Katz & McGinnis, 1999), as was the case in the two programs studied. In addition, taking advantage of community resources that are present at out-of-school sites provided a forum that began the process of orienting schools toward societal participation in shaping the way science will be taught and learned in the future (Darling-Hammond, 1996; NSTA, 2000). To our knowledge, there is no systematic collection of data about the use of out-of-school sites for teacher preparation, and future research into their prevalence and practices would add to our appreciation of their potential.

In addition to contributing to improving teacher preparation programs, the use of an out-of-school site as a community resource helped preservice teachers make associations in their communities that connected school science to the real world (NSTA, 2000). Among the central advantages of out-of-school science institutions are collection materials and exhibitry, and trained personnel from particular fields

of science with deep understandings of these teaching materials. Seeing these materials, their skillful use, and connections to science concepts relevant to all levels of education has the potential to provide teachers with models for their own teaching that deepen their own and their students' understandings of science. In fact, by seeing in these collections readily available materials, teachers could begin to accumulate items for their own classrooms and begin to better accommodate hands-on activities at all levels. Once familiar with an out-of-school institution, practicing teachers in this study brought their students to out-of-school science sites on field trips, in many cases coming to the same institution where they previously taught. Such opportunities hold potential to reinforce students' use of scientific knowledge to make sense of the world, and to give students models for thinking scientifically about matters of interest to them. To our way of thinking, the out-of-school sites served to condition preservice teachers to think of themselves as people willing, and becoming able, to get in front of children and teach science, something that "having to please people" at in-school practica hindered. Additional fine-grained (qualitative) research about relationships between preservice teachers and their in- and out-of-school teaching mentors would help clarify contributions of mentors to becoming teachers.

Preservice teachers' confidence to teach science depends overwhelmingly on their elementary school science experiences plus the number of science courses taken in college (Jarrett, 1999). Thus, since few of our preservice teachers had science majors or minors; had actually taught; or had observed hands-on, inquiry-based science teaching, it should come as little surprise that most of them entered science methods, and the practicum we studied, anxious about teaching science. As with Jarrett's in-school practicum students, inquiry-based science experiences at our out-of-school sites boosted teachers' willingness to teach science once in the classroom (per our practicing teachers) and their confidence to teach science; however, Jarrett's research design could not illuminate just how this happened. Eick, Ware, and Williams (2003) provide insights into this process. Working with preservice secondary science teachers, Eick et al. found that co-teaching a lesson (observing and assisting) with an experienced teacher, then teaching the same lesson in the next class supported by the teacher, improved preservice teachers' comfort in learning to teach, their confidence in their ability to teach and manage their classrooms, their critical reflection, and their awareness of inquiry-based methods. Our study corroborates the importance of observation; in fact, our preservice teachers watched experienced educators and/or scientists teach a lesson several times, then taught the same lesson under the guidance of this person prior to teaching the lesson on their own. In addition, our study indicates that preservice teachers' confidence increased after memorizing the lesson flow and learning enough science content to answer questions; thus, an increase in science knowledge, even limited amounts, contributes to increased confidence to teach. (See Harlen & Holroyd, 1997, for a discussion of the difficulties preservice teachers have in learning some science content.) Finally, our participants found that reteaching the lesson on the same day and over the course of three to five weeks was the amount of time needed to further build confidence, something that is difficult to accommodate at in-school practica. Thus, since low confidence plays a key role in preservice elementary teachers *not* thinking of themselves as people who can teach science, we encourage science teacher educators to explore the potential of the sequence our participants found so helpful: observing a lesson being taught, committing the lesson flow to memory and learning key science ideas, teaching the lesson, and *reteaching* the lesson in a timely fashion. Though space

limitations preclude detailed discussion, opportunities to reflect on their teaching were built into the out-of-school teaching sites and also enhanced confidence. We continue to have deep curiosities about exactly how teacher science knowledge and confidence grew at the out-of-school sites and are contemplating additional research. For instance, what is the nature of the activities preservice teachers taught and to what extent did science knowledge and confidence differ for teachers at the two sites? Our study depended on teachers' sense of their science learning, which may not have accurately represented their content knowledge growth. Adding pre- and posttests of content knowledge to subsequent research would strengthen it. Also, we wonder to what extent a science content course for preservice teachers at out-of-school sites might better close their science knowledge gap.

Though both sites encouraged innovative opportunities to gain certain kinds of knowledge, such as learning science, developmentally appropriate pedagogy, and use of science materials, preservice teachers taking advantage of these opportunities should be explicitly monitored and coordinated with science methods if these opportunities are to have the intended impact. Also, the balance between out-of-school and in-school practica deserves careful consideration by those organizing teacher education programs. In ways we sometimes found surprising, such as learning that our preservice teacher participants had not yet seen hands-on science teaching during earlier in-school practica and were in fact unwilling to attempt teaching at the risk of displeasing classroom teachers, there are advantages and limitations to in- and out-of-school sites of science learning. These differences need to be carefully understood, taken into consideration when developing a teacher education program, and monitored to ensure that preservice teachers have the kinds of experiences needed to become capable teachers of science—especially at the elementary level where science all too often falls by the wayside in classrooms.

Acknowledgements

We are grateful to our research participants who let us into their lives as science teachers, and to two anonymous reviewers whose insightful comments improved our arguments.

References

Abd-El-Khalick, F., & BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*(7), 673-699.

Ahlgren, A., & Rutherford, J. (1993). Where is Project 2061 today? *Educational Leadership, 50*(8), 19-22.

Akerson, V. L., & Reinkens, K. A. (2002). Preparing preservice elementary teachers to teach for conceptual change: A case study. *Journal of Elementary Science Education, 14*(1), 29-45.

Aldridge, B. (1992). Project on scope, sequence, and coordination: A new synthesis for improving science education. *Journal of Science Education and Technology, 1*(1), 13-21.

American Association for the Advancement of Science (AAAS). (1998). *Project 2061: Science literacy for a changing future. Update 1998-99.* Washington, DC: Author.

Anderson, R. D., & Mitchener, C. P. (1994). Research on science teacher education. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning: A project of the National Science Teachers Association* (pp. 3-37). New York: Macmillan Publishing Company.

Bailey, E. (1998). Two stories of collaboration and cross-fertilization: Museum-school partnerships in Massachusetts. *Journal of Museum Education, 23*(2), 16-18.

Baird, J. R., Fensham, P. J., Gunstone, R. F., & White, R. T. (1991). The importance of reflective practice in improving science teaching and learning. *Journal of Research in Science Teaching, 28*(2), 163-182.

Bayer Corporation. (2004). *Making science make sense. Bayer facts of science education in 2004: Are the nation's colleges and universities adequately preparing elementary schoolteachers of tomorrow to teach science? Progress report on decade-long science education reform movement*. Conducted by Market Research. Available online: www.bayerus.com/MSMS/news/facts.cfm. Retrieved September 28, 2004.

Butts, D. P., Koballa, T. R., & Elliott, T. D. (1997). Does participating in an undergraduate elementary science methods course make a difference? *Journal of Elementary Science Education, 9(2),* 1-17.

Cannon, J. R. (1999). Influence of an extended elementary science teaching practicum experience upon preservice elementary teachers' science self-efficacy. *Science Educator, 8*(1), 30-35.

Caton, E. L., Brewer, C. A., & Manning, M. (1997). Teaching with inquiry: Scientist/teacher partnerships for ecological and energy education. Supplement to *Bulletin of the Ecological Society of America, 78*, 65.

Chesebrough, D. (1994). Informal science teacher preparation. *Science Education International, 5*(2), 28-33.

Chin, C-C. (2004). Museum experience: A resource for teacher education. *International Journal of Science and Mathematics Education, 2*(1), 63-90.

Chin, C-C., & Tuan, H-L. (2000, April 28-May 1). *Using a museum setting to enhance preservice science teachers' reflection on their student teaching in a methods course*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Cox-Petersen, A. M., & Pfaffinger, J. (1998). Teacher preparation and teacher-student interactions at a discovery center of natural history. *Journal of Elementary Science Education, 10*(2), 20-35.

Crowther, D. T., & Cannon, J. R. (1999). *How much is enough? Preparing elementary science teachers through science practicums*. Paper presented at the Annual Meeting of the Association for the Education of Teachers of Science, Minneapolis, MN.

David, C., & Matthews, B. (1995). The teacher internship program for science (TIPS): A successful museum-school partnership. *Journal of Elementary Science Education, 7*(1), 16-28.

Darling-Hammond, L. (1996). The right to learn and the advancement of teaching: Research, policy, and practice for democratic education. *Educational Researcher, 25*(6), 5-17.

Denzin, N. K. (1997). *Interpretive ethnography*. New York: McGraw-Hill.

Eick, C. J., Ware, F. N., & Williams, P. G. (2003). Coteaching in a science methods course: A situated learning model of becoming a teacher. *Journal of Teacher Education, 54*(1), 74-85.

Eisenhart, M. A., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33*(2), 261-295.

Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitors' experience and the making of meaning*. Walnut Creek, CA: AltaMira Press.

Ferry, B. (1995a). Enhancing environmental experiences through effective partnerships among teacher educators, field study centers, and schools. *Journal of Experiential Education, 18*(3), 133-137.
Ferry, B. (1995b). Science centers in Australia provide valuable training for preservice teachers. *Journal of Science Education and Technology, 4*(3), 255-260.
Ginns, I. S., & Watters, J. J. (1995). An analysis of scientific understandings of preservice elementary teacher education students. *Journal of Research in Science Teaching, 32*(2), 205-222.
Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International Journal of Science Education, 19*(1), 93-105.
Harwell, S. H. (2000). Impediments to change: An application of force-field analysis to leader master teacher training in an elementary level science systemic reform initiative. *Journal of Elementary Science Education, 12*(2), 7-19
Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education, 28*, 87-112.
Jacobson, W. J., & Lind, K. K. (1992). Progress in science education. *Science Teacher, 59*(3), 38-40.
Jarrett, O. S. (1999). Science interest and confidence among preservice elementary teachers. *Journal of Elementary Science Education, 11*(1), 49-59.
Katz, P., & McGinnis, J. R. (1999). An informal elementary science education program's response to the national science education reform movement. *Journal of Elementary Science Education, 11*(1), 1-15.
Kelly, J. (2000). Rethinking the elementary science methods course: A case for content, pedagogy, and informal science education. *International Journal of Science Education, 22*(7), 755–777.
LeCompte, M. D., & Schensul, J. J. (Eds.). (1997). *Ethnographer's toolkit*. Walnut Creek, CA: Altamira Press, a subsidiary of Sage Publications.
Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.
Lenton, G., & Turner, G. (1999). Student-teachers' grasp of science concepts. *School Science Review, 81*(295), 67-72.
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage.
Mason, C. (1989). Field-based collaboration and cooperation: Vehicles for effective preparation of preservice science teachers. *Journal of Science Teacher Education, 1*(2), 38-40.
National Research Council (NRC). (1996). *National Science Education Standards*. Washington, DC: Author.
National Science Teachers Association (NSTA). (1996). Position statement on *The National Science Education Standards*. Available online: www.nsta.org/position statement&psid=24. Retrieved July 6, 2005.
NSTA. (2000). *NSTA pathways to the science standards: Guidelines for moving the vision into practice* (Elementary school ed.). Arlington, VA: Author.
Neathery, M. F. (1998). Informal learning in experiential settings. *Journal of Elementary Education, 10*(2), 36-49.
Paris, S. G. (1997). Situated motivation and informal learning. *Journal of Museum Education, 22*, 22-27.
Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing science teaching self-efficacy in preservice elementary teachers. *Journal of Elementary Education, 4*(1), 26-34.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education, 80*(3), 283-315.

Ramey-Gassert, L., Walberg, III, H. J., & Walberg, H. J. (1994). Reexamining connections: Museums as science learning environments. *Science Education, 78*(4), 345-363.

St. John, M. (1990). *First hand learning: Teacher education in science museums. Volume 1: Findings*. Inverness, CA: Inverness Research Associates.

Spradley, J. P. (1980). *Participant observation*. Fort Worth: Harcourt Brace College Publishers.

Swift, F. (1999). Learning from objects. *Museum Practice, 4*(1), 55-56.

Tirunarayanan, M. O. (1997). Promoting pre-service science teachers' awareness of community-based science education resource centers. *Journal of Science Teacher Education, 8*(1), 69-75.

Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School Science and Mathematics, 100*(7), 374-379.

Wilson, J. D. (1996). An evaluation of the field experiences of the innovative model for the preparation of elementary teachers for science, mathematics, and technology. *Journal of Teacher Education, 47*(1), 53-59.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Chapter 6). Washington, DC: American Educational Research Association.

Correspondence regarding this article should be directed to

Dr. Karen L. Tonso
Theoretical & Behavioral Foundations of Education
#319 Education
Wayne State University
Detroit, MI 48202
ag7246@wayne.edu
(313) 577-1764
Fax: (313) 577-5235

Manuscript accepted August 10, 2005.