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Supporting Elementary Pre-Service Teachers to Teach STEM Through Place-Based Teaching and Learning Experiences

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Abstract

Although recent educational reforms emphasize the importance of Science, Technology, Engineering, and Mathematics (STEM), many elementary teachers feel less knowledgeable about STEM content and less comfortable teaching STEM than other subjects. This study examined a teacher education program that utilized place-based pedagogies within an integrated block of science, mathematics and social studies methods courses to support elementary pre-service teachers' development as teachers of STEM. Data were collected on elementary pre-service teachers' perceptions of their experiences as they participated in, planned, and enacted integrated place-based STEM education lessons. Findings indicate that experiences with STEM learning and teaching through integrated, place-based activities had a positive impact on pre-service teachers' understanding of place-based approaches, their perceived ability, and projected intent to design and implement place-based STEM learning activities.

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Introduction

Many teacher education programs across the United States are focusing on ways to improve the preparation of education students for teaching and integrating science, technology, engineering, and mathematics (STEM) disciplines (Lederman & Lederman, 2013). STEM and STEM education have recently been placed in the national spotlight because of mediocre student achievement in these disciplines (National Center for Education Statistics (NCES), 2009) and waning student performance in comparison to that of other nations (Organization for Economic

Co-operation and Development (OECD), 2013). There has also been concern over decreasing student interest in science resulting in fewer students entering the “STEM pipeline” (Bybee, 2010; National Academies, 2007) to prepare for professional roles in STEM-related fields. With fewer students entering STEM fields, there is apprehension that the workforce will be unprepared to solve future challenges faced by our nation and world, such as feeding and fueling a growing world population. Furthermore, our world is rapidly changing, and it is increasingly critical for all citizens to develop the ability to apply knowledge of STEM to personal and local issues (Bybee, 2010; Feinstein, 2011). Although emphasis on science is often placed at the secondary level, the elementary grades are a critical time for developing students’ interest in STEM (Conderman & Woods, 2008; DeJarnette, 2012). Research has found that student interest in science declines significantly as they progress through the elementary grades (Pell & Jarvis; 2001). However, elementary teachers are primarily trained as generalists (Li, 2008; Schwartz & Gess-Newsome, 2008) and often enter teacher education programs lacking confidence and interest in teaching STEM subjects (Weiss, Banilower, McMahon, & Smith, 2001). Therefore, addressing concerns regarding declining student interest in STEM requires new approaches for engaging elementary students and preparing elementary teachers. Place-based education has been used as a strategy for engaging students in the study of environmental science and other topics in local settings (Aikenhead, Calabrese Barton, & Chinn, 2006) and to maintain the connection between students and the surrounding world (Gruenewald, 2003). In this study we examined how the use of place-based pedagogies within a teacher education program supported pre-service elementary teachers to develop understandings, confidence, and intention to teach STEM in authentic, integrated, and locally relevant ways.

Place-Based Pedagogy in STEM

Sobel (2004) described place-based education as the process of using the local community and environment as a context to teach concepts in subjects across the curriculum in a way that emphasizes hands-on and real-world learning experiences. In place-based learning, student questions and interests often serve as the focal point, thereby heightening student interest, content relevance, and interconnection of ideas. The multidisciplinary, relevant, and experiential character of place-based education is said to increase students’ engagement, understanding, and academic achievement (Semken & Freeman, 2008; Sobel, 2004).

Ballantyne and Packer (2009) identified experience-based instruction that occurs in the natural environment as a productive pedagogy, providing engaging, and enduring learning. These findings were based on observations of outdoor learning programs and interviews with teachers and students. Important aspects of such pedagogy are hands-on investigation of authentic places, issues, and tasks in students’ own local environments (Yager, 2003).

Place-based pedagogy is consistent with the newly released Next Generation Science Standards (NGSS) (Achieve, Inc., 2013) which highlight the implicit role of mathematics in science and call for instruction that engages students in learning through inquiry and integrating real-world contexts. These standards place an explicit emphasis on crosscutting ideas that highlight the integrated nature of STEM subjects. For example, “systems and system models” and “scale, proportion, and quantity” are two of the crosscutting concepts identified in the NGSS (Achieve, Inc., 2013, Appendix G). From a place-based pedagogy perspective, looking at local environments provides an authentic context for examining concepts such as systems and scale, integrating science and mathematics, and showing students the interconnected nature of real-world issues.

Studies have found that students learning through an integrated curriculum perform as well or better than their peers experiencing traditional instruction in separate disciplines (Czerniak, Weber, Sandmann, & Ahern, 1999; Hill, Kawagley, & Barnhardt, 2006; Vars, 1991, 2001; Weilbacher, 2001). Additionally, students have shown increased interest and motivation when engaged in integrated learning (Czerniak et al., 1999; Erlandson & McVittie, 2001; Hill, Kawagley, & Barnhardt, 2006; Hinde, 2005; Vars, 2001; Weilbacher, 2001). Integrated lessons can help students connect learning across disciplines and with the real world. Such connections are especially important for science and mathematics, which students often see as unconnected or not useful (Aikenhead, 2007; Moscovici & Newton, 2006). However, the 2000 National Survey of Science and Mathematics Education found that only 20% of K-4 teachers reported that they helped students see connections between science and other subjects on a regular basis (Weiss, Banilower, McMahon, & Smith, 2001). Teacher education programs have rarely offered pre-service teachers courses in which they experience learning that integrates multiple disciplines (Roebuck & Warden, 1998). Without such experiences, teachers will not have a vision of high quality integrated lessons or knowledge of how to create them (Furner & Kumar, 2007).

Place-based education in STEM incorporates inquiry activities which enable students to pose questions and investigate problems based in real-world contexts (Buxton & Provenzo, Jr., 2012). Inquiry has long been recommended by national organizations for mathematics, science, and social studies teaching (National Council for the Social Studies, 2010; National Council of Teachers of Mathematics, 1991, 2000; National Research Council, 2000). Many students find inquiry approaches to learning engaging, drawing them into study of questions they find personally interesting (Alberts, 2000; Katehi, Pearson, & Feder, 2009). Development of inquiry skills enhances critical thinking, intellectual growth, and students' ability to take responsibility for their own learning (Jarrett, 1997). When the questions and problems are situated within local environments and communities, inquiry can support and enhance place-based education.

Place-based education has the potential to make STEM education relevant and engaging for students; thus, it is important to incorporate this approach as a component of teacher education. Doing so will prepare teachers to engage students in solving problems in their own communities, which can serve as a powerful tool for involving students in STEM learning. Such pedagogies have been firmly established in environmental education venues (Buxton, 2010; Meichtry & Smith, 2007; Sobel, 2004; Semken, 2005). However, place-based pedagogies have not been widely emphasized within teacher education programs. The model of pre-service methods courses for elementary teachers examined in this study utilized a place-based approach that emphasized the integration of subject areas and inquiry within real-world contexts.

Elementary Teacher Development in STEM

Currently, most teacher education programs prepare elementary teachers to teach all subject areas within the curriculum (Li, 2008; Schwartz & Gess-Newsome, 2008). With their generalist background, elementary teachers typically take few content courses in STEM subjects (Weiss et al., 2001). The 2000 National Survey of Science and Mathematics Education found that elementary teachers' perceptions of their content preparation were significantly lower in science than other subjects, with only 18-29% of elementary teachers considering themselves to be very well qualified to teach science compared to 52-67% when asked about social studies, mathematics, and reading/language arts (Weiss et al., 2001). In addition to a lack of learning experiences in STEM subjects, many students who enter elementary teacher education programs have had negative learning experiences in their own mathematics or science courses leading to insecurities, anxiety, and negative attitudes towards STEM subjects (Amato, 2004; Jarrett, 1999; Philippou & Christou, 1998). Pre-service teachers' attitudes towards STEM subjects affect their attitudes towards teaching those subjects and the ways they will teach in the future (Appleton & Kindt, 2002; Bursal & Paznokas, 2006; Goulding, Rowland, & Barber, 2002; Jarrett, 1999). Elementary teachers' negative attitudes toward STEM subjects can lead to reduced time spent teaching science and mathematics, increased reliance on textbooks, and teaching approaches that are less focused on engaging students in authentic inquiry-based activities (Appleton & Kindt, 2002).

Methods courses can play an important role in addressing conceptual understandings and attitudes toward STEM for beginning elementary teachers. Research has shown that when beginning teachers participate in hands-on STEM learning experiences they develop increased confidence and self-efficacy as STEM teachers. For example, Cantrell, Young, and Moore (2003) examined the self-efficacy of pre-service elementary teachers when teaching science and found that the largest improvements occurred when pre-service teachers engaged in hands-on, inquiry related experiences. Bleicher (2007) also found significant correlations between changes in elementary pre-service teachers' science conceptual understandings and their self-efficacy beliefs when participating in a science teaching methods course focused on supporting conceptual understandings through a hands-on, minds-on approach. Similarly, Amato (2004) found improved attitudes toward mathematics in pre-service teachers who were given the opportunity to develop conceptual and relational understandings of mathematics through engaging in a collection of hands-on, real-world learning activities using a variety of tools and representations of mathematical ideas.

Providing opportunities to teach using authentic outdoor science activities can also lead to positive teacher development and self-efficacy. Carrier (2009) examined elementary pre-service teachers' perceptions of science teaching self-efficacy during a science methods course in which they had the opportunity to teach science lessons to elementary students at an outdoor science camp. Carrier found that the pre-service teachers' initial fears and lack of confidence regarding the teaching of science were reduced after seeing the elementary students' excitement and enthusiasm during the lessons. These examples suggest that providing opportunities for pre-service teachers to experience success, first as learners, and then as teachers of mathematics and science, can support their development of both skill and comfort as STEM teachers.

Context of the Study

According to Luehmann (2007), effective teacher learning occurs "when one has multiple opportunities to participate in a carefully scaffolded sequence of reform-based science-learning experiences, both as learners and as teachers" (p. 835). With this idea in mind, we developed a series of learning activities for our elementary pre-service teachers to engage them first as learners in integrated, place-based inquiry activities, and then support them in developing and enacting such activities as teachers of elementary students within a nearby tribal community. Our elementary teacher preparation program, located at a mid-sized Pacific Northwestern university, is designed so that pre-service teachers take a block of methods courses as a cohort. The “block” format provides stand-alone methods courses in mathematics, science, and social studies during one semester. The methods courses and an associated 30-hour practicum are scheduled for four consecutive mornings each week. Each course is taught by a faculty member with a background in the discipline of his/her respective course (e.g., science and math education), and a wealth of K-12 teaching experience that is infused into the courses.

Prior to implementing the approach reported in this article, the methods block was focused on standards-based disciplinary curriculum, pedagogy, and experiences without integration across courses or emphasis on place-based pedagogies and STEM education. While each course continues to offer many discipline-specific learning activities, we have used areas of synchrony between courses to design integrated learning activities that cut across the three separate courses. We have sought to combine locally relevant experiences situated in the place of instruction while making meaningful connections to local elementary school settings.

In the following sections, we outline the design of the integrated STEM education experiences in the methods block. These experiences include immersive learning at an outdoor science school, seminars in Project Learning Tree (PLT, 2009), and teaching integrated place-based lessons to elementary Native American students. Aikenhead and colleagues (2006) described how place-based science teaching occurs in at least three different venues: schools, local communities, and isolated communities (i.e. reservations home to Native Americans and First Nations). In the methods courses examined in this study, students were provided experiences with place-based learning in all three venues. In our program, Project Learning Tree involved learning on our campus (school venue), the outdoor science school involved learning within the local community; and our work at a nearby school involved learning and teaching in a more isolated community on a local reservation. Although the experiences we have designed for our students are unique to the setting in which we teach, we feel that there are salient themes that can be applied in other settings.

The Outdoor Science School

The outdoor science school is a residential field campus associated with a state university that hosts programs for K-12 and university students. Programming at the school strives to facilitate place-based, collaborative science inquiry within the context of local land, water, and communities. In the math/science/social studies block, an immersive experience at the outdoor science school that highlights place-based pedagogies sets the stage for the semester of coursework and lays the foundation for relationships between students and faculty. At the beginning of each semester, students in the methods block travel to the outdoor science school to engage in standards-based, place-based environmental STEM activities and team building exercises over several days. Learning activities include: STEM content explorations, student led inquiries and data collection, and professional presentation of group inquiry results.

For many pre-service teachers, these activities offer a first experience with learning integrated content and provide a model for integrating Common Core State Standards for Mathematics (CCSSM) (CCSSI, 2010), and national science standards (NGSS) (Achieve, Inc., 2013), as well as state learning standards from multiple disciplines. For example, in a sixth-grade activity exploring ecosystems at the outdoor science school, pre-service teachers measured canopy cover and used ratios to compare canopy cover in various ecosystems. They measured the diameter and height of a tree and used rates to determine the amount of carbon it can sequester and the tree's value in terms of the amount of biofuel it can provide. This activity led to discussion of the best uses of the tree they measured: Is it better to leave the tree to sequester carbon dioxide, provide shade and animal habitat; or to use it for building or for jet fuel? Learners explored limitations and issues for both options. The aforementioned activity targets the NGSS standard, "Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem" (Achieve, Inc., 2013, 3-5-ETS1-2, Engineering Design). In addition, students considered the consequences of human impact on the physical environment, which connects to the social studies standards.

Project Learning Tree Seminar

In order to scaffold pre-service teachers' creation of their own environmentally focused lessons to enact with Native American students at a local elementary school, each semester we facilitate a Project Learning Tree (PLT) seminar on our campus as part of our block courses. PLT is a nationally recognized curriculum resource sponsored by the American Forest Foundation and offers integrated learning activities focused on the environment (PLT, 2009). These activities can readily be adapted to the local context and complement the NGSS. For example, one of the activities in the PLT Pre K-8 Environmental Education Activity Guide is called *Adopt a Tree*. In this activity students explore their local context and the trees associated with their local environment while at the same time engaging in the NGSS identified scientific practices of asking questions, analyzing and interpreting data, and constructing explanations. Additionally, an activity such as Adopt a Tree supports NGSS crosscutting concepts of "structure and function" (Achieve, Inc., 2013, Appendix G) by taking an intentional look at local trees.

We have found that the PLT seminar serves as an excellent curriculum model for engaging students in place-based integrated STEM education and activities. The cornerstone of PLT is a curriculum guide that aligns environmental education activities across content areas and grade levels and can be used with minimal additional resources. The seminar and guide introduce pre-service teachers to planning for integrated STEM lessons.

Reservation School Teaching Experience

In preparing pre-service teachers for the dynamic and contextually rich learning environments they will face upon certification, we must provide them with authentic and diverse experiences with elementary students. Within the rural northwest, pre-service teachers often lack experiences working with students from cultural or racial identities different from their own. Given our close proximity to tribal communities, we have fostered relationships with local schools that predominantly educate Native American students. In a final course assignment, our students plan and enact integrated STEM lessons that target grade-level CCSSM, NGSS, and state standards, and build on the local knowledge and setting, while interacting with a consistent group of Native American students. Working with small groups of sixth-grade students over three days, pre-service teachers have an opportunity to teach, reflect on, modify, and teach revised lessons to a new group of students based on informal assessment and the perceived learning needs and interest of the students. Through this program component, pre-service teachers experience teaching with an integrated approach, and develop skills in managing student inquiry and meeting student learning needs.

As a group, these three experiences introduce pre-service teachers to place-based learning, initially as learners, and subsequently as teachers who plan and then implement place-based lessons for sixth-grade students. All three experiences focus on place-based integrated learning. In each, authentic and local places provide the context for learning: the environment that encompasses the outdoor science school, the region within which our university resides (for PLT), or the local reservation where the 6^{th} grade students learn. Each component engages pre-service teachers or K-12 students in hands-on tasks designed to examine issues and content relevant to the place. Inquiry comprises a vital component of learning at the outdoor science school, and is also included in many, but not all of the PLT activities and lessons at the reservation school.

Methods

Participants in this qualitative study included 50 elementary education pre-service teachers enrolled in the math/science/social studies methods block during the spring and fall 2012 semesters. They were predominantly white females, although a small percentage (< 15%) was male.

The primary research question was: How do integrated place-based learning and teaching experiences support elementary pre-service teachers to teach STEM? Three sub-questions helped us frame our instructional activities and pedagogy for the semester and determined the particular data to collect:

1. How do pre-service teachers describe the nature of learning within placed-based experiences?
2. How do place-based experiences in pre-service methods courses affect teachers' confidence as learners and teachers of STEM content?
3. How do pre-service teachers see their place-based STEM education experiences impacting their future teaching?

Data included transcripts from two focus groups with pre-service teachers, pre-service teachers' written reflections on learning and teaching, observations of pre-service teachers teaching STEM lessons, and coursework artifacts such as lesson plans and elementary student work from STEM lessons planned and taught by the pre-service teachers.

In order to understand pre-service teachers' perceptions of and intentions for future use of place-based pedagogies, two end-of-semester focus groups (Krueger & Casey, 2009) were conducted, one with seven pre-service teacher participants and the other with eight. Focus groups were selected over interviews as a practical way to capture multiple perspectives of pre-service teachers and to increase depth of participation. Each focus group was semi-structured in that researchers asked the same open-ended questions, and prompted elaboration with follow-up questions based on participant responses. Each focus group spent 30-45 minutes discussing views regarding (1) whether and why place-based education is important, (2) the effectiveness of hands-on learning, (3) how the block learning experiences affected their thinking about how to design learning experiences for students, and (4) what they will take to their future classrooms from their own experiences in the block courses.

Written reflections regarding pre-service teachers' perceptions of place-based pedagogies were collected from each pre-service teacher after visiting the outdoor science school and at the end of the semester. Responses were based on reflection prompts requesting descriptions of (1) perceptions of their experiences and learning at the outdoor science school, (2) what ideas or teaching approaches they will take into their own classrooms in the future, and (3) their views of place-based education. We collected all lesson plans that our pre-service teacher groups created for use in teaching at the local elementary school and observed each pre-service teacher teaching at the school at least once. This documentation provided rich descriptions of the context of the learning activities we offered pre-service elementary education students and how they experienced them. All names used in reporting findings are pseudonyms. Data were collected throughout two semesters with different groups of elementary education students. The collection of these various data types across two semesters provided triangulation.

Data were analyzed using a constant comparative method (Glaser & Strauss, 1967). Initial data categories related to understanding place-based learning, confidence as a STEM learner and teacher, and in practice (focus on current and future teaching). Three of the authors read the data, coded evidence of these categories, and identified additional categories. The expanded list of categories and the associated evidence for each category were examined looking for redundancy and overlap, and a final set of distinct categories was selected. We then recoded the data according to the refined category list. We met five times to discuss codes and came to an agreement on codes accurately representing the data. Table 1 presents these categories with a definition and example for each.

Table 1
Code Descriptions and Exemplars

Category	Definition	Example
Nature of place-based learning		
Deeper knowledge	Indication that knowledge is now better connected to prior knowledge or new sense has been made	"Learning takes place in their own local environment, giving it new meaning and depth."
Connection to experience	Connecting learning to field experiences impacts learning depth and quality	"I feel that, as a learner, I was able to grasp the content much better working with it out in the field rather than reading about it from a text."
Content retained	Suggests that the learning is or will be lasting	"If they actually experience it, it gets ingrained better."
Inquiry in place-based education	Indicated that inquiry or place-based learning increased	"Like, you want to do it. You want to be part of it. It's not in the classroom, it's outside of it, you're doing things."

	student interest in the topic	
Integration motivates learning STEM content	Integrating math and science with other subjects increases students' interest and motivation	"Tuning in to different subjects helps see how it's relatable, and helps to get them interested, because they may be interested in social studies, but the minute they hear the word math, they think "Don't wanna do it," so, if you slowly get them into it, then later, they'll realize they're doing math, and having fun."
Confidence as a STEM learner and teacher		
Discomfort with science diminishes	Increased comfort with science	"I have never been very comfortable with the subject of science. It has often intimidated me and made me feel insecure about my intellect. Attending [outdoor science school] changed that for me."
Developing a positive attitude toward science	Indicates ability to learn, investigate, or teach science.	"I did not see myself as a science person at all, but I actually am interested in it and can say I am more of a science person then before going."
Confidence in teaching STEM	Indicates comfort or interest in teaching STEM	"I found a new confidence not only in the subject of science, but in teaching of the subject."
In practice		
Using local environments to teach STEM	Describes benefits, mechanics, or challenges of integrating a place-based approach	"I can still incorporate the outdoors with whatever subject area."
Focus on future teaching	Expresses knowledge of or desire to teach using local environment	"Before….I didn't know how realistic or manageable it could be. I definitely plan to do that in the future classroom."

Findings and Discussion

Examination of prospective teachers' reflections on the place-based experiences during the course highlighted the ways in which the experiences developed their understanding and awareness of place-based approaches, enhanced their confidence in teaching STEM, and provided opportunities for them to see the value of place-based teaching in their future practice. In the following sections we discuss findings in the categories: *understanding place-based learning, confidence as a STEM learner and teacher, and in practice* (focus on current and future teaching).

Understanding of Place-Based Learning

Many of our pre-service teachers had little knowledge of place-based learning prior to entering the methods block as evidenced by their responses in the focus groups and reflections. Programming at the outdoor science school gave them first-hand experience in place-based approaches. As one student stated, “we haven’t learned a lot about [place-based learning] before going on the trip to [the outdoor science school], but now having learned what it is and experiencing it firsthand I now see how helpful it is to the learning process.” Through their experiences as learners at the outdoor science school, pre-service teachers described various ways in which place-based activities influenced their own learning and would support elementary students’ learning. Data coded as representing *nature of place-based learning* are represented in the codes: *deeper knowledge, connection to experience, content retained, inquiry in place-based education,* and *integration motivates STEM learning*.

Deeper knowledge. Pre-service teachers stated in both reflective writing and focus groups that they understood and retained information better through authentic tasks. For example, Sheila stated, “As a learner, I was able to grasp the content much better working with it out in the field rather than reading about it from a text.” Another student explained:

> The biggest thing is having that experience because a person can learn only so far, when they’re just being told something that they have to know … if they actually experience it, it gets ingrained better. Because they’ve gone through it, they’ve seen someone go through it … they have a much more solid base with the content.

Hiebert et al. (1997) describe understanding as a measure of the number and types of connections an idea has to one’s current knowledge. Such encounters with place-based learning offer students multiple ways to connect ideas and experiences.

Connection to experience. In focus group discussions pre-service teachers described an appreciation of opportunities that place-based activities had provided for them to connect their knowledge to multiple modes of sensory experience or to a particular place. They noted that such experiences added meaning to their understandings of science and that they valued the differences in learning outdoors compared to textbooks. In a written reflection, Alex commented that the outdoor science school:

> …was the perfect setting to learn about science. It is so different to get down on your hands and knees and scoop up the soil you are measuring for moisture, versus reading about it in a textbook or seeing it in a movie. Or smelling the sweet vanilla-brown sugar scent of the Ponderosa Pine - there is NO way I would have believed that as a student without experiencing it firsthand myself.

The authentic nature of place-based learning offered a more connected teaching and learning environment. Zach explained:

> The overall benefit of place-based learning is the authenticity of it. A classroom is a completely manufactured experience … The classroom teaches us about the world but without being out in it. So any opportunity to get out of the classroom and into the real world is a rich and worthwhile experience.

Placing students in an authentic learning environment and engaging in activities that integrated content areas helped develop pre-service teachers’ knowledge about teaching and modeled for them ways to engage all learners in real-world activities. Cory recognized:

> With place-based education, the student learning takes place in their own local environment, giving it new meaning and depth. Place-based education provides contextual experiences outside the classroom that is naturally multidisciplinary.

Pre-service teachers found that learning in the natural context impacted their own learning and they expressed that this type of learning would also benefit their future students.

Content retained. In focus group discussions there was strong agreement that place-based learning would lead to more memorable and lasting learning. Various reasons were proposed for retention of learning. For example, pre-service teachers suggested that learning in a familiar or important place allows students to relate content to their individual experiences more readily, heightens support for sense-making, and gives students ownership of the learning process. This contrasts with the typical experiences prospective teachers had in their own elementary, middle and high school classrooms. That is, place-based learning involves students in doing something, rather than just taking in information from a textbook or sterile labs. For example, Kate captured this sentiment:

> I probably would have never become a tree and sagebrush expert if I hadn't experienced it firsthand. I could have googled the trees and plants but never would have remembered it if I wasn't out there experiencing it and identifying the differences and characteristics myself.

These findings indicate that these pre-service teachers placed great value on being able to experience things first hand through a place-based learning approach.

Inquiry in place-based education. A common theme found in focus group discussions and written reflections was the power of an inquiry approach to motivate learning. Overwhelmingly, pre-service teachers explained that inquiry experiences engaged student curiosity and increased student interest. Sean explained that involving students in scientific inquiry engages curiosity:

> They're actually observing, and coming up with their own hypothesis, conclusions, and data. I think it relates to them more if they're actually gathering data that they are interested in, and come up with something. Like we all came up with our idea of doing our project, and what we wanted to do, so obviously we had some kind of interest in it, or curiosity about it. So they're fueling their curiosity, and learning what they want to learn.

Pre-service teachers began to see the relationship of curiosity and engagement to student learning and to understand that student interest and ownership can create motivation for learning. They also began to make connections between inquiry learning and place-based education. Yolanda explained:

> I think that place based education, especially for science and social studies, really gives students ownership of the inquiry process, and the value of asking questions, and their finding an answer to it. Obviously it's more relevant to their lives, but it adds importance and meaning to them.

Inquiry projects conducted at the outdoor science school were a significant part of our curriculum. These projects encouraged the pre-service teachers' personal curiosity and autonomous investigations of STEM topics. Sam explained, "Activities like this help especially. It was in our hands. We had the freedom to inquire and to test whatever we wanted. I think you have more freedom to learn about what you want, and what you're curious about." As learners, pre-service teachers experienced the benefits of hands-on, inquiry learning and later were able to plan and enact their own STEM education units to incorporate these new pedagogies (e.g. teaching lessons from these units at the local school).

Integration motivates learning STEM content. Findings highlight the ways in which pre-service teachers viewed integrated content as providing more relevant and interesting learning opportunities. Shelley reflected on the value of integrating STEM content:

> If I were considering designing a place-based experience, I would want to make sure I incorporated a variety of subject matter relevant to the place, including STEM … I know it feels less intimidating to do science and math hands-on because it feels more practical.

Mathematics content was embedded in learning activities designed to build understanding of pedagogies of place-based and integrated learning, offering pre-service teachers examples of how mathematics content might realistically be used outside the classroom. In focus groups, pre-service teachers discussed the potential of integrated lessons to draw students into doing mathematics. Dana noted, "Integration points out these connections and shows students that you can use math or science concepts in everyday life." Additionally, Kevin said:

> Tuning in to different subjects helps see how it's relatable, and helps to get them interested. They may be interested in social studies, but the minute they hear the word math, they think it's just 'Don't wanna do it', so, if you slowly get them into it, then later, they'll realize they're doing math, and having fun.

Bev described how hands-on STEM activities could change the students' perspective about mathematics. While teaching, her group focused on the river system and integrated all the STEM disciplines. When she told the students, "we're going to do math", the students exclaimed "What?! Sucks!" But Bev shared:

> They were more willing to do it because they got out and had fun, doing outdoor fun activities. That's what I liked about that. It wasn't like 'Okay, we're going to do multiplication.' It was like 'Okay, now we're going to construct a dam, and then look at a piece of math involving that.'

A few pre-service teachers noticed that mathematics could enhance understanding of concepts from other content areas. Erin wrote:

> We had students make maps of river routes and salmon migration … If we hadn't added a math component, students' conceptual understanding on how far salmon travel to get to the ocean and back wouldn't have been as great. Students learned that a few centimeters on the map was equivalent to 40 miles in real life.

These experiences illustrated how integrated lessons could effectively engage students in investigations of mathematics and how mathematics can serve as a tool in understanding another content area.

Confidence as a STEM Learner and Teacher

After participating in the curriculum that modeled place-based STEM education, pre-service teachers reflected on their new perspectives on teaching. While many had commented on earlier discomfort with or dislike of science, multiple students described how their views of science and of themselves as science teachers had changed as a result of the block experiences with place-based integrated STEM. Data coded as representing *confidence as a STEM learner and teacher* are presented in the codes: *discomfort with science diminishes, developing a positive science identity,* and *confidence in teaching STEM*.

Discomfort with science diminishes. Pre-service teachers discussed discomfort with science and teaching science prior to entering the block classes. Approximately 60% of written reflections described prior disinterest or lack of comfort with science, or fears of not knowing or understanding science well enough to teach it effectively. Alicia said, "When I thought about science before, I thought about test tubes and equations and lab coats. After the [outdoor science school] experience I see it in a totally different way, and I am less opposed to it." Monica summarized her own and her peers' thinking:

> In most schools, science isn't very easily approached and [is] sometimes even avoided. Teachers oftentimes don't like science as much as the other subjects and are almost intimidated by it. This feeling is reflected towards many students, which is why before [visiting the outdoor science school] many pre-service [elementary] teachers felt the same way about science. Most pre-service teachers were intimidated by science, and therefore scared to teach it for fear of making the same mistakes their teachers made. [Outdoor science school] helped the pre-service teachers realize that science doesn't have to be hard.

Discomfort of or disinterest in science are not unique to pre-service elementary teachers. Student interest in and enrollment in science courses has been diminishing. Aikenhead (2007, 2011) described traditional school science as intellectually boring and lacking relevance for everyday life. He explained that, as a result, research has shown that for large numbers of students, science content was not learned meaningfully, could not be used effectively, and was largely memorized in preparation for tests. Amber's reflection below portrayed such results but also illustrated that place-based integrated STEM activities can help learners construct a different and more positive view of science:

> I am not naturally drawn to science and not particularly confident in teaching science but being able to physically do science that was meaningful didn't seem as intimidating as I expected. Even when we were making predictions about water quality, I didn't feel negatively about getting incorrect answers or unexpected results. I think that aspect of just being able to take concepts about the environment we were in and discuss them helped me personally learn more about water quality and the [local park] environment.

The outdoor science school reduced this discomfort with science for several pre-service teachers. Pre-service teacher reflections indicated they were able to view science as interesting and accessible to all, especially when focused on local surroundings that can be explored personally and meaningfully.

Developing a positive attitude toward science. Discomfort with learning science content meant that many students had not been interested in it, could not relate it to their own lives or interests, and hence had avoided science when possible. Kelsey shared:

> I did not see myself as a science person at all, but I actually am interested in it and can say I am more of a science person then before going. Being able to see how science isn't just generated in the classroom but is all around us is probably the biggest and most valuable thing I take away.

Aikenhead (2007, 2011) distinguished between traditional school science, which is said to alienate a majority of students and "functional science." Functional science includes "workplace science" needed on the job and concepts and processes for making sense of and using scientific evidence. He advocated offering a school science that creates an inclusive and relevant learning experience for students and teaches them how to learn and use science. The outdoor science school learning activities were designed in this fashion, and our pre-service teachers' reflections illustrated the appeal of such activities for learners and their power in offering students a different view of science. Allie summed it up this way:

> Initially I was skeptical because I just didn't think that I was a science person. But I had never experienced science like I got to experience it at [the outdoor science school]. It wasn't about reading a textbook, doing lab work, or scientific papers. It was simply about using our resources to explore the world around us through the eyes of a scientist.

The aforementioned excerpts attest to the influence that the pre-service teachers' experiences at the outdoor science school had on their own attitudes towards science. Teachers' professional identities and their beliefs about teaching and learning influence the learning opportunities that they offer their students and their expectations of students (Carlone, Cook, Wong, Sandoval, Barton, Tan, & Brickhouse, 2008; Ensor, 2001; Upadhyay, 2009). Professional identity delineates the way teachers bring interpretations of their personal history to teaching (Kang, 2012; Luehmann, 2007) and is strongly impacted by beliefs about the nature of teaching and learning. The pre-service teachers' comments suggest they developed more positive attitudes and beliefs about STEM teaching and increased the likelihood that they will integrate place-based STEM experiences into their future classrooms.

Confidence in teaching STEM. The block learning activities helped pre-service teachers broaden their views of science and gave them tools and ideas to use in their own STEM teaching. They described changes in their own feelings and confidence, and could begin to picture themselves as effective teachers of STEM. Lisa noted some of these changes in her classmates:

> They found a new confidence not only in the subject of science, but in teaching of the subject … They learned about experiential learning and the importance of reflecting, applying, problem solving, decision making, and engaging in the environments around them … The undergraduates do not need to know everything about science, but do need to have an interest in learning more about science and [the outdoor science school] helped them gain that feeling.

Melissa recounted:

> It helped to find out our strengths and weaknesses and to step out of our comfort zone by learning how to teach outside of a traditional classroom while giving us the opportunity to grow and feel more comfortable teaching science and integrating other content areas with it. We were given great ideas to incorporate in proper equipment or resources.

The experiences at the outdoor science school provided pre-service teachers the opportunity to develop more positive conceptions of science and mathematics, reduce their discomfort and develop more positive attitudes towards those subjects, leading to more confidence in themselves as future teachers of STEM.

In Practice

The sequence of activities in the methods block provided pre-service teachers with the opportunity to experience place-based STEM education as learners, to learn instructional strategies for teaching STEM through integrated place-based lessons, and then to apply their developing understandings to a local setting with students. In this section we describe pre-service teachers' experiences putting their learning into practice during the development and teaching of an integrated unit at the local school and their thinking about their future teaching. Data coded as *in practice* are represented in the codes: *using local environments to teach STEM* and *focus on future teaching*.

Using local environments to teach STEM. In developing and enacting an integrated, unit with predominately Native American students, pre-service teachers drew on their own STEM education learning experiences from earlier in the course. They created integrated learning activities to build on connections the Native American students already had with their local environment and included science, mathematics, and social studies content.

For example, by focusing on a current issue that is important to the local tribe, pre-service teachers deeply engaged their elementary students in learning facts and perspectives about dams and created a model dam. Pre-service teachers also implemented learning activities that simulated dam removal strategies. Dams are controversial in this community because they prevent salmon from reaching their spawning grounds; therefore, these activities were relevant to the place, responsive to the local culture, and highly engaging while integrating science, mathematics, and social studies content. Ben commented:

> It doesn't make any sense to not use the resources available to you. When there's stuff as unique as being able to come down here … school already has a stereotype of "ugh, I gotta go to school, do homework … And so, getting out of the classroom and into a place like this, just kind of piques different interests.

Experience with teaching integrated curriculum built skill and comfort for creating future integrated lessons. Pre-service teachers enthusiastically described many ways to integrate STEM into future place-based lessons. For example, Megan said:

> You could easily tie math, science, and technology together into one lesson by having students measure soil moisture during the different months and then graph it. If different groups of students were measuring different plants, you could have a comparison graph and discuss possible hypotheses as to why different plant types have different characteristics in the soil. This is just one of the many ways you could use place-based learning to incorporate all the elements of STEM.

After teaching her lessons and recalling her experiences at the outdoor science school, Toni stated:

> It became clear to me that it is really easy to incorporate STEM into place-based education. When the students are out in the community learning via hands-on activities, there is a lot of opportunity to integrate each aspect of STEM. For example, we used iPads to blog about our findings, LabQuests to measure the pH balance of the soil and PowerPoint, charts and tables to present our experimental findings. Incorporating all aspects of STEM into place-based learning experiences will provide students with many advantageous application skills.

Planning and teaching place-based STEM lessons showed pre-service teachers that such pedagogies are not without challenges. A salient challenge arose when planning and teaching place-based lessons at the school, which was located on a nearby reservation that had been relatively unfamiliar to most of the pre-service teachers prior to their work there. Prior to planning we had made one visit to the school to familiarize pre-service teachers with the setting, the school, classrooms and the students they would work with; yet the setting was largely unknown to the pre-service teachers. Planning lessons had included research into the local environment and customs; however, pre-service teachers did not always know what to look for or what questions to ask, which led to some valuable lessons. For example, Cassie learned the importance of knowing the local community and practices as well as the local environment:

> We planned this big activity about water…and a few days before, I realized I don’t even know where they get their water, and I’m thinking we’re talking about a stream, but they are using wells, and I missed that whole point altogether because I’m not a part of their community. That was my fault, I should have done more research. I think I was laughing at the place connection. I was trying to give it to them, but I didn’t have it … I don’t think I have to live there, but I really should have done more research.

Pre-service teachers also recognized that it is not the place itself that makes place-based learning meaningful, but the way it is used in the learning experience. To use place effectively requires careful thinking and planning. Todd noted:

> If you just go places for the sake of going somewhere, it kind of loses its meaning, like it really needs to be focused and have a reason for doing it, not just go out and find a place. I guess it presents its own challenges. You have to make the classroom interesting. You have to do all the extra work, if you’re going to make it a meaningful experience.

Both planning and teaching with place-based pedagogies can be time-consuming when compared with more traditional forms of teaching content. Cindy shared:

> I haven’t seen it used much in the classroom … I think it’s more time consuming for maybe the teacher to get it all prepared and put together. I think maybe that’s why we’re not seeing it in the classroom. I mean, I just spent 45 minutes digging holes. You can’t really just do that with students to learn about moisture content.

Jenny also observed that local and state learning standards (those in place just prior to the adoption of the Common Core State Standards) may be interpreted as requiring different learning outcomes than the critical thinking, connecting and analysis skills fostered in inquiry place-based integrated learning. She reflected:

> I don’t really think the standards foster what inquiry based and place-based learning is all about. Standards are pretty clear cut, student can multiply numbers 1-10 or whatever. They’re not like “students will gain appreciation for nature and how to come up with a hypothesis or whatever.” Standards are all like, we need a student to be able to do that, and that, and that … I feel like a lot of the inquiry stuff, I don’t know about if that’s going to get like down to that real strict standard stuff that they want you to have for your students.

These pre-service teachers are in transition from student to teacher, and many will be immersed in student teaching in their next school term. It is important that they are aware of both the benefits and challenges of place-based pedagogies if they are to move forward with enacting such learning experiences. They are well aware of the need to base each lesson on specific learning standards. If we wish to foster future use of place-based, integrated learning, it is imperative that place-based work with pre-service teachers continually focuses on specific connections between each lesson and the learning standards on which it is based. Lessons without such clear connections may easily be labeled as fun and enriching, but not central to meeting grade-level standards, and will less likely be chosen to use with future students.

Focus on future teaching. Through the learning experiences provided in the block methods courses, pre-service teachers furthered their awareness and appreciation of benefits and challenges of integrating other subjects with STEM and contextualizing this learning in a particular place. Teaching students in a local context provided pre-service teachers with valuable experience enacting place-based pedagogies. Pre-service teachers remained strongly enthusiastic about such teaching and repeatedly declared their intentions to offer similar learning opportunities to their future students. In focus group discussions pre-service teachers excitedly discussed plans and ideas for engaging their own future students in integrated STEM learning through inquiry and use of local environments and resources. Hilary illustrated her thinking and enthusiasm:

> Having the [outdoor science school] experience really opened my eyes to the benefits of experiential [learning]. I plan to incorporate adventure learning into my future classroom as much as possible, even if it is just a trip out to the playground to look at plants.…It became clear to me that it is really easy to incorporate STEM into place-based education. When the students are out in the community learning via hands-on activities, there is a lot of opportunity to integrate each aspect of STEM.

This example indicates that participants had opportunities to learn pedagogies for place-based STEM learning and that they intended to use these in their future classrooms. The findings highlight the ways in which pre-service teachers, through participation in activities demonstrating place-based STEM integration, gained a deeper understanding of the role and benefits of place-based pedagogy in teaching STEM related content. They developed an understanding of the ways in which authentic, hands-on activities embedded in local contexts are meaningful and well connected. These prospective teachers developed more positive attitudes about teaching STEM content and expressed a desire to include place-based pedagogies in their future STEM teaching.

Conclusions

In this article we reported results from research conducted with 50 prospective teachers in linked elementary mathematics/science/social studies methods courses that used place-based experiences to support undergraduate students' development as elementary teachers of STEM. Our learning activities highlighted both inquiry and the integrated nature of place-based learning.

Findings from the study highlight how engaging pre-service teachers in place-based learning activities can support them in understanding the nature of place-based pedagogies and the capacity of these pedagogies to impact student engagement and learning. These outcomes lend support for prescriptions from Woodhouse and Knapp (2000) that learning should be situated in natural and human communities. Our study also indicated that experiences with

STEM learning and teaching in an integrated, place-based, inquiry format can move pre-service teachers toward positive attitudes regarding learning and teaching STEM. In order to feel capable of teaching STEM, teachers need not only knowledge of STEM content, but comfort with that content, knowledge of pedagogies for teaching STEM, and practice using these pedagogies (Luehmann, 2007). As Appleton and Kindt (2002) remind us, teachers' own learning experiences influence their teaching practices. By providing opportunities for pre-service teachers to experience learning STEM through place-based inquiry and opportunities to practice teaching students in this way, place-based education has made it possible for our prospective teachers to embrace science and teaching STEM related content.

In order to prepare teachers to meet the challenges of a rapidly changing human landscape, we, as teacher educators, need to provide authentic, and meaningful experiences that are situated in place, build community, and show pre-service teachers that they have resources and partners eager to support the educational mission of community schools beyond the walls of their school buildings. We also need to engage, support, and encourage pre-service teachers in using these teaching practices in real and complex situations (Appleton & Kindt, 2002; Czerniak et al., 1999). Our findings suggest that within teacher education courses, methods instructors can and should employ place-based pedagogy as a way to increase knowledge of STEM related content; provide opportunities to explore local issues, resources, and places; improve prospective elementary teachers' comfort with learning and teaching STEM content; and prepare pre-service teachers for effectively using local spaces for inquiry instruction. Integrating a suite of novel experiences into methods courses can provide pre-service teachers with valuable experiences that will help them conceptualize and deliver similarly situated experiences for their future students. As Allysa said:

> I want to be able to teach my students authentic lessons that will help carry meaning so that they will actually remember what they learn and build upon their base knowledge. I want to be able to create the want to learn more like how we experienced [that at the outdoor science school].… Quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future success of students and I plan to use this based on the [methods block] experience by using my resources around the school/classroom and if we can't escape out to a place I will do my best to bring the place into the classroom to make each lesson more authentic and meaningful.

The results of our study show that pre-service teachers respond powerfully to reimagined teacher preparation.

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