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Encouraging Prospective Teachers to Engage Friends and Family in Exploring Physical Phenomena

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Abstract Involving people outside of a science course can foster learning for students enrolled in the course. Assignments involving friends and family provided such opportunities in an undergraduate physics course for prospective teachers. These assignments included reflecting upon prior experiences, interviewing friends and family members, engaging them in exploring physical phenomena, and teaching them with relevant websites. The six strands of science learning articulated in Learning Science in Informal Environments (National Research Council in Learning science in informal environments: People, places, and pursuits. National Academies Press, Washington, DC, 2009) provided a framework for analyzing the prospective teachers' responses. Through such assignments, the instructor created opportunities for the prospective teachers to use and build upon knowledge learned in class as well as to gain confidence and experience in facilitating the learning of others.

Keywords Physics · Prospective teachers · Informal science · Literacy learning

> "I love science now… I never liked it ever and I was never confident about how I was going to put it in a classroom… but now I feel like I'm a lot more confident in it and I actually can talk…about it."
> (Prospective elementary school teacher, Winter 2009)

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The negative affect toward science that this prospective teacher initially experienced is typical for many elementary school teachers. Tosun (2000) reported, for example, that preservice elementary teachers used primarily negative terms when describing their past experiences with science during elementary, middle, high school, and college. During a series of interviews, Tosun heard words such as *stressful, dull, frustrating, meaningless, boring*, *and repetitive*. Developing a positive attitude toward science is important, as teachers who dislike science transmit this attitude to their students (McDermott 1990).

Beginning elementary and middle school teachers also lack the confidence and appropriate set of skills and knowledge to be effective teachers of science (Appleton 2006). After reviewing the minimal science requirements for elementary and middle school teacher certification in most states, a recent national report declared, "Clearly the scientific knowledge of K-8 teachers is often quite thin" (National Research Council 2007, p. 300).

The purpose of this study is to document and interpret an effort to improve the ways that prospective elementary teachers view and understand science. This study also addresses the need to connect the learning that is happening inside the science classroom to practical applications and situations outside of it. The intent is to incorporate aspects of everyday life as a regular part of the science learning process in school.

The context for this study is an undergraduate physics course, Inquiring into Physical Phenomena, that emphasizes questioning, predicting, exploring, and discussing what one thinks and why (van Zee et al. 2010; http://physics.oregonstate.edu/coursewikis/ph111). The physics course emphasizes small group work, primarily using conversations rather than lecture, similar to what is called for in reform-based efforts (National Research Council 2003). Some of the assignments involve friends and family members. These represent one way to begin helping science learners use their knowledge across contexts in appropriate ways. This study communicates to science faculty, education faculty, and informal science educators the influence that these kinds of "friends and family" assignments can have on student learning. The hope is that similar experiences will be integrated into a variety of learning environments.

Background

The six strands of science learning (National Research Council 2009) provide a framework for interpreting the prospective teachers' responses to the friends and family assignments. Formal schooling is only one small part of a person's activity across the lifespan; much more of a person's time is spent outside of a classroom (Falk and Dierking 2000). In *Learning Science in Informal Environments: People, Places, and Pursuits*, a committee formed by the National Research Council (2009) synthesizes findings from many domains in order to describe and provide evidence for out-of-school free-choice learning.

The NRC report describes six strands of science learning as shown below. Indicating the potential for connecting inside and outside of school experiences, the report states, "The six strands illustrate how schools and informal environments can pursue complimentary goals and serve as a conceptual tool for organizing and assessing science learning" (NRC 2009, p. 4). We chose to use this framework to examine responses to the friends and family assignments because we needed such a tool to interpret what was happening when our students engaged friends and family members in exploring science at home as part of their own learning within a formal course structure.

Learners in informal environments:

Strand 1:	Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world
Strand 2:	Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science
Strand 3:	Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world
Strand 4:	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena
Strand 5:	Participate in scientific activities and learning practices with others, using scientific language and tools
Strand 6:	Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science

Strand 1 refers to learning experiences that foster excitement, interest, and motivation. In order to sustain long-term engagement, it is necessary to foster learners' interest in science by making connections to their everyday cultural practices (Nasir et al. 2006). Interest is a filter that learners can use when deciding what, how, where, when, and with whom to learn (Falk and Dierking 2000). Rigid expectations and strict performance guidelines, such as those imposed by school, can diminish interest, making it imperative to create experiences free from these as often as possible (Jolly et al. 2004).

Strand 2 recognizes the need for learners to have opportunities to remember and use concepts, explanations, models, and facts that they learn both in class and during their experiences outside of class. Learners build upon prior experiences as well as upon views that they have formed in a wide variety of contexts (Scott et al. 2007). Such prior experiences and conceptions can serve as resources for cognitive growth toward expertise (Smith et al. 1993).

Strand 3 focuses on the skills needed for the practice of science, such as the ability to manipulate, test, explore, and question the world in order to make sense of it. Making sense of the natural world involves developing explanations based on evidence (Sandoval 2003), modeling salient aspects of the phenomena (Lehrer and Schauble 2010), and articulating one's reasoning in arguments with others (Osborne 2010).

Strand 4 emphasizes reflection. Dewey (1938) suggests reflection is the heart of the disciplined mind; that it is a way for a learner to decide on the most important pieces of information and internalize them for later use. Etkina (2000) demonstrates a way to increase the amount of reflection by physics learners: ask them to keep a journal. Over time, student journal writers reportedly asked more questions and predicted what types of questions the teacher might ask in the future. The role of reflection in learning has been documented outside of the classroom as well. The

Exploratorium, a science museum in San Francisco, for example, has explicitly designed exhibits “that support observation and reflection” (Allen 2004, p. S28).

Strand 5 highlights the role of social participation in using the language and tools of science. Fostering discourse that enables learners to develop arguments in support of their claims is key (Driver et al. 2000; Duschl 2008; Kelly 2007). Outside of the classroom, in such spaces as museums and galleries, von Lehm et al. (2001) suggest designing exhibits that promote communication among visitors and then developing effective methods for studying their interactions. Within the college classroom, restructuring courses to encourage more questioning and to allow for group work can lead to students reporting shifts in how they think and talk about physics (Manogue and Krane 2003).

Strand 6 considers learners’ view of themselves, as people who know, use, and can contribute to the learning, and for this study’s purposes, to the teaching of science. For instance, Brickhouse et al. (2000) find that the ways girls viewed themselves relative to science affected the ways they engaged in science activities. Olitsky (2006) reports that learners must develop a positive science identity in order to be effective users of science. Hull and Greeno (2006) note the importance of providing opportunities for participants to act competently, such as mentoring or serving as guides for others.

These strands represent an effort to bring the worlds of formal and informal learning together. The middle four of the six strands are adapted from the proficiencies articulated in the report, *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC 2007), whereas the first and last strands are synthesized from the report, *Learning Science in Informal Environments* (NRC 2009). The purpose of this study is to explore how prospective teachers respond to homework assignments requiring them to teach family and friends science concepts they have just learned themselves in the physics course.

This study examines science learning experiences within a formal course structure that reaches out to informal learning environments. The specific research question explored was: *How does facilitating informal explorations with friends and family outside of a physics course foster learning for the prospective teachers enrolled in the course?*

Methodology

This study is an example of practitioner research (Cochran-Smith and Lytle 2009; Roth 2007; Zeichner and Noffke 2001). Crowl (2010) documented and interpreted her teaching practices and students’ learning in a physics course in which she initiated the friends and family assignments. She developed these assignments in collaboration with a graduate assistant colleague (Devitt), course instructor (van Zee), and faculty mentors (Jansen and Winograd). The physics department of a research-focused university formally initiated the four-credit physics course for prospective elementary and middle school teachers in Winter 2008 (van Zee et al. 2010). The design of this experimental course continued to develop each term as the instructors interpreted what was happening and generated new approaches. The lead instructor (van Zee) designed the course collaboratively with the chair of the physics department (Jansen) and a literacy professor from the College of Education (Winograd). We selected from curricular materials that encouraged students to generate their own powerful ideas of physics as they explored physical phenomena (American Association of Physics Teachers 2001; Ukens et al. 2004), drew on specific lessons guiding explorations (McDermott and Physics Education Group 1996), and adapted approaches emphasizing development of scientific explanations (Goldberg et al. 2008). A guiding principal was to engage the prospective teachers in exploring physical phenomena in ways we hoped they would engage their own students in the future.

The physics course met twice each week for 10 weeks. Each class was two and a half hours. The course covered many topics, including light, naked eye astronomy, thermal phenomena, and force and motion (first quarter) and electricity, magnetism, sound, and renewable energy (second quarter). The course was the site for an investigation of ways to integrate physics and literacy learning, so the instructor (van Zee) also explicitly incorporated aspects of literacy learning in the course. Aspects of literacy emphasized were learning to speak clearly, listen closely, write coherently, read with comprehension, and critique media in physical science contexts (van Zee et al. 2006, 2010). An experienced elementary teacher, now a graduate assistant (Devitt), facilitated activities focused on literacy learning such as creating word webs, developing arguments based on evidence, and giving book talks (Devitt 2010).

Prospective teachers completed part of a homework assignment outside of the classroom with friends or family members. These were a form of free writing (Drabick et al. 2007). They posted summaries and reflections on an electronic discussion board. At the end of the course, they wrote a paper discussing what they had learned about a topic that they had explored throughout the term, interpreted how they learned this, and tried to pinpoint when and how their understandings had changed. They also reflected on what had fostered their learning.

There were four types of "friends and family" assignments created for this course, all with considerable choice given to the prospective teachers. Each assignment had general guidelines but the *where, when, who, how* and sometimes *what* was left up to the prospective teachers. The assignments also gave them a platform for thinking about how they might apply their in-class learning outside of the classroom. Below is a description of the four types of assignments and some commentary about the ways we used these in the course.

Engaging Prior Knowledge

This type of assignment asked students to think about previous learning experiences and to describe what fostered their learning or to tell a story about a time when they had learned a particular piece of information. These acted as jumping off points to which students could incorporate new information. For example:

> <u>Reflecting on Prior Experiences</u>
> Describe experiences inside or outside of school in which you learned some physics and enjoyed the process. Then identify aspects that fostered your learning. How do these compare with the aspects that foster science learning that we generated in class?

We assigned this type during the first week of the course or near the beginning study of a topic.

Interviewing Friends and Family Members

The prospective teachers interviewed people about the topic they were studying in class. The guidelines suggested interviewing one person of the age they wished to teach and one of a different age. The goal was to enable them to experience two different approaches to understanding. They designed the protocol, recorded the responses, and summarized findings in their posts. In some cases, we explicitly asked them to reflect on their experience. For example:

> Interview about Heat and Temperature
> Interview two people about their understandings about heat and temperature. If possible, one should be a student of the age you would like to teach and the other should be an adult. Report:
>
> a. brief description of your interviewees (gender, estimate of age)
> b. your "protocol" (questions you asked)
> c. example responses for each individual as accurately as you can
> d. summary of your findings
>
> Post your report of the interview here. Read what your classmates have posted to get a sense of what people know about the relation between heat and temperature.

We assigned this type of friends and family assignment once during the study of a topic.

Exploring Physical Phenomena

As a way to help the prospective teachers use their knowledge and their teaching skills outside of the classroom, we asked them to facilitate explorations of physical phenomena with friends and family. They were able to choose to use an exploration they had conducted in class or to create their own. They posted a description of what they did, a summary of how it went and a reflection on what they thought about the experience. For example:

> Exploring Mirrors with Friends and Family
> With at least one friend or family member, explore and explain a property of mirrors. It can be something that we have already explored in class or something new. You choose how and what to explore. Please summarize your experiments and comment on what you learned about teaching and learning.

We assigned this type during study of a topic, sometimes as often as once a week.

Analyzing Websites

After the prospective teachers had explored phenomena in class and had had a chance to become somewhat comfortable with the topic, they explored the Internet for possible websites that accurately depicted the topic at hand. Then, they engaged a friend or family member in an exploration of the site and helped their friend or family member learn something new about the topic. They provided the website address, a summary of what they explored and a reflection about what it was like to engage the friend or family member using technology. For example:

> Exploring Sound Websites
> Find a website related to sound that has fun and factual information on it. Invite a friend or family member to explore the website with you. How well does this website work as a source of information about the physics of sound? What aspects of the website help your friend/family member to understand the physics of sound? What aspects of the website hinder learning? What did you learn about learning and teaching from this experience? Please include the URL for the website in your reflection.

We assigned this type once near the end of the study of a topic.

Participants

Participants included prospective teachers who enrolled in the physics course when it included friends and family assignments (Winter 2009, $n = 10$; Spring 2009, $n = 9$; Fall 2009, $n = 7$; Spring 2010, $n = 14$). The assignments were initiated when the first author became involved in the course design. The participants were mostly white female early childhood and development majors. The first author was a graduate assistant with prior experience as a science museum educator and a deep commitment to integrating formal and informal educational experiences. Another graduate assistant (Devitt) was a former elementary teacher. The chair of the physics department (Jansen), an associate professor of science education (van Zee), who served as instructor of the experimental course, and an associate professor of literacy (Winograd), made instructional decisions collaboratively as they designed ways to model integrating science and literacy learning.

Data Sources

Data sources included responses to all of the friends and family assignments, which were posted electronically so that everyone could learn from the variety of experiences reported. The first author conducted interviews (8–20 min) near the end of the term (Winter 2009, $n = 7$; Spring 2009, $n = 5$; Fall 2009, $n = 8$; Winter 2010, $n = 4$; Spring 2010, $n = 12$). She initiated these informal conversations by asking what had fostered their learning in the course.

Data Interpretation

The six strands of science learning articulated in the NRC 2009 report provided a framework for interpreting the prospective teachers' responses to friends and family assignments. We modified the strands slightly from the original listed in the report to fit this specific context because we asked the prospective teachers to consider the roles that they will take on when they become teachers. The original strands were written from a prospective of looking only at learners, so we revised three strands to fit the ideas of teaching and helping others to learn. In Strand 1, for example, "teach and" has been inserted into "Experience excitement, interest, and motivation to *teach and* learn about phenomena in the natural and physical world." In Strand 4, "and others" has been inserted into "Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own *and others'* process of learning about phenomena." In Strand 6, "and teachers" and "and to the learning of science" have been inserted into "Think about themselves as science learners *and teachers* and develop an identity as someone who knows about, uses, and sometimes contributes to science *and to the learning of science*."

In order to analyze all of the friends and family assignments, the first author started by pasting each assignment response into a spreadsheet. She broke each response up into one or two sentences, each in its own row, so that she could compare each segment of a response to the six strands separately. She and the fourth author analyzed each segment by themselves and then compared. The inter-rater reliability rate was 76 %. After discussing each entry that was different, and then reanalyzing, the new reliability rate was 83 %. We deemed this percentage reliable enough to make claims from the data. We chose the examples used in this paper because they were representative of the kinds of responses collected for a given assignment and because they highlighted a particular strand.

A set of six assertions (Lincoln and Guba 1985) was developed to describe how the friends and family interactions fostered prospective teachers' learning of physical phenomena. In the example responses provided in the next section, statements directly relevant to an assertion are bolded, with words in brackets included for the sake of clarifying interpretations of participants' comments with respect to the assertion.

Use of the Friends and Family Assignments

During Winter 2009, the first author initiated the explorations at home based on explorations in class with one assignment. The instructor (van Zee) already assigned interviews for homework and included two that term. By Spring 2010, we were incorporating a friends and family assignment, primarily explorations, into every weekly homework. We gave full credit for completion, not content. This was a key component of the assignments. In order for the prospective teachers to feel comfortable conducting assignments that were very different from traditional homework assignments, we wanted them to focus on the act of talking science rather than on producing precisely accurate science content. Before the start of class, we read through the posts and made it a priority to address any content issues in very general ways during class. The amount of reflection by the prospective teachers increased when we explicitly requested it; assignments that did not explicitly request reflection tended to yield shallower posts.

In some versions of the course, these were stand-alone assignments to be completed for five points each week, comprising 10 % of the grade (50 out of 500 points). In some courses, we incorporated a friends and family assignment as part of the regular weekly homework for two points out of ten, comprising 4 % of the grade (20 out of 500 points). We did not notice a difference in attitude or completion between these two configurations.

Findings and Interpretation

The data from posts on the electronic bulletin board and interviews contained rich information about the influence that these types of assignments can have on science learners. Responses to the friend and family assignments demonstrate aspects of learning across the six strands articulated by the National Research Council (2009). Each of the assertions below is an interpretation in terms of one of those strands. The number of each assertion corresponds to the strand number from the report. We drew evidence from responses to all of the friends and family assignments during the Winter, Spring, Fall 2009, and Winter, Spring 2010 courses.

Assertion 1: Friends and family assignments were a way for the prospective teachers to experience positive affect toward science as described in Strand 1, such as interest and excitement for learning and teaching science.

The prospective teachers' responses indicated a shift in interest not only for the person who was facilitating the exploration but also for the friend or family member who was participating. Prospective Teacher #28, for example, described a change in her roommate's response to an exploration of refraction phenomena in which a dot drawn on the side of a cup appears to rise into view when water is poured into the cup and covers the dot.

> **I performed this experiment with my roommate who HATES science** and is majoring in business. **She thought it would be extremely lame**, and me just making a fool out of myself. **Lo and behold, she was amazed**! She had no idea how it worked. I think it was important for me to not give a lead into this, but instead to just have her observe. If I had said, now you know light refracts as it changes mediums, here let me show you… She would not have been so excited. Instead, I was practically a magician. **So, she called in the rest of the dorm, and we played around for a while! It was fun to watch them learn, and be eager to learn**. I am going to take this to my 4th grade classroom that I am volunteering in. I hope they have fun with it!
> (Prospective Teacher #28, Reflecting on Refraction Phenomena, Winter 2009)

The roommate initially was not interested but the prospective teacher persisted and eventually won her roommate's (and dorm's!) attention and excitement in exploring phenomenon.

Assertion 2: Friends and family assignments created experiences for the prospective teachers that were relevant to Strand 2 such as the opportunity to remember and use, outside of class, concepts, explanations, models and facts learned in class.

For some topics, the prospective teachers found a website of their choice and facilitated the learning of a friend or family member by using the website information. Prospective Teacher #19, for example, found that even though she understood most of the information included on the website, it was still beneficial to talk with her friend about it.

> This website (http://moonphases.info/moon_phases.html) shows a really cool diagram that shows the phases of the moon as seen from earth and then as seen from the solar system and breaks it down nicely. **This helped my friend see all the different phases and be able to understand** that just because of what we are see on earth does not mean that is actually how the moon looks. She found it interesting seeing the view from the solar system and seeing how there is always half of the moon lit up no matter what. The diagram also shows all the different angles of the moon and explains very well how the angle works with the Earth being the angle vertex. It also talks about the diameter of the sun and the distance compared to the drawing. This website talks about the months without full moons and blue moons and moon rise times corresponding to the phase at which the moon is in. **I think it possibly could explain all the phases of the moon a little better but its still really good. I found out that although I already knew a bunch of this stuff going through it and talking about it with my friend helped reinforce this information into my head.** And I also got really excited about looking at this website and explain stuff to my friend even though it was mostly what I already knew.
> [Prospective Teacher #19, Exploring Moon Websites, Fall 2009]

This prospective teacher recognized her friend's interest in the subject matter but emphasized her own excitement for teaching it also. She felt confident enough to critique the website's content while she was engaging her friend in the explanations of the phases of the moon.

Assertion 3: Friends and family assignments created opportunities for the prospective teachers to apply a variety of ways, as stated in Strand 3, to investigate and make sense of the natural and physical world.

Many of the prospective teachers duplicated explorations done in class with their friend or family member as a way of practicing their science learning and teaching. This prospective teacher, for example, facilitated an exploration of mirrors with her aunt.

> My aunt is in town this week. She was asking all about school, life, friends, etc. When I told her about this class, she became pretty interested. I asked her to do this assignment with me, so that I could show her what we are doing. I started by taking her to the bathroom **and asking her what she could see**. **She could see herself and things behind her. I had her take a step to her left. Her view had changed. She could still see herself, but she could now see the cabinet, shower and scale. Then I gave her a blank sheet of paper and asked her draw a diagram of the bathroom situation, using arrows to explain what she saw in the mirror. She drew herself and a blue print of the bathroom.** She drew arrows from herself to the mirror and back to all of the objects. I took her outside, thankfully it was nice out**. I showed her what happens when we bounce a ball off of a wall. It bounces off at the same**

> **angle it comes in at. I related this back to her diagram and showed her that her view of the bathroom changed every time she moved because her angle to the mirror and objects changes. She had never thought about it before**. It was really cool to watch someone I have always imagined to know all the answers to still be learning. **But weirdest is that I was the one teaching her! WOW!** She really liked what I showed her, and said that she would always think of me now when she looks in the mirror!
> [Prospective Teacher #23, Exploring Mirrors, Fall 2009]

This prospective teacher recognized her newfound pleasure in thinking about the science of everyday things. She also has a deeper interest in asking questions and trying to help others to develop understandings. By going outside and bouncing a ball off a wall, she shared with her aunt a model of the way light bounces off a mirror that had been used in class and then applied the model in this new setting. Note that this prospective teacher did not comment on the direction of the aunt's arrows from herself to the mirror rather than from the mirror to her eyes; this is the kind of detail needing discussion that we would attempt to notice in these reflections and address in a general way within the next class discussion.

Assertion 4: Friends and family assignments helped the prospective teachers reflect on their own processes of learning science as well as those of others, just as suggested by Strand 4.

We asked the prospective teachers to think back to times in their lives when they remembered learning science and to figure out what had fostered their learning. Prospective Teacher #14, for example, remembered playing with magnets as a child.

> When I was about seven years old, my dad brought home a bundle of powerful magnets. At first I wasn't all that impressed with them because we had several magnets on our refrigerator. When he showed me that some ends stuck together and others didn't, I became intrigued. My brother and I would play for hours trying to force two ends that repelled each other together, and trying to pull apart two ends that stuck together. It was a blast!
> The aspects of this experience that fostered my learning were that it was a hands-on activity and it was fun and interesting to me. **If my dad had not allowed me to play with the magnets myself, I would've never realized and understood how they worked. Allowing individuals to experience physics on their own terms gets them engaged and excited about what they are learning!**
> [Prospective Teacher #14, Aspects of Fostering Student Learning, Winter 2009]

The idea of free exploration is something that this prospective teacher recognized as a process that worked for her and that she was inferring would work for others.

Assertion 5: Friends and family assignments created experiences relevant to Strand 5, for prospective teachers to collaboratively participate in learning science using language and tools.

There is evidence of the prospective teachers using the strategies they learned in class to engage friends and family members in science learning. This prospective teacher decided not to impose a science exploration on her roommate but instead to try to find something that the roommate was interested in exploring. Once identified, she led her roommate through the exploration using questions and scientific explanations.

> While I was trying to decide what I was going to explore with my roommate, the idea struck to see what she was interested in instead of telling her what she should be interested in. **I guided her through some thoughts by asking questions. When I asked her the question**, "Can you see this water bottle in the mirror from anywhere in the room??" she said, "You know what, I have no idea. Lets figure it out!" So that is exactly what we did. We looked at my vanity mirror that was sitting on my desk; in front of it sat a water bottle. Then we moved around the room and noted where we could see the bottle and where we could not. **After some prompting and questioning she began to understand the concept that you must be standing at the same angle at the object in order to see the bottle in the mirror.**
> [Prospective Teacher #4, Exploring Mirrors, Fall 2009]

The opportunity for this prospective teacher to listen and interpret what another science learner was saying contributed toward developing her own inquiry-based teaching methods.

Assertion 6: Friends and family assignments helped the prospective teachers to view themselves as learners and teachers of science and as people who know, use and can contribute to science and the learning of science, which directly pertains to Strand 6.

The prospective teachers' responses indicated they had been reluctant to talk with friends and family members about their science understandings. The following quote came from one who commented on changes in her views of herself with respect to science and to teaching science as well as changes in her behavior. She stated that initially she had been nervous to talk with her brother about physics because of his expertise as an engineering major; then she reported becoming confident enough to talk with him about what she was learning in class:

> **I love science now; I never liked it ever. I was never confident** about how I was going to put it in a classroom because I was always thinking, "Oh my gosh, my curriculum and my future classroom… what am I going to do with science? Look up on the internet and just throw out an experiment or something?" But now **I feel like I'm a lot more confident in it and I actually can talk to my brother who's an engineering major and he does a lot of physics classes** and so I'm like this is what I'm learning about [magnetic] poles and circuits and he'll be like, "Oh I'm not learning that until next term," but **I can tell you [the brother] about it because I know some stuff so I feel more confident in that way**.
> [Prospective Teacher #10, interview, Winter 2009]

In talking with her brother about her physics learning, she had a new sense of pride about her physics understanding and more confidence in her science teaching.

We designed the assignments to give the prospective teachers experience teaching and talking about science to a variety of learners young and old but because the study took place on a residential campus, often they spoke with roommates, parents, or siblings by phone. We heard anecdotal evidence that they did not mind being assigned this type of homework because it did not feel like work. It involved talking casually or trying something out with a friend or family member rather than more typical assignments of reading journal articles or writing a formal paper. On an end of the course questionnaire, we asked the prospective teachers to rate on a scale from 1 to 5 the extent to which they found "speaking with friends and family when exploring topics from class with them" to be interesting and useful. The mean rating was 4.1, the median was 4, the mode 5, with a range from 3 to 5 ($n = 14$). A comment accompanying a rating of 3 was somewhat negative: "It was alright for a little bit but after a while my friends got kind of sick of it. It would be easier if we could actually teach/speak with kids—but that's more unlikely." Comments accompanying a rating of 5 were more positive: "It was great that I spoke to other people about what I was doing in class. It was a time I could confirm to myself that I knew the material. Also, it was great practice teaching."

Discussion

The research question guiding this study was: *How does facilitating informal explorations with friends and family outside of a physics course foster learning for the prospective teachers enrolled in the course?* The six strands of science learning articulated by the 2009 National Research Council report, *Learning Science in Informal Environments,* provided a framework for analyzing the prospective teachers' responses to a particular type of assignment, friends, and family assignments. Aspects of all six strands were evident in the responses, showing that the prospective teachers experienced increased interest and motivation, remembered and used scientific concepts and explanations, generated questions and designed explorations to make sense of their world, reflected on the process of learning for themselves and others, actively participated in science activities and reasoning with others and began to view themselves as teachers and learners of science. Involving friends and family outside of the class created ways for learners to think about and use their science knowledge across contexts.

The friends and family assignments gave the prospective teachers the opportunity to try out their new knowledge in a safe way, creating an environment that promoted success and the positive affect to which Strand 1 refers. Many prospective teachers who enrolled in the physics course admitted that initially they were not comfortable with science, especially physics. This is not uncommon. In a study by Weiss (1994), for example, more than half of the teachers surveyed did not feel prepared to teach science in a classroom. The negative affect that some reported that their roommates had expressed at the beginning of the activities is similar to the negative words that emerged in interviews with preservice teachers (Tosun 2000). However, positive affect and an appropriate skill set are important for teachers to have, because they are role models in the classroom. If they feel negatively toward science, they can transfer that feeling to their students (McDermott 1990). The friends and family assignments enhanced the prospective teachers' interest in learning and teaching science by giving them a great deal of choice in how, where, when and, with whom they facilitated their assignments, a condition important in fostering learning (Falk and Dierking 2000). However in being required to complete the assignments, they were given limited choice, which has been shown to be more effective, at times, than no choice or totally free-choice (Bamberger and Tal 2007). The assignments also enhanced interest by helping the prospective teachers to make connections to their respective cultural practices, a need articulated by Nasir et al. (2006). Their electronic posts revealed that the assignments were enjoyable to complete. These types of experiences are advocated by Jolly et al. (2004).

Every week the prospective teachers used new science concepts, explanations, and models in new settings outside of the classroom in ways similar to those described in Strand 2. They reported using knowledge long after it was emphasized in their homework. For example, a tool that they created to explore a phenomenon sparked questions from others as many as 8 weeks later, requiring them to recall the related physics. Such experiences enabled the prospective teachers to draw on resources in a variety of contexts (Smith et al. 1993) through an ongoing process of building and refining their knowledge and understandings (Scott et al. 2007).

The friends and family assignments created ways for the prospective teachers to make sense of their world through observation and exploration as described in Strand 3. Restructuring a class to incorporate more questioning in collaborative settings, as in this physics course, has been shown to shift the ways students think about and talk about physics (Manogue and Krane 2003). The prospective teachers then used similar discourse processes in helping friends and family members develop explanatory models for phenomena such as mirror images. Thus, the assignments created opportunities outside of class for experiences of the kind advocated in the literature for reasoning (Sandoval 2003) and using models (Lehrer and Schauble 2010).

The process of reflection emphasized in Strand 4 is a key component of the friends and family assignments because, while the prospective teachers facilitated their activities, they were forced to decide what the most important pieces of information were and internalize them (Dewey 1938). The online response posts were one way to promote reflection and were similar to the journals described by Etkina (2000). These gave Etkina a better idea of how students were interpreting the information in class. This physics course used friends and family assignments in a similar way by asking the prospective teachers to reflect on their learning processes.

The friends and family assignments became one way to promote communication among the prospective teachers and other people in their lives through social interactions in which they used scientific language and tools as described in Strand 5. Both inside and outside of the course, the prospective teachers talked about and explained their ideas about science, as is recommended for fostering learning (Duschl 2008; Kelly 2007; Osborne 2010). The friends and family assignments afforded the prospective teachers with opportunities to participate in learning as a social event with others (Zimmerman et al. 2010). By asking them to report on these experiences, we had a lens with which we could study their learning during a socially mediated process (Astor-Jack et al. 2007).

The friends and family assignments provided opportunities for the prospective teachers to create positive views of themselves as people who know about and use science as described in Strand 6. Occasionally, they were apprehensive about conducting the friends and family assignments with people outside of class but after completing the activity they reported that it was fun or interesting. Through these experiences outside, as well as inside class, they began to develop identities as both science learners (Brickhouse et al. 2000; Olitsky 2006) and teachers. These assignments also provided opportunities for a form of mentoring, producing a sense of competency as described by Hull and Greeno (2006). Simply by engaging in the assignment activities, the prospective teachers felt as though they were contributing to the teaching and learning of others.

Conclusions and Implications

The findings of this study are limited to the physics courses in which the participants were enrolled. The data represent thoughts of the prospective teachers during the time they were enrolled; long-term impacts have not been assessed. Over more than a year that data were collected, the structure of the course changed in response to the participants' interests and experiences. The friends and family assignments evolved, for example, from occasional to regular weekly requirements because the experiences were so meaningful for the prospective teachers. These data are limited in that the responses are self-reports about these experiences. There are no audio or video records of the interactions with friends and family.

Limitation #1 Easily Accessible Supplies and Real Contexts are Imperative

Friends and family assignments should be created with two things in mind: content covered in class and real world application of this content. Of the four types of assignment discussed in this paper, facilitating an exploration was the most engaging. However, students need easy access to all necessary resources, and they need to understand the real world application of the problem in order to gain credibility among the friend or family member participating. If possible, hand out materials in class or create assignments that can be completed using household materials and explicitly discuss real world context.

Limitation #2 Reading Student Responses Takes Time

Planning an appropriate assignment and reading through responses takes considerable time outside of class. Introducing the first of these assignments may take class time because students likely will not be familiar with this type of homework. Then, after students complete an assignment, it may take time in class to address any content issues evident in their responses.

Limitation #3 Completion Grade, Not Content Grade

Students may feel reluctant to facilitate these assignments if they are not confident in their abilities and knowledge. Giving a completion grade rather than a content grade enables students to focus on the act of talking with others about the content rather than being anxious about what they think they know or do not know. A completion grade requires the professor to read through responses, however, and address any content issues in a general way during class.

Limitation #4 Explicitly Ask for Reflection

Our participants did not reflect readily on their experiences. It was important to word the assignments in ways that encouraged them to think and report more deeply than simply stating what happened during the facilitation. The amount of reflection increased when explicitly asked for in the assignment, making it a necessary part of each assignment's description.

Friends and family assignments have the potential to be built into any curriculum, no matter subject or grade. This study has shown that these types of assignments can create positive experiences for learners and blur the line between in-class and out-of-class learning. Such assignments also can create a platform for discussion, engaging important people in the students' lives directly in their learning. Using friends and family assignments with prospective teachers can empower them to view themselves as authentic teachers and begin to learn to listen and assess what others are saying. Such assignments can foster their awareness of the science understanding of others and enable them to put their own knowledge in perspective. In both undergraduate science courses and science teaching methods courses, instructors can make such assignments in a variety of ways, from using a standard format for a regular weekly basis to an occasional informal request.

Future research on friends and family assignments should include documentation across contexts as well as longitudinal studies. Documenting with video or audio, how the prospective teachers engage friends and family members at home will allow for deeper reflection on the task. This will also allow the experiences to be shared with their peers in the class. In order to truly study the impacts of these types of assignments on science learning and teaching, it is necessary to track prospective teachers through other courses and into their teaching careers. Also, infusing such assignments into methods courses and other subject-matter courses may enhance learning and allow prospective teachers to practice teaching strategies that may be useful in their careers.

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