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Science Museums & Specialized Content Courses for Prospective Elementary Teachers: Implications for Learning to Teach Science

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Abstract

This study explores opportunities for preservice elementary teachers to experience science teaching and learning in informal settings and how this complements their learning in a specialized content course for teachers. We examined survey responses of 69 preservice teachers enrolled in a physical science content course who concurrently volunteered at a local science center, and how this experience served as a potential source of PCK. Survey responses indicate that, beyond simply learning about content and activities, preservice teachers can also learn much about *learners* as they observe children exploring science in informal settings, and that these experiences may shape their expectations for students' interest, knowledge, and abilities in science—expectations that can play an important role in their future science teaching, as well as the way in which they perceive the material they are learning in content courses as being appropriate for elementary learners.

Science Museums & Specialized Content Courses for Prospective Elementary Teachers: Implications for Learning to Teach Science

Though teachers are using more hands-on activities to teach science now than a decade ago, science nonetheless continues to be taught less often than other subjects in the elementary classroom (Bayer Corporation, 2004). Elementary teachers' avoidance of teaching science has been attributed to interrelated factors including low science teaching self-efficacy, negative attitudes toward science, and science anxiety (Ramey-Gassert, Shroyer, & Staver, 1996), which can stem from poor content preparation and a lack of knowledge of science (Atwater, Gardener, & Kight, 1991).

The importance of teacher knowledge has been emphasized in the *National Science Education Standards* (NRC, 1996). An effective teacher, as defined by the *Standards*, possesses knowledge of science content, curriculum, learning, teaching, and students. The integration of these knowledge bases forms a teachers' pedagogical content knowledge (PCK) or knowledge of ways to help students understand subject matter. This includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction (Magnussen, Krajcik, & Borko, 1999). Sources of PCK for prospective teachers can include classroom observation as a student (either K-12 or during teacher education), coursework in teacher preparation programs, as well as coursework in the sciences (Grossman, 1990).

Prior research has shown that specialized content courses for teachers can facilitate development of robust subject matter knowledge (Haefner & Zembal-Saul, 2004) as well as understanding of the nature of science (Abd-El-Khalick, 2001). In our own experience as science teacher educators, however, we find that prospective teachers often fail to connect their

coursework in science to their future teaching, thus limiting the degree to which science courses may impact their developing PCK. Incorporating experiences in informal learning environments (such as science museums) may be one way to address this.

Informal science experiences include those that are connected with such places as nature centers, science centers, museums, aquariums, zoos, parks, and planetariums and are often used to supplement and enhance learning in K-12 classrooms. These places hold the potential to inspire imaginations, teach lessons, and shape thinking in students of all ages. Only when students and teachers alike have access to a wide variety of sources of information, including those found in informal settings, can effective science instruction occur (McComas, 2006).

It is reasonable to assume that experiences that take place in informal domains may be valuable to preservice science teachers since exhibits in those settings have moved increasingly from "hands-off" to "hands-on" and can provide valuable opportunities to view and experience science as inquiry in ways that may translate to their own teaching practice. As the *National Science Education Standards* state, "If reform is to be accomplished, professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability" (NRC, 1996, p.56). Yet, incorporating informal science experiences into teacher education programs at the undergraduate level is not common. Wojnowski (2006) points out, "Despite its importance, informal education is frequently not well used or integrated into formal education institutions."

There is growing support, however, for the use of out-of-school science settings for educating prospective teachers—most often in conjunction with elementary science methods courses (Kelly, 2000). As Kelly, Stetson, and Powell-Mikel explain, "the college classroom provides the contextual framework for science conversations and active investigations, while the

informal learning environment acts as a springboard for discussions and inquiry-based explorations with elementary students" (2002, p. 46). Informal settings provide prospective teachers with access to teaching materials and activities, interaction with science content and education experts, and opportunities for repetitive teaching—all of which can promote learning to teach science (Chin, 2004). As Jung & Tonso caution, however, "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" (2006, p. 16). The purpose of this exploratory study was to characterize the nature of these "different opportunities" for supporting teacher learning in informal environments, and how these might complement teacher learning in a specialized content course for teachers. Specifically, we were interested in examining (1) the nature of the opportunities informal environments afford prospective teachers to participate in the teaching/learning process; (2) the ways in which the experience informs prospective teachers' pedagogical content knowledge (PCK) for teaching science

Methods

Physics for Elementary Teachers is a required course (taught by the second author) for elementary education majors at a large Midwestern university, and is a prerequisite to the science methods course and early field experience in science teaching. The course enrolls approximately 180 students each semester, and includes both a lecture and laboratory component. In addition to in-class activities, all students are invited to participate in an out-of-class science learning experience for credit. This experience is intended to help students build connections between their learning in the course and their future teaching.

Though specific opportunities can vary from semester to semester, they typically include facilitating activities for students at the annual Physics Open House, volunteering at the university's Saturday Science Program for Kids, or working with local scout troops to assist them in earning their science badges. Many students choose to volunteer at Exploration Station (pseudonym), a local hands-on museum of science, health, and technology. Though students earn credit for only one volunteer shift, we have noted that over 90% of those who volunteer at Exploration Station end up completing multiple shifts. This prompted us to examine more closely the nature of prospective teachers' experiences working at Exploration Station.

Following each visit to Exploration Station, students complete a volunteer survey consisting of three open-ended questions:

1. Describe what you did during your participation today. Include the exhibits/activities you worked with.
2. What is something that impressed you about the children and/or adults with whom you worked today?
3. How are your experiences today relevant to your future teaching?

In this study, we examined survey data from one academic year (fall and spring semesters) to learn how the experience volunteering at Exploration Station complemented both what students were learning in the course and their learning to teach science more generally. Specifically, we were interesting in knowing:

- What opportunities does the Exploration Station afford prospective teachers to participate in the science teaching and learning process?
- How does the experience serve to inform prospective teachers' PCK for teaching science?

Surveys were completed by sixty-nine preservice teachers (6 males, 63 females. Collectively, the participants completed a total of 206 shifts (Table 1). The number of shifts worked by each participant ranged from 1 to 6, with an average number of shifts of 2.94. Ninety one percent of the participants completed multiple shifts at the science museum.

Table 1. Number of Volunteer Shifts Completed by Participants

Number of shifts completed	Number of participants	Percent of participants
1	6	8.70%
2	25	36.23%
3	19	27.54%
4	4	5.80%
5	13	18.84%
6	2	2.90%
Total	**69**	**100%**

Data Analysis

Data were analyzed using modified analytic induction (Bogdan & Biklen, 1998). In our initial round of open coding, we utilized low-inference to characterize responses to surveys. Similar codes were collapsed together into a single code, and categories were formed based on the redundancy and intersection of codes. Frequencies within each category were tabulated in a spreadsheet using the individual (rather than the survey) as the unit of analysis. Categories were then used to develop themes are assertions from the data. The first author developed the coding schema, which was validated through blind analysis of a sample of the data (15%) by the second author. Initial categories and assertions were then proposed by the first author. The second author served as a peer debriefer by searching the data for contradictory and confirmatory evidence for each category and assertion.

Findings

Our first research question was concerned with the opportunities Exploration Station affords prospective teachers to participate in the science teaching and learning process. Survey

results reveal a wide range of activities in which prospective elementary teachers engaged during their volunteer shifts at the museum. These are summarized in Table 2.

Table 2. Opportunities to Participate in Science Teaching and Learning at Exploration Station

Volunteer Activities	Number	Percent
Interacting with children	67	98.53%
Assisting individual children	44	65.67%
Offering explanations to children about exhibits	25	37.31%
Demonstrating how exhibits work	25	37.31%
Exploring alongside children	20	29.85%
Answering childrens' questions	19	28.36%
Monitoring safe/appropriate use of exhibits	19	28.36%
Asking children probing questions	16	23.88%
Observing children as they explored	13	19.40%
Encouraging children to try out an exhibit	11	16.42%
Guiding childrens' explorations	8	11.94%
Interacting with adults	14	20.59%
Interacted with adult visitors	9	64.29%
Interacted with staff	8	57.14%
Taught other new volunteers about the exhibits	1	7.14%
When no visitors were present	48	70.59%
Learned about stations from staff	32	66.67%
Engaged exhibits on their own	29	60.42%
Received advice from staff members	10	20.83%
Walked around	9	18.75%
Assisted in cleaning and organizing	5	10.42%
Didn't know what to do	1	2.08%

Nearly all prospective teachers had the opportunity to interact with children during their shifts, and almost all (98.53%) assisted individual students as they visited the various museum exhibits. A smaller percentage of participants (20.59%) reported interacting with adults during their shifts. These interactions were between adult visitors, staff, and other volunteers. Some of the interactions were helpful to the preservice teachers:

> Some of the things that the former teacher told us were very helpful. The things she told us will help me become a better teacher. She was talking about fossils and things like that. I think I might try to bring fossils into my classroom and have my students study

> them. I think that most students would find that enjoyable. It is probably something that a lot of kids probably haven't done before. (G1)
>
> I was able to talk to parents about how these activities differed from the activities done in their child's classroom. I learned that they obviously liked the hands-on activities and that parents are willing to contribute to a classroom if it is a hands-on activity. (S1)

Over half (70.59%) reported experiencing periods of time during which no visitors were present during their volunteer shift. During these instances, prospective teachers engaged in the exhibits on their own and/or assisted museum staff in cleaning and organizational tasks. Survey responses suggest, however, that even in these cases, there were opportunities for prospective teachers to increase their content knowledge and gain ideas for their future teaching:

> Learning about each station so that I would be able to answer visitors' questions gives me the opportunity to practice explaining concepts to children. It takes practice to put scientific information into words that anybody can understand, which is a crucial skill to have as a teacher. (W1)
>
> My experience helped me get ideas for the kinds of things we could make in my classroom. (A2)

Thus, preservice teachers were still able to benefit from being in the informal science setting.

Our second research question was concerned with the insights about teaching and learning science that prospective teachers gleaned from their experience at Exploration Station, and how the experience may serve as a source of PCK. To answer this question, we searched the data for themes and patterns relating to prospective teachers' of students, teaching and learning, and curriculum.

Knowledge of Learners

In a traditional school-based field placement prospective teachers' attention is often focused on the actions of the teacher; what we found is that during the informal science education experience (and in the absence of a teacher) prospective teachers' attention was focused primarily on the *children.* Survey responses indicate that from their museum experience, prospective teachers developed a deeper understanding of the affective, cognitive, and behavioral characteristics of young learners (Table 3).

Table 3. Prospective Teachers' Knowledge of Learners

Dimension	Number	Percent
Affective dimensions	58	85.29%
Surprised by children's interest, engagement, curiosity, enjoyment	*56*	*96.55%*
Surprised by children's determination/persistence	*8*	*13.79%*
Noticed some children didn't care how things worked/had fun anyway	*5*	*8.62%*
Noted girls seemed bored; boys were more interested in exhibits	*1*	*1.72%*
Surprised that children were not afraid to touch animals	*1*	*1.72%*
Cognitive dimensions	56	82.35%
Students' Ideas/Knowledge	43	76.79%
Learned about children's ideas about science	*25*	*58.14%*
Learned about the kinds of questions children ask	*16*	*37.21%*
Underestimated what children know	*12*	*27.91%*
Better understood the nature of children's thinking	*11*	*25.58%*
Noticed children often viewed science as "magic"	*1*	*2.33%*
Students' Abilities/Skills	42	75.00%
Underestimated children's abilities	*25*	*59.52%*
Surprised by length of children's attention span	*17*	*40.48%*
Observed children's problem solving skills	*12*	*28.57%*
Children's' learning	*12*	*28.57%*
Underestimated children's' creativity/imagination	*3*	*7.14%*
Surprised at children's' listening skills	*2*	*4.76%*
Surprised at children's' observation skills	*1*	*2.38%*
Behavioral dimensions	21	30.88%
Surprised how polite and/or well-behaved children were	*14*	*66.67%*
Surprised at children's' sense of independence	*6*	*28.57%*
Learned that children like to help each other learn science	*2*	*9.52%*
Noticed children are competitive/ motivated to improve performance	*1*	*4.76%*
Noted children are good at entertaining themselves	*1*	*4.76%*

As prospective elementary teachers interacted with students, they expressed surprise at the curiosity, interest, engagement, and enjoyment of science (96.55%) of these young learners.

> I forgot just how amazed and excited children are about science. (R)
>
> I assumed they would be vary anxious and not want to spend very much time at one station. Well, I was surprised at how long some of their attention spans were! (K1)
>
> This experience will also show me some of the areas kids are really interested in, and other areas that it will take a little more encouragement to get the kids to experiment and explore. (OO1)
>
> I was excited with how excited the kids were and how much they wanted to learn how to do the activities on their own. It was fun to watch them figure things out. (QQ2)
>
> I learned today how much children <u>love</u> science! I really want to bring science alive in my classroom, much like [Exploration Station]! (MM1)

Similarly to the way in which they had underestimated students' interest in science, they realized they had underestimated students' prior knowledge and abilities as well:

> I was impressed by how inquisitive the preschool students were… I did not know the preschool students were as smart as they were! (C3)
>
> Kids knew a lot more than I thought they would. (T)
>
> My experience [interacting] with the little boy made me realize that children really are more capable of doing things than I thought they were. (AB)
>
> It helped me see how students like to do things on their own. (AD)

Many of the preservice teachers were also surprised and impressed with the children's level of cognitive ability, particularly in the areas of prior knowledge and skills. Of those who

commented on children's cognitive abilities, had underestimated children's ideas about science (58.14%), students' questions (37.21%), and the nature of their thinking (25.58%).

> Seeing how young children interact with science materials and exhibits allowed me to gain experience with how children think and impressed on me that children know more than we think they do. I think some people don't give students enough credit at times and spoon-feed them information instead of allowing them to explore and discover on their own. The kids I worked with at [Exploration Station] were extremely intelligent and caught on to a lot more than I would have expected at first. This will encourage me to keep an open mind when I teach and not to underestimate the abilities of my students. (AAA2)
>
> I was impressed by how much children knew. While they didn't know the vocabulary to explain it, they knew how it happened or why it happened. (AA1)
>
> I really learned that children are much more knowledgeable than what most adults think. Like I have said, the children were doing things I would or could have never dreamed doing so young. (XX2)
>
> I was impressed by how much each of the kids enjoyed being there and how many questions they had. It was also amazing to see how much they already knew about science. (SS1)
>
> I was impressed that the children at the museum asked how the exhibits worked. I did not think that preschool age children would want to know how things worked. I thought that they would be too excited running around trying all the different hands-on activities. (K3)

With regard to students' abilities and skills, the preservice teachers who commented on student behavior were most impressed by children's abilities in general (59.52%), attention span (40.08%), problem solving skills (28.57%), and learning ability (28.57%). As students observed children interacting with the exhibits, they gained insight into how the children approached problems, their questions, and the nature of their thinking:

> Watching the boy explore the exhibits gave me insight into how you thought and processed information. (U1)
>
> I was impressed that even very young children can think scientifically. They do not realize they are predicting, experimenting, and reflecting on whet happened, but they were. (Q3)
>
> I have realized that young children are more intelligent and capable of doing more than I give them credit for. As a result, I may do more in-depth activities in my classroom and have faith in my students that they will be able to do it. Challenging children is good! (Q3)

Several of the preservice teachers also commented on children's persistence and independence in working through the museum activities. They commented on children's sense of independence (28.57%), their willingness to help and learn science from their peers (9.52%).

> They helped me to see how students like to do things on their own. (EEE2)
>
> The children wanted to do it all themselves. It was great! They were curious and insisted upon trying to attach the motors in ways that didn't facilitate it running quite "correctly". They would keep at it, though, until it worked. (Y2)
>
> Learning to help students when you can, but also lets them learn at their own pace. (JJ2)

> It helped me realize that as a teacher I should try to let my students figure things out and experiment for themselves first, rather than always telling them what to do. (QQ2)
>
> I believed that I learned that kids are more eager to participate if they are in a competition. I also learned that they are eager to improve. This will help me know how children function when learning. (O3)

Teaching and Learning

In addition to heightening preservice teachers' awareness of students' abilities, the museum experience also gave them insight into the teaching process and increased their pedagogical knowledge for teaching science to children, particularly concerning instructional methods and strategies. (Table 4). Indeed, comments regarding activities and ideas for the classroom were common in prospective teachers' explanations of the relevance of the Exploration Station visits to their future teaching:

> There were a lot of exhibits I would love to use in my future classroom. (AF2)
>
> Working on hands-on activities is the best way for students to learn. I hope to have activities in my room someday. (UU3)
>
> In my future teaching I want to do some of the experiments that they had. By having this training I will be better prepared to teach activities similar to this in my future classroom. (LLL1)
>
> Things that I have learned here, I will use in my classroom. Also, interacting with the children will help my skills when I have my own students. (UU2)

Furthermore, despite the informal nature of the Exploration Station, students nonetheless drew parallels between their role as "assistants" at the museum with their role as "facilitators" in their

future classrooms. Indeed, many found themselves taking on a less directive role than they anticipated.

Table 4. Preservice Teachers' Knowledge of Teaching

Aspect of Teaching	Number	Percent
About teachers/Role of the teacher	12	17.65%
saw teachers as facilitators	*5*	*41.67*
demonstrated the need for patience with young children	*4*	*33.33*
feel the need to provide information/answers to students	*2*	*16.67*
learned students expect teachers to know "everything"	*1*	*8.33*
learned that teachers need to listen/pay close attention to explanations	*1*	*8.33*
Methods/Strategies	49	72.06%
Assessment	*2*	*2.94%*
learned ways to elicit prior knowledge	1	50
learned ways to assess understanding	1	50
how to identify misconceptions	1	50
Classroom Management	*32*	*47.06%*
ideas to make science fun/interesting	15	46.88
learned ways to excite students about science	13	40.63
practiced classroom management skills	10	31.25
increased awareness of safety issues w/ students	3	9.38
learned how to engage students in an activity	3	9.38
to build understanding, students must be ready to learn	1	3.13
Questioning	*8*	*11.76%*
use of resources to answer students' questions	4	50
learned about how/what questions to ask students	3	37.5
learned/practiced ways to stimulate students' thinking	1	12.5
students want to be asked questions	1	12.5
Communication	*19*	*27.94%*
understand how to explain to children	13	68.42
better able to explain science concepts	8	42.11
improved communication skills	2	10.53
how much info is too much	1	5.26
Supporting Student Learning	*13*	*19.12%*
understand how to assist students' learning	8	61.54
realized that students learn in different ways	4	30.77
ways to increase students' understanding of science concepts	3	23.08
how to overcome misconceptions	1	7.69
Methods	*2*	*2.94%*
learning cycle	1	50
learned to use "wait time"	1	50
Working with diverse learners	*3*	*4.41%*

> Since many of the children knew what they were doing, they didn't need much assistance. I think that teachers are there to assist in the child's learning, but they

obviously can't learn for them. These exhibits help the children learn on their own, and if they need assistance we are here for them to ask, just like in a classroom. (P)

My experience today will help me in the future because I have learned to let kids explore things themselves – however, I can scaffold them through figuring things out. (T3)

It helped me realize that as a teacher I should try to let my students figure things out and experiment for themselves first, rather than always telling them what to do.(P)

I think that teachers are there to assist in the child's learning, but they obviously can't learn for them. These exhibits at [Exploration Station] help the children learn on their own, and if they need assistance we are here for them to ask, just like in a classroom. (CCC1)

It was clear the experience afforded the preservice teachers the opportunity to develop their identities as teachers and their understanding of what it means to teach science. Most participants felt that this experience increased their preparedness to teach science by deepening their understanding of scientific concepts as well as boosting their confidence in their ability to teach science to children. For two participants, the museum experience was also helpful in deciding if teaching was the right career path (Table 5).

This experience helped me to see how much I enjoyed this interaction and whether or not it [teaching] is for me. (F1)

Table 5. Knowledge of Teaching

Self as teacher	30	44.23%
Preparedness to teach science	*23*	*76.67%*
Increased confidence in abilities to teach science	*17*	*73.91%*
Deepened understanding of science concepts	*11*	*47.83%*
Developed a better understanding of what teachers do	*8*	*26.67%*
Recognized a need to learn more to teach science well	*4*	*17.39%*
Helped decide if teaching is the right career path	*2*	*6.67%*

They also realized the importance of communicating scientific concepts to students in simple terms and on their own level. Through interactions with diverse age groups at the museum, the preservice teachers realized that they need to become skilled at providing simple explanations to students in terms that children can understand.

> My experience today was helpful to my future teaching in that I helped explain scientific concepts in simple terms to children. I also had more interaction with children at a smaller age; it taught me that you must have patience with them. (K5)
>
> Being able to explain the concepts I had learned in [the course] proved to be more of a challenge than I had expected. I experienced this with kindergartners at the magnetism station. I had to break up the concept and use simpler vocabulary so they might understand. Instead of talking about protons, neutrons, and electrons, I helped them just to understand the attraction between positive and negative. (Because of short attention spans, I had to get a basic explanation out quickly before I lost their complete attention.) I had to act fast and make the explanation fun so they would want to learn about it. (AA1)
>
> I was able to explain to the younger children in terms that they understood. I think that it is important that you do not use words they will not understand. (EE4)
>
> It takes a lot more for a student to explain why something works rather than just what it is. (LL1)
>
> As a future teacher I will be asked questions by both my students and parents. I will need to know how to explain something to each group. I will also need to be able to engage my students in activities. (R4)

Many preservice teachers commented that interacting with adults in the museum helped to prepare them for working with parents by showing them how interested parents were in their

children's learning. The participants realized that parental support is crucial to the success of their students.

> My experiences today are relevant to my teaching because it reinforces the idea of parental involvement. I know that parental involvement is essential to teaching. If I can get parents involved in my class the way they were at the [Exploration Station], I know I will have done a nice job. (XX3)

Knowledge of Curriculum

Most importantly, the preservice teachers' experience at the science museum demonstrated the power of "hands-on" learning for students. This translated into the development of the belief that these types of experiences should be provided for enhanced student understanding in their future classrooms (Table 6).

> Even though I had learned about how all the things work throughout my years at school, I felt like I had never actually applied my learning. That tells me that science teachers need to do more hands-on teaching. (U1)
>
> I got to see how much fun science can be for these kids. As a teacher I need to be sure to include hands-on activities in science to interest kids. They wanted to know everything they could about what they were doing. (W2)
>
> My experiences exploring the various activities today shows me that science can be presented in a very fun and educational way (not the way I used to see science). Now I see that science can be much more than just a textbook. (XX1)

Preservice teachers' heightened awareness of children's abilities was important to their learning in their physics course as well; at the Exploration Station, they were able to observe elementary-

age students interacting with and exploring exhibits focused on many of the same physics principles and concepts they were learning in the university-based course (Table 7).

Table 6. Knowledge of Curriculum, Learning Activities, and Resources

	Number	Percent
Curriculum/Activities	50	73.53%
Value of hands-on activities to learning science	35	70.00%
Views "hands-on" learning as valuable	*17*	*48.57%*
Witnessed the "power" of hands-on learning	*14*	*40.00%*
Learned the value of letting students explore for themselves	*9*	*25.71%*
Views science as "hands-on" learning	*7*	*20.00%*
Believes "hands-on" activities help students construct an understanding of phenomena	*1*	*2.86%*
Believed "hands-on" activities reduce children's' fear of making mistakes	*1*	*2.86%*
Appropriateness of activities for elementary learners	26	52.00%
Learned about activities students enjoy	*17*	*65.38%*
Learned examples of activities to use with children	*13*	*50.00%*
Plan to use laboratory activities from course with students	*3*	*11.54%*
Connected science activities to theory	*2*	*7.69%*
Developed a sense of age-appropriate science activities	*2*	*7.69%*
Learned activities don't have to be complicated to hold students' attention	*1*	*3.85%*
Concerned that "fun" activities can take away from the science learning	*1*	*3.85%*
Learned ideas for setting up learning activities in the classroom	15	30.00%
Learned how informal education settings can serve as a resource	7	14.00%

Thus, they not only gained a deeper understanding of related physics concepts, but also the content became more relevant to their future teaching.

> This experience went right along with everything we are learning in the course. (G)
>
> The kids were doing an activity similar to what we did in lab. I didn't think that 8 year olds were capable of learning the same physics I am learning in college! (M2)
>
> I began to understand some things better. [Exploration Station] kind of shows that things we have learned in [the course] kids are interested in. Children are very interested in science. It shows that if you teach science and things we have learned in [the course], most kids will be interested in. (G2)

In some cases where preservice teachers lacked the necessary background information to understand the exhibits, they were able to learn through collaborative exploration:

> I felt a little unprepared, but I was able to learn alongside the visitors and explore with them. (J)
>
> This experience related to what we are learning in [the course] by the way in which you try to get kids excited about science. All the kids were so amazed at the exhibits. The experience also taught me that you need to make learning fun so students will want to learn. This goes along with how we learn fun ways such as making a periscope and the quiz board to show kids scientific techniques. (K4)
>
> My experience today opened up a whole new world for me. I was allowed to see that the things we have been doing in lab (such as shadows and sound) can actually be applied to real life and in a way that children understand. (XX1)

Table 7. Relevance of the Museum Experience to the University Physics Course

	Number	Percent
Connections made directly to the course	36	52.94%
Exhibits mirrored course activities	25	69.44%
Museum exhibits demonstrated course concepts	16	44.44%
My familiarity w/ activities from the course helped in explaining concepts to students	15	41.67%
My learning in the course helped prepare for [Exploration Station] experience	12	33.33%
The experience increased my understanding of concepts presented in the physics course	5	13.89%
I learned ways to get children interested in science concepts learned in the course	4	11.11%
Students learned science through collaborative exploration, just as we did in the physics course	1	2.78%

Implications

Though there is an emerging body of literature regarding students' learning in out-of-school contexts, there have been few studies of *teacher learning* in informal settings (Chin, 2004; Jung & Tonso, 2006). Indeed, of the studies carried out to date, all have been conducted in

the context of science methods courses and accompanying field practica. Our study contributes to this growing body of knowledge by exploring the use of informal science education settings in conjunction with a science *content* course for teachers. The findings of this study have implications for both science teacher preparation as well as continued research into the role informal settings can play in the preparation of prospective science teachers.

The volunteer opportunity at Exploration Station was originally intended to support preservice teachers in making connections to the content they were learning in the physics course. Survey responses indicate over half of the students did make such connections explicitly. Overwhelmingly, however, the connections they made were to their future teaching. Interestingly, almost half of the preservice teachers in our study commented on aspects of their experience that shaped their perceptions of themselves as teachers, including gaining confidence in their abilities to teach, and realization of a need to develop stronger content knowledge to teach science effectively. Thus, an early practical experience such as the one at Exploration Station may be useful for preservice teachers to help decide whether teaching is the right career path.

Survey responses indicate that, beyond simply learning about content and activities, preservice teachers can also learn much about *learners* as they observe children exploring science in informal settings, and that these experiences may shape their expectations for students' interest, knowledge, and abilities in science—expectations that can play an important role in their future science teaching, as well as the way in which they perceive the material they are learning in content courses as being appropriate for elementary learners.

Comments made by prospective teachers in our study suggest that the hands-on experience at Exploration Station differed from their own science education experiences as

children—and, as such, it challenged their prior expectations. For example, an overwhelming majority of respondents indicated they had underestimated children's interest in science, their prior knowledge, and their abilities. Thus, the Exploration Station volunteer experience helped *raise* their expectations for their own future students.

Though the physics course is taken prior to the elementary science methods course, there is evidence that the opportunity to volunteer at Exploration Station nonetheless provided preservice teachers with an environment that modeled pedagogy consistent with what they would learn later in the methods course. Preservice teachers experienced tensions of negotiating their role as facilitators of learning, and developed strategies for questioning and stimulating student thinking. Additionally, the majority (70%) commented explicitly on the importance of "hands-on" learning to science, and the value of letting students explore for themselves. Though we aren't suggesting here that the volunteer experience provided them with all of the pedagogical knowledge needed for teaching, we do see it as a way to provide early exposure to pedagogical strategies and problems of practice that might lay a strong foundation for further learning in the methods course. Entering a methods course with beliefs about teaching and learning such as those cited above might make prospective teachers more receptive to learning and enacting reform-based methods, such as inquiry, in their future classrooms.

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