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Case Studies of Innovative Science Teacher Professional Development Programming at Biological Field Stations

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CASE STUDIES OF INNOVATIVE SCIENCE TEACHER

PROFESSIONAL DEVELOPMENT PROGRAMMING AT

BIOLOGICAL FIELD STATIONS

by

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A capstone submitted in partial fulfillment of the requirements for the degree of
Master of Arts in Education: Natural Science and Environmental Education.

Hamline University

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“Environmental education should facilitate making the leap towards the transcendent which gives ecological ethics its deepest meaning. It needs educators capable of developing an ethics of ecology, and helping people, through effective pedagogy, to grow in solidarity, responsibility and compassionate care.” (210)

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CHAPTER ONE

INTRODUCTION

Introduction

During many people’s formative years their most memorable and impactful learning experiences are in the out-of-doors in a natural environment. Direct relationships with the ecosystem and place, relationships with a teacher, mentor, or scientist, or the opportunity to explore and foster their sense of wonder and curiosity made these experiences memorable. For me, it was direct relationships with places, excellent mentors, many opportunities to explore outside, and my innate sense of curiosity and love of learning that fostered my sense of wonder. I believe the best education instruction happens when teachers work to foster wonder and curiosity through inquiry-focused direct experience and intentional observation. Today’s teachers need to be well equipped with the scientific knowledge and appropriate techniques so their students can benefit as much as I did. Biological field stations’ innovative inquiry-focused field-based professional development opportunities are some of the best places to train teachers to increase environmental literacy within their students.

This introductory chapter introduces my capstone topic and research question, offers my personal rationale for choosing this topic, shares what I hope to learn, and provides context for my research study.

Research Question

My research question focuses on teacher professional development at biological field stations with the following question: *What are the innovative practices of existing*
teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators? The intent of this qualitative multiple case study research is to look at programmatic goals, designs, strategies, and core teaching and facilitation philosophies to help inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

**Effectiveness of Inquiry and Field-based Learning**

Field-based inquiry-focused experiential education is, in my experience, the most effective education method to cultivate environmental literacy and stewardship ethics. Taking the classroom into the field allows students of all abilities and capacities to learn and allows teachers to facilitate the learning process in a meaningful way that is significant and memorable to the learner (Meyer, 1998). Outdoor experiential learning lends itself to inquiry, wonder, and curiosity, which are core elements of lifelong learning and positive student outcomes. Using the environment as an integrating context for learning has broad ranging benefits for students including:

- Better performance on standardized measure of academic achievement in reading, writing, math, science, and social studies;
- reduced discipline and classroom management problems;
- increased engagement and enthusiasm for learning; and,
- greater pride and ownership in accomplishments. (Lieberman & Hoody, 1998, p. 1)
Learning out-of-doors in a natural place-based setting offers unique opportunities for learners to explore across multiple disciplines, through direct hands-on learning methods. Sobel (2013) defined place-based education as “The process of using the local community and environment as a starting point to teach concepts in language arts, mathematics, social studies, science and other subjects across the curriculum” (p. 11). Outdoor place-based experiences can create the space for learners to formulate research questions using their own curiosity and sense of wonder. Learners can conduct experiments that potentially contribute to the broader collection of scientific data for the particular site and beyond. In my opinion, creating authentic learning opportunities is critical in effective education.

Today, from my 10 years of experience working with K-12 classroom teachers teaching environmental education lessons in their classrooms and during field trips, many do not always feel confident nor knowledgeable enough to create these outdoor inquiry-based learning experiences for their students. I believe there is a need to create highly effective opportunities for teachers to learn from scientists, incorporate inquiry-focused learning into their curriculum, and give their students authentic field-based learning experiences. I argue the best way to do this is by modeling innovative teaching techniques for teachers through field-based, inquiry-focused teacher professional development experiences with scientists and researchers.
Personal Interest In Study

Creating a Biological Field Station

In August 2015, I was asked to work as a private consultant conducting a needs assessment and feasibility study for the potential development of a new biological field station in the southern Rocky Mountains. The biological field station concept could become a place for multiple higher education institutions and nonprofit organizations to collaborate through field courses, land management planning, and natural resource research. Initially, it will house a long-term climate and soil moisture monitoring station which will provide open-source data for student research as well as for the larger scientific community. It could become an ideal location for visiting students and faculty from across the region to gather and share their research. Finally, it could serve regional K-12 teachers, through teacher professional development programming that highlights and implements the current research happening at the site.

I chose to research and explore innovative practices for developing and facilitating teacher professional development programming at biological field research stations in order to make my capstone study relevant to my professional community. I conducted four case studies of innovative biological field station teacher professional development programs to inform future programming at the new biological field station and other existing biological field stations across the country.

Personal Field-Based Learning Experiences with Scientists

As a student, field-based inquiry-focused learning has always been the most effective for me. I have also seen others learn effectively through these methods and
techniques. Learning from scientists out in the field significantly influenced my career path. Looking back to my own school-based learning experiences, the most memorable and influential learning moments were experiential, hands-on, authentic, inquiry-focused explorations. Many of these were facilitated at my schools, yet most were outside in the field.

Many of the programs I participated in during my K-12 academic career had a profound effect on my career path and my passion for teaching environmental education and natural sciences. These included the Missouri State University’s “Women in Science” program, an annual Girl Scout event; STARS camp, a three week science camp sponsored by Pittsburg State University’s Biology Department; Conservation Honors Camp sponsored by the University of Missouri and the Missouri Department of Conservation; and PRIMO a three week inquiry-focused, hands-on osteopathic medical school camp at the Kirksville College of Osteopathic Medicine.

While attending Missouri State University, I chose my undergraduate classes according to which ones included the best field trips. I participated in multiple field trips through the biology and geology departments; ultimately finishing with a degree in biology and a minor in geology. The most memorable experiences of learning in the field included ecology field trips with faculty to conduct crayfish population studies at the local stream, weekend geology field trips to various geologically significant regions of the state, and multiple week long field trips in the Western United States learning about ancient volcanoes, mountain geology, and desert ecology. The most hands-on real-world learning happened in my speleology class where we went out every Monday night to
map, monitor, and explore local caves. These hands-on field-based learning experiences still influence who I am and the work I do today. Each of these experiences modeled the possibility of who I could become in my career, my interests and hobbies, and fostered my lifelong love of learning.

The most transformative undergraduate learning experience was during my last semester of college at the Grand Canyon Semester at Northern Arizona University and Grand Canyon National Park. This was the most exemplary field-based, real-world authentic learning experience in my college career. The program included interacting with world renowned researchers and scientists, participating in project based learning, designing and conducting individual research projects, and collecting and contributing data to ongoing research projects within the National Park. We also participated in a wilderness backpacking trip and rafted the Colorado River through Grand Canyon, while learning how the unique landscape and its people create the southern region of the Colorado Plateau.

Graduate school field courses where the learning was facilitated through a real-world framework have been the most effective for me. I include all these examples from my life as a student because I believe they exemplify the value of hands-on, real-world, applied experiential learning in the field for learners and educators. Throughout all of my learning in my life, it has not only been the experience, but also the teachers and mentors along the way, who fostered and guided me to understand science and to love learning.
**Teaching Teachers**

I have facilitated teacher trainings and trained interpreters through my role of Project WET (Water Education for Teachers) Coordinator and Facilitator, National Fishing in Schools Instructor, Certified Interpretive Trainer, Land Ethic Leader, Watershed Education Trainer, Leave No Trace Master Educator, and now as the Water Educator Network Coordinator in Colorado. I have also spent many years teaching adult learners through various interpretive naturalist programs and workshops. Teaching educators is satisfying because I know that my influence reaches beyond them to the multitudes of students whom they teach. Most of the educator trainings I have facilitated have been experiential field-based programs. During the programs, it is rewarding witnessing the teachers’ “ah-ha moments” around teaching and experiential environmental education content and concepts. When learners of any age wrestle and grapple with new sometimes complex information and then all of sudden “get it” it is satisfying to the instructor. It is these moments that I am reminded how gratifying it is to be a teacher.

**Influences on Personal Educational Philosophy**

My philosophy of education includes teaching through inquiry, guiding the process of science, offering direct experiences in the natural world, facilitating discussions, and inspiring learners to be observant and curious. The ideology of Joseph Cornell, Steve Van Matre, Freeman Tilden, Larry Beck and Ted Cable, John Muir Laws, BEETLES, The Private Eye, and the Land Ethic Leaders programs all have instrumentally influenced my personal teaching style, educational philosophy, and my
perspective on what makes programming innovative. Collectively these innovative giants continue to inspire my understanding of what is possible through innovative educational practices. These leaders in innovative environmental education have influenced many and their work has contributed to innovative education and interpretation programming around the globe. I am interested in finding threads of their work in my case study sites’ teacher professional development. Here I will describe a bit about each and how they have influenced me.

**Sharing Nature with Children**

Joseph Cornell published his first edition of *Sharing Nature with Children* in 1979. In his book and throughout his career of teaching workshops he shared his principles for teaching outdoors which include: 1. Teach less, and share more, 2. Be receptive, 3. Focus the child’s attention without delay, 4. Look and experience first; talk later, and 5. A sense of joy should permeate the experience (Cornell, 1998). These five principles informed the development of Cornell’s Flow Learning Sequence which include: Stage One: Awaken Enthusiasm, Stage Two: Focus Attention, Stage Three: Offer Direct Experience, Stage Four: Share Inspiration (Cornell, 2015).

Cornell’s *Journey to the Heart of Nature* (1994) also served as a framework for me to teach and create programming. This program inspires young adults to explore and create a relationship with special natural places. Cornell’s philosophy informed my style and programmatic design in 2001 as I designed and implemented a nature program at my Girl Scout camp.
Acclimatization and Institute for Earth Education


Interpreting our Heritage

In *Interpreting Our Heritage*, Freeman Tilden gave eloquent language and definition to the field of or “interpretation.” His legacy of defining and professionalizing the field of interpretation during the 1950s is still relevant to the profession today, 60 years later. Tilden created the first formal and widely accepted definition of interpretation: “An educational activity which aims to reveal meaning and relationships through the use of original objects, by firsthand experience, and by illustrative media, rather than simply to communicate factual information” (Tilden, 1977, p. 8). Through the art of interpretation he helped interpreters discover the “soul” and meaning of things and places to then share with others, typically park visitors.
It was during my time at working as an interpretive ranger with the National Park Service when I was formally introduced to Tilden’s work and the field of interpretation. I quickly realized that every great teacher I ever had was also an interpreter as they “[capitalized] mere curiosity for the enrichment of the human mind and spirit” and guided learners to the “revelation of a larger truth that lies behind any statement of fact” (Tilden, 1977, p. 8). The best teachers always worked to create personal connections and meanings to the facts they were teaching.

The Gifts of Interpretation

Beck and Cable’s (2011) *The Gifts of Interpretation* also influenced and shaped my philosophy of education, teaching, and interpretation. I read their 2002 first edition while completing my Certified Interpretive Guide training and I strongly connected with their thinking. Cable and Beck (2011) stated, “The most effective interpreters orchestrate their interpretation to elicit a response from the audience: astonishment, wonder, inspiration, action, sometimes tears” (Introduction p. xxi). They continued, “Interpretation is a process, a rendering, by which visitors see, learn, experience, and are inspired firsthand… Interpretation may provoke visitors to initiate a long-term path of exploration and learning related to cultural or natural history or both” (Introduction p. xxi-xxii). I believe the most effective and invested teachers do the same.

Intentional Curiosity

I was first introduced to the work of John Muir Laws during a national annual conference of the National Association of Interpretation. His programming trains one’s mind to see deeply and with internal curiosity. He teaches nature journalling techniques
capturing one’s observations, questions, and reflections enriching one’s experiences while developing gratitude, reverence, and the skills of a naturalist. He works to share love and connection to nature through art and science.

Laws’ naturalist observation prompt that I have learned and since implemented with learners is “I notice, I wonder, It reminds me of” (2016, p. 6). In my experience, this deep observation practice fosters remarkable inquiry and curiosity in people. John Muir Laws claimed that this practice was inspired by Kerry Ruef (1992).

**Private Eye**

The Private Eye Project is an acclaimed, hands-on learning process and professional development program which stresses interdisciplinary and connected thinking using everyday objects, a jeweler’s loupe for magnification, and simple questions (Private Eye Project, 2015). I was first introduced to this program while learning about John Muir Laws’ work. The investigative program is focused on the “drama and wonder of looking closely at the world, thinking by analogy, changing scale and theorizing” (Ruef, 1992, p. ix). The questions used in the Private Eye loop included “What else does it remind me of? What else does it look like?” (Ruef, 1992, p. 25) and “Why is it like that?” (1992, p. 30). This process of looking closely, asking questions and recording the observations with drawings or descriptive words fosters inquiry and innate curiosity.

**BEETLES Project**

Upon meeting the director of the the BEETLES (Better Environmental Education, Teaching, Learning & Expertise Sharing) project at a national conference I was
immediately convinced and became persistent in accessing the program’s resources for educators and reflecting on practice through coaching. BEETLES is “an infusing outdoor science program with research-based approaches and tools to improve science teaching and learning in the field” (Regents of the University of California, 2016, para. 1). It provides lessons and rationale for outdoor science instruction designed to inspire instructors to improve their teaching. The student activities “inspire students’ wonder and curiosity about the natural world, support their innate tendencies for exploration, and guide them to make explanations based on evidence” (Regents of the University of California, 2016, para. 1).

**Land Ethic Leaders**

Aldo Leopold said that “nothing so important as an ethic was ever written... it evolved in the minds of a thinking community” (Leopold, 1966, p. 263). Participating in the Land Ethic Leaders program with the Aldo Leopold Foundation, I was invited to be a leader in building a grassroots level land ethic within my community (local and professional). I learned techniques to facilitate dialog and lead activities allowing people to explore the meaning and value of conservation in today’s world. Leopold’s method of developing a personal land ethic is the root of the program - observing the natural world through scientific inquiry, participating in purposeful work on the land, and reflecting on the experience. Leopold believed that together these activities can bring people to a new understanding and respect for the landscape around them.

Each of these giants and programs have significantly influenced my teaching philosophy, practice, and helped me form my ideal innovative education programs. These
giants inspire me to strive to teach less and share more, use direct experiences, foster personal relationships to places, allow for solitude and silence, reveal meaning and relationships, create a sense of wonder and inspiration, allow for deep intentional observation which fosters deep curiosity and inquiry, cultivate connected thinking, model reflective teaching in the field, hold space to create a land ethic among my thinking communities, and perform purposeful work on the land. I believe these tenets are critical in creating relevant, purposeful, and innovative teacher professional development programming for science teachers. By modeling these practices through workshops and programs, in addition to concrete scientific content, I believe teachers will be inspired and more confident to provide effective instruction for their students.

**Purpose of Research**

I investigated four biological field stations that conduct innovative teacher professional development opportunities for this research study. I explored innovative programs that provide:
Table 1.

*Criteria Established for Multi-Case Study Innovative Teacher Professional Development at Biological Field Stations*

| Programming Criteria Established for Multi-Case Study Innovative Teacher Professional Development at Biological Field Stations |
|---|---|
| 1 | focused on bringing teachers and scientists or researchers together |
| 2 | outdoor field-based |
| 3 | focused on inquiry-based learning and instruction |
| 4 | worked toward increasing environmental literacy for both the teachers and their respective students |
| 5 | focused on STEM education |
| 6 | included a strategy for increasing diversity/inclusion as a means to attracting minorities to the science and natural resources field |
| 7 | data-driven assessment and evaluation of efficacy of teacher/scientist partner programs |
| 8 | programmatic structure for implementation and transference back into the K-12 classroom or field experience |
| 9 | planning and logistical strategies |

The four case study sites all conduct innovative teacher professional development that model strategies for excellence, how to overcome barriers, and innovative program design principles which could be implemented in the development of new teacher professional development programs elsewhere.
Research Approach

I used a qualitative multiple case study to conduct four case studies from a pragmatic worldview. My qualitative approach of using case studies was appropriate for exploring and understanding how research field stations teacher professional development programs have been developed and are facilitated. The flexibility of the qualitative method involved emerging questions and procedures in my research. The data collected led to analysis that built from details to larger themes and then interpretations of my findings. My pragmatic worldview of research allowed me as the researcher to choose the appropriate steps forward in my research based on what worked for the presented research problem. This worldview does not include a belief that there is an absolute right way of doing this research. Instead, I believe there are many possible approaches for collecting and analysing data. By conducting case studies I was able to ask “how” and “why” questions about innovative teacher professional development programs and then analyzed the findings.

Chapter Summary

In conclusion, I believe direct experience, hands-on, inquiry-focused, field-based learning is the best type of education for most learners of all ages and biological field stations can provide this type of learning opportunity for teachers to then implement in their classrooms and field learning sites. This multi-case study informs and improves the development of new and existing teacher professional development programming at biological field stations. This research study allowed me to explore my personal passion and teaching philosophy as well as leverage my past education and teaching experiences.
The purpose of this qualitative multiple case study research was to explore how current innovative programming may inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

**Introduction to Chapter Two**

Before conducting the four case studies, I first explored current academic literature regarding innovative teacher professional development conducted at biological field stations. The Chapter Two Literature Review begins with the definition of biological field stations, their function, a brief history, and their contributions to the larger scientific community. Then, I explored the need for stronger environmental literacy among American adults as well as examples of environmental literacy advancements occurring in regions of the country. Thirdly, I looked into the benefits of learning outdoors in the field alongside scientists. Finally, I explored the importance of inquiry-focused teaching and looked at some examples of teacher professional development occurring at biological field stations.
CHAPTER TWO

LITERATURE REVIEW

Introduction

There is a need for K-12 science teachers in America to seek methods opportunities to incorporate more authentic inquiry-focused science learning experiences into their curriculum as we know that:

...students need to learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor. Students therefore need to be able to devise and carry out investigations that test their ideas, and they need to understand why such investigations are uniquely powerful. (Alberts as cited in National Research Council, Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry and Center for Science, Mathematics, and Engineering Education, 2000, p. xiii)

Teachers also need additional scientific knowledge in order to provide effective learning experiences for their students (Environmental Literacy Council, 2016). At the same time, biological field stations are seeking ways to integrate scientific research into formal and informal education and conducting outreach activities to provide engaging learning opportunities for people of all ages and backgrounds (National Research Council, Division on Earth and Life Studies, and Board on Life Sciences, 2014). As a means of bridging these gaps, this study explores ways to bring teachers and scientists together in living laboratories where inquiry is practiced every day. This study’s research question is:
What are the innovative practices of existing teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators?

Biological field stations are living laboratories or field research laboratories where students, faculty, scientists, and others conduct hands-on, inquiry-based scientific explorations such as one-day field experiments, week-long studies, or long-term research projects. There are opportunities for teachers and scientists to work together and learn from each other at field stations across the country. Teachers can access new scientific knowledge, experimental designs, and field techniques through scientists who are learning how to better communicate their work to wider audiences through accessible and relevant methods.

Overview

This literature review explores current academic and professional literature regarding biological field stations and their capacity to facilitate science teacher professional development opportunities.

First, Chapter Two shares and defines biological field stations, their primary function, and their geographic locales around the world. This section also discusses the importance of field stations’ contributions to the scientific community and contributions to the broader understanding of how the natural world works through long-term research projects and data collection. Finally, this section introduces the larger national and international networks of field stations.

Second, the need for increased environmental literacy among adults is explored.
Environmental literacy is defined from an American perspective using the 2015 *Environmental Literacy in the United States: An Agenda for Leadership in the 21st Century* from the National Environmental Education Foundation in addition to a definition from the North American Association for Environmental Education. This section also introduces initiatives advancing environmental literacy specifically in Colorado.

Third, the chapter discusses the benefits of learning in a natural setting through hands-on, authentic learning opportunities out-of-doors. The literature reveals that during field experiences students learn more in-depth content. Researchers argue when students do their own explorations and experiments, they tend to own their findings, cultivating excitement and inspiration around field science.

The fourth section explores the relationship of teachers learning with and from scientists. The authors demonstrate multiple benefits for teachers while learning from scientists. Specific programs that bring teachers and scientists together are discussed including: Science Education Leadership Fellows (SELF), Columbia University’s Summer Research Program (CUSRP), and Teachers in the Woods program.

The fifth section discusses the importance of field-based inquiry-focused learning and teaching with preservice and experienced teachers alike. Researchers argue that, not only is there a need for experienced teachers to become better field-based, inquiry-focused teachers, but preservice teacher education programs must also incorporate this model of teaching into their curriculum at colleges and universities.

The last section looks closely at professional development programs for science
teachers at biological field stations. The literature explores the rationale for teachers learning through real-world scientific explorations and how this increases their self-efficacy in teaching science in their classrooms. It also introduces a few current teacher professional development opportunities. This section closes with suggestions from the authors on bridging the culture and language gap between teachers and scientists, specifically for those who are working together at biological field stations.

Definition of Biological Field Stations

Biological field stations are places where students, faculty, researchers, community members, and others conduct hands-on science investigations, learn from researchers, and gain knowledge of the local ecosystem. Biological field stations are typically run by academic institutions, private non-for-profits organizations, or governmental agencies. The beginning of this section describes the variety of functions of biological field stations and their geographic locale. The second section discusses the contributions of biological field stations to higher education and science in general and introduces the Organization of Biological Field Stations and its network nationally and internationally.

Function and Locale of Biological Field Stations

Biological field stations and marine laboratories are centers for sustained, investigative, ecological, place-based research, education, outreach, and stewardship; they also create professional networks of scientists and students (Eisner, 1982; Hodder, 2009; Klug, Hodder, & Swain, 2002; National Research Council, Division on Earth and Life Studies, and Board on Life Sciences, 2014; Tydecks, Bremerich, Jentschke, Likens,
& Tockner, 2016). The National Research Council, Division on Earth and Life Studies, and Board on Life Sciences (2014) stated:

A field station is a center of scientific research, conservation, education, and outreach that is embedded in the environment in a location that is usually protected and that serves both the local community and the larger scientific community. The research conducted at a field station is often focused on local environmental regions, but national and international scientific projects are common. (p. 7)

There is a synergistic relationship between education and research at biological field stations (Lohr & Stanford, 1996). Education at biological field stations reaches from outreach programs with K-12 students to undergraduate students and faculty to landowner education, implementing best land-management practices. Biological field stations,

...transform the lives of students of all ages and serve as training grounds for the next generation of scientific leaders. Because many [biological field stations] are embedded within local communities, they are on the front lines of integrating science into decision-making and of communicating science to the general public. (Tydecks et al., 2016, p.1)

The experimental scope, scale, and diversity of landscapes where field stations exist is broad and diverse. Hundreds of biological and marine laboratories are located around the globe with stations or laboratories in nearly every major biome.
Biological Field Stations Contributions to Science

Many biological field stations in the United States have been in existence for decades and some for a hundred years or more (Tydecks et al., 2016). Most biological field stations host long-term research projects from which scientists have collected data for decades. These robust, long-lasting data sets contribute to the larger scientific community to better understand climate, biodiversity, and the natural world as a whole system while focusing on these elements in very specific locations. Biological field stations “serve as a gateway into the complexity of biological sciences. [They] are to the study of higher-order biological systems what research and teaching hospitals are to the medical sciences” (Klug et al., 2002, Section I. Introduction, para. 3). In 1982, Wilson wrote of the importance of biological field stations. He stated:

I believe that in the not too distant future a much larger share of biological research, from biochemistry to ecology, will be conducted at field stations that consist of nature preserves and have ready access to laboratories equipped to analyze and monitor processes at every level of biological organization, including the molecular. Field stations will also serve as key centers of education at all levels. Universities and other institutions wise enough to invest in such stations now, even in the face of limited financial resources, will assure themselves of a much larger share in the future action. (p. 320)

Wilson’s vision continues now into fruition 34 years later with the continuation of field studies and long-term research and data collecting at multiple biological field stations and marine laboratories around the globe.
Robust data collections have the most profound impact when combined together to tell an integrated story of biodiversity instead of independent site-specific stories. In an attempt to create a strong network for sharing data, best practices, and other resources, the Organization for Biological Field Stations (OBFS) was formed. The mission of OBFS is “to help member stations increase their effectiveness in supporting critical research, education, and outreach programs” (Organization for Biological Field Stations, n.d., para. 2). The National Association of Marine Laboratories (NAML) also serves as a network to link research and education together across the country. Their mission is:

...to stimulate research and promote education in the marine sciences. NAML seeks to provide a forum for the resolution of problems common to non-profit marine laboratories in the United States. The association encourages the wise use and conservation of marine and coastal resources. (National Association of Marine Laboratories, n.d., para. 1)

There are also international networks to connect field stations and marine laboratories around the globe. In 1989 the Organization for Biological Field Stations recognized a need to explore the potential of an International Organization for Biological Field Station. Since then, the organization has established goals and objectives to be an effective network of international field stations sharing data, best practices, and resources (Wyman, 2009). There is now a widely accepted understanding of the need and importance of field stations collaborating with each other across the country and around the world.

Many biological field stations and marine laboratories rely on funding from the
National Science Foundation to conduct research along with private donations, foundation grants, and academic institutions.

**Environmental Literacy in America**

Environmental literacy and environmental concern in the United States is lower today among the adult population than one might expect. The National Environmental Education Foundation (2015) reported that “Americans focus on air and water quality, but the proportion of Americans concerned about environmental problems has declined over the past decade” (p. 15). Scholars hypothesized that if someone is more environmentally literate, he or she is most likely more concerned about the environment. According to the literature explored in this section, one method for improving environmental literacy across all sectors of the population is by increasing environmental literacy among teachers and empowering them to teach environmental topics well. This section begins by discussing current research from the National Environmental Education Foundation that explicitly defines current deficiencies across the United States. The second section addresses the need for environmental literacy to address social, political, and economic dimensions of everyday life in order to create more engaged citizens. The final section discusses efforts to improve the identified need for environmental literacy improvements in Colorado as identified in the Colorado Environmental Education Plan. The Plan identifies the need for stronger teacher professional development in environmental education.

**Environmental Literacy as Defined in the United States**

Environmental literacy is a term that can easily be represented with multiple
definitions and must be clearly defined. Two nationally-recognized environmental organizations in the United States have complementary definitions for environmental literacy. The National Environmental Education Foundation’s definition is:

...an environmentally literate person is someone who, both individually and together with others, makes informed decisions concerning the environment; is willing to act on these decisions to improve the wellbeing of other individuals, societies, and the global environment; and participates in civic life. (2015, p. 11)

It is important to note that environmental literacy does not measure the amount of time one spends outside or how environmentally-minded someone is; rather, environmental literacy focuses on people making informed decisions, having self-efficacy, and being a responsible steward and active citizen. Moseley (2000) stated that “…the ultimate goal of environmental literacy is acquiring life-sustaining, responsible environmental action skills” (p. 24). The North American Association for Environmental Education defined an environmentally literate person as:

...someone who, both individually and together with others, makes informed decisions concerning the environment; is willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participates in civic life. Those who are environmentally literate possess, to varying degrees:

- the knowledge and understanding of a wide range of environmental concepts, problems, and issues;
- a set of cognitive and affective dispositions;
● a set of cognitive skills and abilities; and

● the appropriate behavioral strategies to apply such knowledge and understanding in order to make sound and effective decisions in a range of environmental contexts. (Hollweg et al., 2011, p. 2-3 - p. 2-4)

These two definitions create a common understanding of environmental literacy for this research study.

**Need for Improved Environmental Literacy**

Environmental issues are not the primary concern for American adults today. During a twelve-year period from 2000 to 2012, the proportion of Americans worried about air and water pollution dropped 23 and 24 percent, respectively (National Environmental Education Foundation, 2015). In 2000, “Gallup noted that ‘Americans overall favored the environment over the economy by a better than 2-to-1 margin (67 percent to 28 percent).’ But, today Americans prioritize the economy over the environment” (National Environmental Education Foundation, 2015, p. 16). This suggests that, according to popular opinion, one’s economic needs speak louder than the needs for healthy water to drink and air to breath.

The 2013 Benchmark Survey Report looked at how environmentally informed average American adults were. “Environmentally informed” was defined as “The amount of information that the public is exposed to about various environmental issues” (National Environmental Education Foundation, 2013, p. 7). The average score was only 51 with the highest possible score of 100. Also, Americans feel less and less able to make a significant difference through their actions for the environment (National
Environmental Education Foundation, 2015). The level of self-efficacy toward environmental stewardship is decreasing as environmental literacy declines among American adults.

The National Environmental Education Foundation’s *Environmental Literacy in the United States: An Agenda for Leadership in the 21st Century* (2015) report shared data and findings from the National Environmental Education Foundation’s 2013 Benchmark Survey Report, which was a snapshot of American adults’ understanding, behaviors, and attitudes toward the environment. The Benchmark Survey Report stated, “85 percent are very concerned about their personal and the health of their family; 53 percent believe that natural environments make people healthier” (National Environmental Education Foundation, 2013, p. 12). Data also indicated Americans getting outdoors in greater numbers and participating in green behaviors like recycling (National Environmental Education Foundation, 2015). However, the data suggested that American adults are distracted by other priorities, overwhelmed by the complexity of the issues we face, polarized about problems and solutions, misinformed about key issues, and less confident than they once were about the ability to take major steps to address environmental problems. (National Environmental Education Foundation, 2015, p. 15)

This data suggested that environmental literacy has decreased among American adults, environmental concern is on the decline, and skepticism is growing.

In 2005, the National Environmental Education Foundation (then called NEETF) published *Environmental Literacy in America: What Ten Years of NEETF/Roper*
Research and Related Studies Say about Environmental Literacy in the United States. In the Preface, Wood and Barlet explained:

...we have a confused public that performs poorly on basic environmental literacy questionnaires. But 95% of this public supports environmental education in our schools. And most Americans want environmental education to continue into their adult lives. Over 85% agree that government agencies should support environmental education programs. A large majority (80%) believe that private companies should train their employees to help solve environmental problems. People want to understand environmental issues and how they apply to their daily lives. (as cited in Coyle, 2005, p. ii)

This recognized need for increased environmental literacy has been present for the past few decades. In 2002, Lowe suggested,

In the modern world of rapid change, where much of the knowledge and many of the skills that people will need in their future life do not yet exist and so cannot be taught, the formal education must emphasise the processes which will prepare people for that world. An explicit commitment to environmental literacy will therefore lead to a better educational preparation for the complex, rapidly-changing world of the future. (p. 8)

Now more than ever before, the world needs an educated citizenry ready to participate and make the tough decisions that lie ahead, including climate change, responsible resource extraction, and species extinction, among others (Hollweg et al., 2011). “Every day people make decisions that affect their environment...it is imperative…that the public
learn and understand how their actions and lifestyle intersect [with] the environment’’ (Chepesiuk, 2007, p. A496).

The National Environmental Literacy Assessment Project was conducted in 2007 and was a national baseline study of middle grade students. It was funded by the United States Environmental Protection Agency’s Office of Environmental Education and the National Oceanic and Atmospheric Administration (NOAA) and was conducted by the North American Association for Environmental Education (NAAEE). It provided baseline data for environmental literacy among sixth and eighth grade students as well as presented data describing schools, programs, teachers, and students involved with the study (Marcinkowski et al., 2013).

The major findings of the National Environmental Literacy Assessment Project were reported as composite scores with a range from 24-240. The mean composite score was 142.14 for the sixth and eighth graders combined, which falls in the mid-range of possible scores, reflecting a moderate level of environmental literacy. The highest scores were achieved in the ecological knowledge and environmental effect categories, while the lowest was in behavior and cognitive skills (Marcinkowski et al., 2013).

Environmental literacy goes beyond content knowledge of environmental science to include the social, political, and economic dimensions (Lowe, 2002). Chepesiuk (2007) also explained that environmental literacy proponents validate the need for people to have strong problem-solving skills that help them evaluate different viewpoints. These claims are critical in understanding that environmental literacy is a framework through which to function in all aspects of everyday life and work. With this recognized need for
higher environmental literacy among American adults, one could argue that this begins with better education for American students, and that it begins with well equipped and knowledgeable teachers.

**Environmental Literacy Advancements**

Across the United States, multiple states recognize the need for improved environmental literacy with the development of environmental literacy plans in various forms. In Colorado, environmental literacy was a strong focus for state leaders and the legislature during Governor Hickenlooper’s term. During the 2010 legislative session, Governor Hickenlooper signed the *Colorado Kids Outdoor Grant Program* into law. The legislation required the State Board of Education to adopt a statewide plan for environmental education (HB 10-1131 § 1.2, 64th Gen. Assemb., Reg. Sess., Colorado, 2010). The final draft of the *Colorado Environmental Education Plan: Leveraging Resources to Advance Environmental Literacy* was published in 2012 and serves as a guide to enhance environmental literacy across the state using existing resources and programs. The *Colorado Environmental Education Plan* similarly defines “environmental literacy” as “a student’s knowledge, understanding, skills, and motivation to make and act upon responsible environmental decisions as individuals and as members of their community” (Colorado Department of Natural Resources et al., 2012, p. 10).

The goals outlined in the *Colorado Environmental Education Plan* (2012) articulate how to best ensure that “all Colorado’s pre-K-12 students have access to high quality environmental education opportunities both in the classroom and outdoors” (p. 7). One of the three goals is to provide more high quality teacher professional development
in environmental education as a means of increasing environmental literacy, as seen in Table 2. It is recognized in the state of Colorado that there is a significant need for strong environmental education professional development for teachers in order to increase environmental literacy across the state among pre-K-12 learners.

Table 2.

*Colorado Environmental Education Plan Goal #3*

<table>
<thead>
<tr>
<th>3. Connect school districts and teachers to professional development opportunities in environmental education:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Increase teachers' content knowledge</td>
</tr>
<tr>
<td>b. Improve teachers' pedagogical content knowledge and skills, including the use of:</td>
</tr>
<tr>
<td>● Interdisciplinary, place-based and research-based instructional strategies;</td>
</tr>
<tr>
<td>● Innovative technologies as an integral element of environmental education; and</td>
</tr>
<tr>
<td>● Concept-based approaches that underpin environmental education principles</td>
</tr>
</tbody>
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In addition, the Environmental Literacy Council partnered with the National Science Teachers Association (NSTA) to create multiple professional development modules that incorporate environmental issues into curriculum for teachers to access (Environmental Literacy Council, 2016).

**Learning In the Field**

Firsthand learning in the field has been suggested time and time again as one of the most authentic and successful learning environments for learners of all ages, including adults. Teachers learning in the natural world allows them to gain a stronger understanding of ecological content and awareness. These experiences also help teachers
become more comfortable and empowered to bring science to their students in direct and authentic ways, as suggested by the literature in this section. Teachers can also gain the confidence to facilitate environmental science learning opportunities in an experiential manner. Martin (2001) claimed that “Once an educator discovers the rich curriculum that is embedded in the places where they are, their view of school shifts and they become more effective educators” (p. 1).

It is during field course experiences, as shown in the research below, that learners gain a more authentic and in-depth understanding of scientific content and understanding of the natural world. The National Research Council, Committee on Science and Mathematics Teachers Preparation Staff, and Center for Education Staff (2000) recommended,

...that STEM departments at two- and four-year colleges and institutions offer college-level courses that provide teachers with strong exposure to appropriate content...and must recognize that teachers’ content knowledge of science...matures with time and experience. Coursework should include in-depth courses rather than broad surveys of subject matter. (pp. 119-120)

Wingfield and Black (2005) pointed out that many educators in higher education recommend instructors adopt fieldwork and other hands-on activities into their courses. Davis also claimed (as cited in Kozar & Marcketti, 2008) that field-based instruction has proven to be worthwhile in enhancing student learning, including retention of subject matter and improving students’ problem solving skills.

Learning in the field is an authentic, learner-centered opportunity bringing the
classroom outdoors, which can foster critical thinking and analysis skills, yet for teachers can be intimidating for teachers. Kozar and Marcketti (2008) concluded that field learning experiences “contributed to student engagement in the learning process, increased their understanding of...content, and allowed students the opportunity to apply their knowledge through hands-on real life situations” (p. 310). These real-life, hands-on learning opportunities are foundational to a student’s experience. It is documented throughout the literature that students regularly comment that it is the field learning experiences that are the highlights of their undergraduate experience (Krupa, 2000).

However, teachers sometimes find it difficult to teach outdoors. Martin (2001) explains:

Many teachers will try things outside the classroom, and most will make this effort just once. There are lots of reasons for this, not the least of which is the perceived loss of control of the teaching environment outside the confines of the classroom...they need lots of experience to overcome this. A two-hour field trip doesn’t do it. (p. 2)

According Krupa (2000), Louis Agassiz, the father of biological field stations, started the first station on Penikese Island (Massachusetts) for the purpose of providing school teachers from across the country with firsthand experiences in nature in 1873. His goal was to train teachers to teach biology. Janovy has authored numerous books and articles describing how exciting learning in the field can be, as well as the essential role of biological field stations in forming emerging naturalists and biologists. A few of his book titles include *Outwitting College Professors*, 2nd ed. (2010), *On Becoming a Biologist*, 2nd ed., (2004), *Teaching in Eden: the Cedar Point lessons* (2003), and
Dunwoody Pond: Reflections on the high plains wetlands and the cultivation of naturalists (1994). Janovy and Major (2009) described that “...those of us who teach field courses routinely...claim that a biological field station provides one of the most effective environments for permanently altering a college student’s attitude, interest, and performance in biology” (p. 220). At biological field stations, “students identify new questions; develop the natural history, research, and technical skills needed to enable future research; and develop the science skills that allow for a highly productive workforce and scientifically literate citizenry. In turn, time at an FSML is often highly motivational for students” (Tydecks et al., 2016, p. 10). These direct experiences can have long-lasting, profound impacts on students and learners of all ages.

It is also during field learning experiences that teachers and students can easily gain ownership of their investigations and experiments. Janovy and Major (2009) explored this premise:

…a field station is the one place in today’s higher education establishment where you can actually play the role of a productive scholar, abbreviated, perhaps, but nevertheless real, in some exceedingly important ways, all the while surrounded by natural beauty. The ontogeny of a scientist throughout history often has followed this same course: looking at a natural environment in a new and unbiased manner, letting curiosity and personal interest drive the selection of problems to explore in depth, framing the appropriate questions and the testable predictions, struggling with the logistical demands and time management of research, then bringing one’s efforts to closure with a paper and presentation. (p.
It is at biological field stations where learners can become inspired to be biologists, ecologists, and other types of scientists. Field stations “provide a venue to viscerally engage students in exploration and discovery” (Tydecks et al, 2016, p. 22). Real, hands-on investigations instill strong understanding and ownership that can otherwise be difficult to foster in students.

**Learning From Scientists**

There is an interesting tension between teachers and formal scientists. Teachers do not typically have easy access to scientists and scientists do not typically know how to effectively share their research with teachers (Kim & Fortner, 2007). However, there is much research that highlights the importance of cross-pollination between the two fields. This section begins by discussing the importance of and recommendations for teachers working with scientists, followed by examples of teachers learning from scientists during professional development experiences. It also discusses teacher self-efficacy after learning from and along with scientists while conducting authentic first-hand investigations and experiments together.

Teachers who have the opportunity to work alongside scientists gain experience that is otherwise difficult to obtain and yet is essential to the development of an effective science teacher. Kim and Fortner’s (2007) research concluded that there is strong evidence that when scientists collaborate with educational projects, teachers’ science teaching and learning improve. They also explained that it is key to develop cultures of collaboration and connections “to scientists through a continuum of teacher education:
preparation-induction-professionalization” (Kim & Fortner, 2007, p. 48). During teacher pre-service training little time is spent connecting teachers to the scientist profession and can lead to the “manifestation of the different professional cultures of scientists and educators” (Kim & Fortner, 2007, p. 49) that are sometimes difficult to bring together.

According to Klug et al. (2002), “The historic schism between scientists and science educators continues to be a barrier…” (Section A.3). In order to move forward from this dissension, Klug, Hodder and Swain offered a couple suggestions:

1. The provision of teacher professional development opportunities. Working with teachers and curriculum specialists in the schools in developing direct field station or marine laboratory experience or indirect (e.g. school yard or distance learning) field experiences which integrate into the existing curriculum and meet district, state, and national science standards will lead to programs that will reach a large number of students.…

2. The engagement of teachers in research. Individual teachers who have an emerging or already developed interest in facilitating field experiences should be identified and encouraged to pursue that interest…. This research should also provide increased opportunities for scientists and teachers to work together in developing curricular material with activities related to research in ecological and field biology. (Section A.3)

When teachers get the opportunity to work with scientists, they take on some of the characteristics of a scientist. One teacher who participated in an Research Experience for Teachers (RET) program said “that her students now see her as a scientists as well as
a teacher” (Musante, 2006, p. 569). Another teacher who also participated in an RET program stated, “It’s really important for teachers to gain credibility with students… so that they see their teacher as a biologist who can bring real examples into the classroom” (Musante, 2006, p. 596). Working with scientists as colleagues improves teachers’ sense of status experienced as fellow scientists. Also, the camaraderie established from solving problems together during field work was notably improved (Dresner & Worley, 2006). The National Research Council, Committee on Science and Mathematics Teachers Preparation Staff, and Center for Education Staff (2000) claimed that more scientists must become well informed and engaged with education efforts to provide appropriate content knowledge to current and future teachers.

**Programs That Bring Teachers and Scientists Together**

The National Research Council, Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry and Center for Science, Mathematics, and Engineering Education (2000) found it important for teachers to work with scientists: “It is critical to include partnerships between educators, universities, and research institutions’ scientists in creating opportunities for teachers to conduct scientific research in both preservice and inservice programs” (p. 113). A few programs have taken this direction to heart and have offered experiences for teachers to work with scientists. Also, in contrast, there are many scientists who are working to be stronger communicators and educators. One program described below, *Communicating Science* is addressing this at the Lawrence Hall of Science.

**Science Education Leadership Fellows Program.** During the Science
Education Leadership Fellows Program described by Moreno et al. (2001), elementary school teachers are paired with scientists for two years to create joint-learning communities and promote interaction of elementary school students with professional scientists. Not only did the teachers learn new science content knowledge and gain access to new teaching resources, leadership skills, and teamwork, but the scientists also learned education best practices, such as using the learning cycle and facilitating inquiry learning experiences (Moreno et al., 2001). The teachers reported that their students demonstrated increased enthusiasm for science after interacting with a “real scientist,” and the teachers achieved a deeper understanding of how science works and became more confident and effective in the classroom (Moreno et al., 2001).

**Columbia University’s Summer Research Program.** The Columbia University’s Summer Research Program (CUSRP) is a teacher research program that is founded upon the premise that “experience in the practice of science improves the quality and authenticity of science teaching and thereby increases student interest and achievement in science” (Silverstein, Dubner, Miller, Glied, & Loike, 2009, p. 440). Teachers who are selected are appointed as Visiting Scholars at Columbia University and receive a $6000 stipend per summer as well as a faculty mentor and email account to access university library resources. The teacher is paired with a laboratory on campus to do science first-hand with faculty and graduate students. Upon completing the program, multiple alumni teachers responded to an implementation survey, which revealed a significant increase in self-efficacy in teaching science, understanding scientific knowledge, and science literacy (Silverstein et al., 2009).
**Teachers in the Woods.** During the Teachers in the Woods program, teachers participate in a 6-week summer institute developing ecological knowledge and field experience by assuming the responsibilities of a field ecologist by working directly with practicing scientists and teaching colleagues in national forests and national parks. The program proves to have a strong impact as much as 5 years after participating. Teachers commented that they continued to apply what they had learned in the years following. Some teachers had started field ecology projects at their schools, changed their classroom environments, and implemented long-term student science projects. The three most influential, longest lasting, and impactful pieces of the program have been partnerships with scientists, teacher networks, and the strong emphasis on direct experience. (Dresner & Worley, 2006)

**Communicating Science.** The *Communicating Science* course was designed by the Lawrence Hall of Science at the University of California-Berkeley as a means to help scientists gain the knowledge, skills, and practices to teach science through inquiry and participatory approach. The course has been designed with “learner centered practices and sound educational principles at its core, and the strategies advocated for teaching with children are also employed in teaching the course with adult learners” (Lawrence Hall of Science, 2011, para. 1). The program began innovative science teaching methods for university science students and has now evolved to many different settings, purposes, and audiences, including but not limited to aquarium scientists and non-formal educators. (Lawrence Hall of Science, 2011)

Each of these programs are exemplars of innovative programming bridging the
gap between scientists and educators. They paired teachers with scientists in many cases allowing the opportunity for them to work together through direct experiences doing science, and created long-lasting communities of practice.

**Inquiry-focused Outdoor Field Experiences for Teachers**

University students in teacher preparation programs are generally open and receptive to learning new scientific knowledge and teaching methodologies, techniques, and skills. In this section, the impacts of the field-based inquiry-focused model of instruction with preservice and experienced teachers are explored. The National Research Council, Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry and Center for Science, Mathematics, and Engineering Education (2000) stated:

For students to understand inquiry and use it to learn science, their teachers need to be well-versed in inquiry and inquiry-based methods. Yet most teachers have not had opportunities to learn science through inquiry or to conduct scientific inquiries themselves. Nor do many teachers have the understanding and skills they need to use inquiry thoughtfully and appropriately in their classrooms. (p. 87)

When teachers are shown and taught how to incorporate innovative hands-on environment-based inquiry activities into their lessons, they “feel deeply rewarded as they see students...respond enthusiastically to what they are learning, [and the teachers are inspired to look for] opportunities to explore new subject matter than traditional, discipline-based teaching” (Lieberman & Hoody, 1998, p. 10.)
As referenced below, many classroom teachers do not receive enough exposure to field-based inquiry teaching methods when in education courses. Just like preservice teachers, experienced teachers also need access to field-based, inquiry-focused professional development opportunities.

Higher education institutions that offer teacher education programs may or may not do a thorough job of instructing teachers to teach through inquiry. The National Research Council, Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry and Center for Science, Mathematics, and Engineering Education (2000) suggested that there is room for improvement: “Programs are needed that explicitly help teachers learn inquiry abilities and understandings… these programs need to help teachers learn how to teach through inquiry” (p. 112). The Pacific Northwest State Standards mandate science inquiry methods, yet most teachers have not been taught inquiry-focused science teaching techniques (Dresner & Moldenke, 2002). The style of learning in our nation’s colleges and universities does not typically involve active, authentic scientific investigation or problem-solving processes and inquiry skills, but rather includes large introductory lecture and lab formats rich in content (Nugent, Kunz, Levy, Harwood, & Carlson, 2008). Dresner and Moldenke (2002) also suggested that “[teachers] need to participate in a science inquiry project themselves before they can begin to include it in a meaningful way into their own practice” (p. 659).

Students claim to learn more from field experiences than classroom settings and gain stronger inquiry skills also in the field. According to a study by Nugent et al. (2012), students in field courses “gained significantly more inquiry knowledge and skills in areas
of differentiating between observations and inferences, critical thinking, and cooperative learning” (p. 523). In an earlier study by Nugent et al. (2008), they found that students’ high-level questioning skills were significantly higher after a field course, but the course had no impact on low-level questioning. Instead of focusing on low-level questions in order to pass a test, the students used high-level questions more frequently. This allowed the students to more fully understand the content, satisfy their curiosity, and learn the material. The students in the field course wanted to gain an understanding of the content. Not only was high-level questioning increased, but so were the students’ use of cooperative learning strategies, differentiation between observations and inferences, deep learning (knowledge building), and confidence in teaching science.

This literature suggests that modeling inquiry and teaching teachers to be comfortable with inquiry is necessary in science teacher professional development. Biological field stations practice inquiry and conduct the process of science daily. They have the capacity to inspire teachers to embrace and get excited to teach students through inquiry.

**Teacher Professional Development at Biological Field Stations**

While learning at biological field stations, teachers gain confidence for teaching science, build enthusiasm to teach through inquiry, and are able to use an authentic context to better understand scientific content. There are examples of teachers learning from scientists in hands-on, authentic, inquiry-based learning models around the country and around the globe, as discussed by members of the Organization of Biological Field Stations on their listserv (personal communication, 2015-2016) yet many of these
programs are not formally documented in academic literature. This section shares examples and also discusses improvements for creating more teacher professional development opportunities at biological field stations. Learning through the lens of a biological field station can be exciting, influential, and educational for both teachers, and the scientists or researchers at the field station (Dresner & Starvel, 2004).

Science teachers need not only participate in in-service trainings, but also in outdoor trainings and experiences during professional development opportunities. Duschl, Schweingruber, and Shouse (2007) suggested that “In order for groups of teachers to engage in instructionally meaningful science-specific learning activities, they will require substantial guidance and input from external support providers” (p. 310). These external providers offer a context in which teachers can deeply explore content and gain meaningful learning experiences. Kielborn and Gilmer (1999) explained that a benefit of contextual learning is that it provides:

...a way to collaborate and form partnerships with other institutions, including other universities, schools, science museums, businesses, and governmental laboratories. This type of collaboration benefited schools, teachers, and students in many ways. Such associations also influenced partner agencies as well, increasing their communication with educational institutions. (p. 25)

In order for teachers to have real-life contextual experiences doing science with experts and scientists, many times they need to look beyond the walls of their institutions to external organizations.

Many biological field stations incorporate long-term research studies into their
sites; they “play a fundamental role and offer long-term commitment in supporting global programs and networks such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the Group on Earth Observations Biodiversity Observation Network (GEO BON), the Long Term Ecological Research (LTER) Network, the Ocean Observatories Initiative (OOI), and the Global Lake Ecological Observatory Network (GLEON)” (Tydecks et al., 2016, p. 169). These opportunities to conduct meaningful, valuable science are ideal for teachers to get involved with, as evidenced by The National Research Council, Committee on Science and Mathematics Teachers Preparation Staff, and Center for Education Staff’s recommendation in 2000 that “Teacher education…[should] be structured in ways that allow teachers to grow individually in their profession and to contribute to the further enhancement of both teaching and their disciplines” (p. 109). When students collect scientific data and share it with larger databases, they learn the process of science; it also allows them the opportunity to contribute to the broader scientific community. Creating unique learning opportunities for K-8 science teachers that:

...involve the ‘doing’ of scientific activities is particularly interesting, as many report very limited exposure to science course work and inquiry experiences in particular… in these settings, science teachers gain experiences with a broad range of scientific issues, including the generation of researchable questions and working as a community to interpret evidence and determine what counts. (Duschl, Schweingruber, & Shouse, 2007, p. 311)

Science teachers can gain meaningful authentic skills and experiences doing
science at biological field stations. Dresner and Moldenke (2002) stated: “Teachers… need to experience a meaningful authentic field science project for themselves before being capable of providing one of sufficient intellectual quality for their students” (p. 659). He continued, “[Teachers] need firsthand background knowledge of field ecology and an adequate set of field skills themselves before adequately taking on the task of training students to do so” (p. 662). Many biology field stations offer these important opportunities for teachers.

Field Station Research Opportunities for Teachers

The National Science Foundation (NSF) funds many opportunities for teachers to learn from scientists at biological field stations through the RET Program. These are paid, hands-on summer science research experiences within varying scientific fields (Dubner & Storm, n.d.). A professional scientist who receives an NSF grant in the biological sciences can apply for additional funding to invite teachers to be involved in his or her research project (Musante, 2006). The goal of these programs is:

… to help build long-term collaborative partnerships between K-12 science, technology, engineering, and mathematics (STEM) teachers, community college faculty, and the NSF university research community by involving teachers in research and helping them translate their research experiences and new knowledge into classroom activities. (Dubner & Storm, n.d., para. 2)

Biological field stations are known to host RET participants. The National High Magnetic Field Laboratory is one example of a field station offering a RET program that consists of a 6-week residential experience for teachers to participate in real-world
science research (Robinson, 2004).

The Teachers in the Woods Program, as described earlier, is another example of professional development at a biological field station. It provides teachers with opportunities to directly participate in meaningful scientific research working side-by-side with scientists during a summer program. The goals of the program include enhancing teachers’ skills and stimulating greater intellectual rigor, broadening the teachers’ concepts of themselves as science teachers, and providing the necessary confidence to lead students through similar science research projects (Dresner & Worley, 2006).

The Organization of Biological Field Stations and the National Ecological Observatory Network (NEON) are two examples of networks that provide access to possible sites for authentic field studies and can provide robust scientific data sets to use in inquiry-based classroom activities and discussions for science teacher professional development programs and K-12 education. Also, local natural areas such as county parks, open space, and scout camps can be effective locations for immersive hand-on scientific research experiences for teacher professional development programs (Kerlin, 2012.).

**Chapter Summary**

As seen in the literature, there are multiple locations around the world where important long-term research in the field is contributing to the scientific understanding of how the natural world works. There is tremendous opportunity for science teachers to engage in this science by working with the researchers and scientists, learning to teach
through inquiry-focused, field-based authentic techniques, and keeping their students engaged in the biological field sciences through biology field stations. When teachers become empowered and excited about learning new knowledge and practical skills in their field, they transmit this enthusiasm to their students. This means that when teachers build their confidence and self-efficacy around inquiry-focused field-based, and authentic real-world learning opportunities for their students, environmental literacy will undoubtedly increase.

Introduction to Chapter Three

Chapter Three presents a detailed description of the methodology for this research study. It begins with an explanation of the research methods used and the context of this qualitative multiple case study. It discusses how research sites were chosen using specific criteria as well as participants in the study. The Human Subjects Committee and Institutional Review Board process is shared along with any potential risks and benefits to the sites and participants.

Additionally, a thorough discussion of the data collection techniques and analysis is presented. Details are provided for the use of an initial questionnaire and follow-up interviews with the participants. Next, the process of labeling, sorting, and creating categories for the data is explained. Finally, the soundness of the study is described through triangulation, reliability, and validity of the study.
CHAPTER THREE

METHODOLOGY

Introduction and Research Question

Biological field stations often develop and facilitate science teacher professional development programming. The previous chapter presented a literature review that supports the premise that innovative science teacher professional development programming at biological field stations includes learning in the field alongside scientists through inquiry-focused, hands-on experiences. Chapter Three discusses and presents the methodology used to research and support this study question: What are the innovative practices of existing teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators? The purpose of this qualitative multiple case study research is to look at programmatic goals, designs, strategies, and core teaching and facilitation philosophies to help inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

Overview

This chapter introduces the research methods used for this qualitative multiple case study. It begins with an explanation of the research model chosen and provides relative context for the study. Next, a thorough discussion of how the research sites were chosen through a framework of specific criteria is presented. Also an explanation of the participants in the study is discussed. Then, a description of the Human Subjects
Committee and Institutional Review Board process is shared along with any potential risks and benefits to the sites and participants.

Additionally, a thorough discussion of the data collection techniques and analysis is presented. Details are provided for the use of an initial questionnaire and follow-up interviews with the participants. Next, the process of labeling, sorting, and creating categories for the data is explained. Finally, the soundness of the study is described through triangulation, reliability, and validity of the study.

**Research Model and Methods**

I chose to use a qualitative multiple case study approach to investigate my research question because it is the most suitable method to produce a rich data set to inform my question. Merriam (1988) suggested that case studies are “particularly useful for studying educational innovations, for evaluating programs, and for informing policy” (pp. 32-33). I implemented this paradigm as a means to qualify teacher professional development programming. Merriam (1988) also argued that case studies are evaluative in that they assess the merit of a particular program. Case studies are interpretive by nature. Researchers use the data to analyze, interpret, or theorize about a particular program and this leads to a combination of description and interpretation, or description and evaluation (Merriam, 1988).

**Context of Research**

The context of this study was biological field stations in the United States that currently host and facilitate science teacher professional development programming. Biological field stations vary greatly in administration, ecosystem, current research, and
education outreach strategies. The teacher professional development programming also varies based on curriculum standards for individual states, teaching philosophy, grade level, available funding, goals of the field station’s parent academic institution, and the local ecosystem and natural landscape. Due to the variability of the individual biological field stations, specific criteria was used to find commonalities and themes of the professional development programming as described later in this chapter.

Independent of this study, I was contracted to conduct a needs assessment and feasibility study for a new biological field station. Part of this process was to explore possible education outreach programming for the future field station. Science teacher professional development was identified as an important consideration for future programming. Also, as I serve on the board of directors for the Colorado Alliance for Environmental Education and the Northwest Regional Council for Colorado’s Environmental Literacy Plan; I have a vested interest in increasing science and environmental literacy across Colorado. Teacher training and professional development is one of the most effective leverage points for increasing environmental literacy, which is supported by the third goal of the Colorado Environmental Education Plan (Colorado Department of Natural Resources, Colorado Alliance for Environmental Education, & Colorado Department of Education, 2012): increase environmental education professional development opportunities for teachers. Teaching teachers is a method for creating an exponential reach for innovative practices and content as teachers teach and influence many students over the course of their career.
Research Sites

Case study sites for this research project were biological field stations that currently host science teacher professional development programming. The Organization of Biological Field Stations (OBFS) was critical to this study as a mechanism to communicate with over 300 field stations in the United States (and some additional sites outside of the United States). The OBFS listserv (personal communication, 2016) was used to access biological field stations for this the study.

Selection of Sites

Case study sites were selected from a list of voluntary biological field stations. I sent an email to the OBSF listserv to invite participation in my study, and from those responses, I selected four field stations representing varying administrative institutions, geographic regions of the country, and innovative programs.

The four case study sites were assigned the following pseudonyms: New England field station, Upper Midwest field station, Big River field station, and Pacific Northwest field station.

Case Study Participants

The case study participants were the case study sites’ administrators: directors, executive directors, program coordinators, education directors, and outreach coordinators. Other participants included science teachers who had participated in the sites’ programming.
Data Collection Procedures and Tools

I used questionnaires, interviews, artifacts, documents, observations, and field notes to collect data for my case study sites. I began by sending a questionnaire (see Appendix A) to the administrators at each site. Then, I hosted focused telephone interviews with the administrators with the four case study sites. I also thoroughly investigated their websites, materials, and other resources provided to me by the administrators. I sent the administrators the teacher questionnaire (see Appendix B) to forward on to teachers who had previously participated in their professional development programming.

Questionnaire for Biological Field Stations

I used online survey form technology for the initial questionnaire for the four biological field stations. The questionnaire included qualitative and quantitative questions (see Appendix A) to gain information and data from the biological field stations about their professional development programming.

I used a list of criteria to frame the questions for the biological field stations’ questionnaire. This criteria included the following:
Table 3.

*Criteria Established for Multi-Case Study Innovative Teacher Professional Development at Biological Field Stations*

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Available program assessment and evaluation data provided rich and robust information about program effectiveness. The transference criteria also made the entire study more robust as it allowed me to gather data about how professional development opportunities are transferred back to a teacher’s teaching environment.
Interviews with Study Site administrators

I conducted focused telephone interviews with at least one administrator at each site. These included the site director, executive director, program coordinator, education director, or outreach coordinator. I prepared interview questions based on the established criteria listed above to start the conversation and glean information from the administrators, yet the interviews were expected to be fluid and dynamic (see Appendix C).

Artifacts and Documents

I asked each of the study site administrators to provide materials regarding their teacher professional development programming for the study. I investigated websites, brochures, curriculum, and evaluation reports to gather data about the programming. I took thorough notes using my Artifact and Document Data Collection Tool (see Appendix D) while examining and reading through the artifacts and documents.

Questionnaire for Teacher Participants

I created an online questionnaire for teacher participants. I emailed a link to the questionnaire to the administrators from the four case study sites and asked them to forward it on to teachers who had participated in their professional development programming. A convenient sample of 11 teachers completed the questionnaire. I used specific criteria as the framework for constructing the teacher questionnaire (see Appendix B).

The criteria for the teacher questionnaire was focused on the teacher’s perspective of the effectiveness of the professional development programming. It was important to
learn if and how they had integrated the knowledge gained from the professional development program into their teaching back at home.

**Observations and Field Notes**

I visited each case study site to collect data during their teacher professional development programs. I was an *observer as participant*, as described by Merriam & Tisdell (2016). I observed teacher professional development programs while they were occurring during my site visits. The site visits varied from one day to two and half days depending on the logistical circumstances at each site. Those participating in the professional development programming were aware of my presence and my intentions as a researcher.

While observing the case study sites’ professional development programming, I took thorough field notes using my Field Notes Data Tool (see Appendix E). I documented evidence of innovative teacher professional development facilitation and programming practices as described in my criteria earlier in this chapter.

**Teacher Focus Group**

At one site I was not able to observe a teacher workshop in action, and instead conducted a small focus group with six teachers, a convenience sample. I provided the teachers with notepads to record their responses to my predetermined questions (see Appendix F). The questions were determined by the study criteria and were created after conducting the administrator interview in order to expand upon and dig deeper into concepts and ideas brought up during the interview.
Data Analysis Procedures

Case study research is a recursive process in which the researcher is interacting with and making sense of the information collected from multiple sources throughout the investigative process (Hancock & Algozzine, 2006). Case studies are an intensive, holistic, analytical approach to a single case (Merriam, 2009). Case study researchers follow several guidelines as they work through a case study. The first guideline involves the ongoing refinement of the fundamental research question in light of the new data gathered early in the investigation. A second guideline is to stay focused on the research question being explored as it is easy to be distracted by the abundant available information obtained from questionnaires, interviews, and artifacts. The third guideline involves collecting and interpreting only the data that is potentially meaningful to the research study. The fourth guideline is to develop a system for labeling, sorting and obtaining access to information and data acquired during the research effort. Finally, the fifth guideline is to involve the use of all available resources that can assist in the collection and synthesis of information (Hancock & Algozzine, 2006).

Case study research is very fluid and responsive to the process of data collection and the culture of the case study sites. Analysis is inductive: “Although categories and ‘variables’ initially guide the study, others are allowed and expected to emerge throughout the study” (Altheide, 1987 as cited in Merriam, 2009, p. 68). Analysis for this study began deductively by creating assumptions as described throughout Chapter Two. If an instance of the study fit the assumption and criteria, it stood; if a case did not fit the assumption or criteria, the assumption was revised (Merriam, 2009). As the researcher, I
used this context when analyzing, interpreting, and theorizing the phenomenon through descriptions, interpretations, and sometimes evaluation.

Creating Categories for Data

I coded, categorized, and organized the data sets from the four comparative case studies using my initial criteria for analysis and synthesis. Each case data was edited, redundancies were sorted out, parts were fitted together, and data was organized topically first within the case. Then cross-case analysis was completed as suggested by Merriam (2009).

Creating categories, sorting categories and data, and naming the categories was the core of the analysis. The thematic categories which emerged were responsive to the purpose of the study and included:

1. Create scientist identity in teachers,
2. Leverage master and veteran teachers in program design,
3. Build ongoing communities of practice,
4. Take care of your people,
5. Embrace the place and,
6. Find the story in the data.

The categories were exhaustive because they allowed for all the data collected to be included. Categories were mutually exclusive: a particular unit of data was only able to fit into one category. Created categories were sensitizing, which meant that the naming of the category was as sensitive and as exact as possible in order to capture the meaning of the phenomenon. Finally, the categories were conceptually congruent, which meant that
the same level of abstraction was characterized in each category of the same level as suggested by Merriam (2009).

The data collected from these case studies was analyzed and synthesized to generate a robust explanation of innovative science teacher professional development programming at biological field stations.

**Triangulation, Reliability, and Validity**

The soundness of this qualitative case study can be judged by its triangulation, reliability, and validity. Case study research uses multiple types of data by applying and combining several research methods into one study. This method is called triangulation (Hancock & Algozzine, 2006). Reliability of a case study method is increased when the researcher documents procedures in a detailed manner so that the study can be replicated by another researcher who should arrive at the same findings (Yin, 2003). Validity is based on determining whether the data and findings are accurate and credible from the standpoint of the researcher and the participant (Creswell, 2014).

**Triangulation.** This study used triangulation through multiple sources of data including observations, questionnaires, interviews, and artifacts.

**Reliability.** This study’s methodology has been documented clearly so that it could be conducted by fellow researchers and they could arrive at the same findings.

**Validity.** Validity strategies used in this study included triangulating, member checking, using rich thick descriptions, clarifying bias, presenting negative or discrepant information, spending prolonged time in the field, peer debriefing, and using an external auditor.
Institutional Review Board and Human Subjects Review

I submitted my research proposal to the Institutional Review Board (IRB) and completed the Human Subjects Review at Hamline University after my proposal was approved. I completed a Human Subjects Committee (HSC): Exempt (Short) Application. I provided the HSC with information concerning the case study sites and participants. In addition, I provided the HSC with a description of my research study including the purpose, study sites, participants, and research methods in the study. I also identified the potential risks and benefits of the study. Finally, I included a timeline for the study.

Case Study Sites Consent

The case study sites, their administrators, and the teachers who had participated in the sites’ professional development programming formally agreed to be participants in the research study. The formal consent letter contained information about the study, its potential risks and benefits, assurance of confidentiality, and assurance of voluntary participation. Case study site participants, their administrators, and teachers had the option to opt-out of the study questionnaires, interviews, focus group, and site visits. In addition, the case study sites, their administrators, and teachers could withdraw from the study at any time without penalty.

Potential Risks and Benefits

Case study site and participant anonymity and vulnerability were potential risks. Collected data could cause the case study sites to be vulnerable by exposing or uncovering something that was not working well, such as the teachers not having ideal experiences. This was averted by framing the data collected from the case study sites in a
positive light with potential negatively viewed scenarios as opportunities for growth.

Everyone in the study was kept anonymous by using pseudonyms throughout the study.

Data was only recorded on my personal computer and camera.

Potential benefits of the study were to inform the future development and facilitation of science teacher professional development programming at biological field stations across the country. The intention was to improve the quality and effectiveness of innovative science teacher professional development at biological field stations and also increase the amount of programming across the country.

Summary

I chose to use a qualitative multiple case study approach to gain insights into innovative practices for science teacher professional development programming at biological field stations. First, I selected sites to study through an email list-serve voluntary invitation. I used a questionnaire to gather data from the case study sites’ administrators and then followed through with a focused interview. Simultaneously, I asked the administrators to forward along a questionnaire to teachers who had completed their professional development program(s). In addition, I spent time reading and collecting data from the sites’ artifacts and documents, including but not limited to websites and other pertinent documents regarding their programming. Finally, I analyzed the data into categories and interpreted the data for innovative practices.

Introduction to Chapter Four

Chapter Four will share the data and results of this multi-case study research. The methodology detailed in Chapter Three was put into practice by conducting
questionnaires, interviews, and case study site visits. A narrative summary of the data is shared for each of the criteria for each field station. The detailed data is compiled in Appendices G-J at the end of this report.
CHAPTER FOUR

RESULTS

Introduction and Research Question

The purpose of this qualitative multiple case study is to look at programmatic goals, designs, strategies, and core teaching and facilitation philosophies to help inform the future development and facilitation of science teacher professional development programming at biological field stations across the country. In this chapter, the results are presented for the research study question: What are the innovative practices of existing teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators?

This chapter begins with an overall set of results for the research study and then presents results from each case study site. A narrative summary of the data is shared for each of the criteria for each field station. The detailed results are located in the Appendices G-J.

Study Results

This qualitative multiple case study took place March through May 2016 and included questionnaires, phone interviews, site visits, and, in one case, a focus group. I visited all four of my case study sites for two days. In three of the cases I observed a professional development workshop being conducted at the field station. At the fourth site, I was not able to observe a workshop; instead, I met with a focus group of teachers who had previously attended a teacher workshop at the field station. I used the criteria established earlier in the study (see Table 3 on page 64) to frame the collection of data.
The results are organized by case study site and an exhaustive explanation of each criteria for the site.

My experiences confirmed Merriam’s (2009) claim that collecting data through case study research is fluid and dependent on the individual case study site. I did conduct four administrator interviews, one for each site, and, at one site, I interviewed an additional second administrator. In three of the four case study sites I did get data from teacher questionnaires, and in the fourth I was not able to get any teacher questionnaire data. For three of the four sites between two and five teachers responded to the questionnaire. Finally, because I collected abundant data from the previously mentioned data tools, it was not necessary to collect data from artifacts and documents.

**Case Study 1: New England Field Station**

The New England field station is a private Ivy League university’s experimental forest field station with a long history in forestry and ecological research. The 3,750 acre rural field station is a Long-Term Ecological Research (LTER) site and receives funding for its teacher outreach program from the National Science Foundation (NSF) who funds the LTER program along with other grants and funding from family foundations. The field station has a part-time school outreach coordinator funded by grants, NSF, and private donations.

The teacher professional development programming is primarily based on teachers setting up schoolyard research studies. The program goal is to engage students and teachers in the process of science through authentic field science investigations, allowing them to experience first hand what it is like to be a field scientist. The field
station works to connect children to nature by getting kids outside. The field station scientists have developed simple protocols for schools similar to the more complex protocols the scientists are using to study multiple forest issues. A series of three teacher workshops are offered each year, each building from the first. Upon completing the first two workshops, teachers set up their own schoolyard research plot and begin to teach their students to collect and log data. A few schools have been collecting data for over 10 years and have data sets the students learn to analyze and interpret. Many teachers have been participating in this program for over 5 years and some for over 10 years; there is a strong retention rate.

These next sections will summarize the data collected for each set of criteria used in this study. The data was collected through an administrator questionnaire, administrator interview, teacher questionnaires, field observation during my site visit and artifacts and documents. An exhaustive record of this data is in Appendix G.

**Bringing teachers and scientists or researchers together.** Scientists are key to the entire programmatic structure of the New England field station’s teacher workshop programming. Six scientists serve in different capacities during the three annual workshops by presenting background content, demonstrating protocols, explaining how to use data, and making themselves available and accessible to teachers for dialogue and questions. Most of these scientists have a personal commitment to education because they themselves are parents. Also, those working on NSF funded research need to demonstrate creating “broader impacts” per the grant agreement. The administrator explained during the interview that the scientists are sincerely interested in the success of the program and
value the teachers’ perspective and talent while providing expertise and renewed enthusiasm to teachers. My observations during the site visit also confirmed this.

The teachers highly value the relationship formed with the scientists during the workshops. One teacher stated in the questionnaire that she appreciated learning directly from the scientists who developed the protocol for their research projects. The teachers view the scientists as experts, yet also believe they are scientists too. Although sometimes the scientists may need help breaking down a process into manageable steps and translating jargon, generally they are great at answering questions and are patient with the teachers. Another teacher explained her experience in the questionnaire:

I went from not really knowing how to form a question based on the data to asking questions and to figuring out how to use the data to ask more questions, to facilitating the question process with students, to transferring the techniques in other science applications.

**Implementing outdoor field-based programming.** Teachers go out to the forest during two of the three annual workshops to learn how to conduct protocols for their research studies. Also, large chunks of time are spent indoors to focus on certain content and work with data. This professional development would not be possible without the field component for teachers to fully grasp a clear understanding of how to set up their research studies in their own school yards. Throughout my field observations during the site visit the teachers were able to practice and troubleshoot through the protocol with their colleagues and also take photos to help them remember how to conduct the protocol back at their school.
**Implementing inquiry-based learning and instruction.** Structured inquiry is modeled through the New England field station teacher workshops. The scientists provide the study question and hypothesis for the teachers and then the teachers work to answer the question using the predetermined protocols designed by the scientists. The scientists model inquiry by communicating uncertainty. According to the administrator, scientists are generally comfortable with uncertainty, yet teachers generally are very uncomfortable with it and prefer to be right and know the answers. This helps the teachers grow their ability to problem solve and think outside of the traditional lab experiences. The teacher workshop gives teachers the tools to incorporate the process of science into their classrooms and schoolyard research sites.

**Increasing environmental literacy for teachers and students.** Science literacy is the primary focus of this teacher professional development program by offering a forest ecology training institute for teachers of grades 2-12, according to the program’s website. It has been identified by the administrator and field station that data literacy (data management, graphing, analysis, and interpretation) is where teachers need the most help. Through extensive workshops, online tools, and ongoing support, the field station has prioritized data literacy in its professional development programming. Local naturalist content is also shared throughout the workshops.

Every teacher comes to the workshop with a different level of background knowledge. The middle and high school teachers generally have a stronger capacity for science content and instruction, while the elementary teachers have a lower capacity of science content and confidence in teaching science, according to the administrator.
**Implementing STEM education.** It was made clear through the administrator interview, questionnaire, and site visit that the New England field station’s teacher professional development focuses on science, technology, math, and less on engineering. The program does not involve designing an experiment but rather following predetermined protocols. Data literacy has been identified as a primary priority by the field station staff team for teacher workshop programs, and there have been noted successes for both high school and elementary teachers. The teachers have gained confidence in using technology to manage data, graph and manipulate data, as well as analyze and interpret data.

**Increasing diversity and inclusion.** Most often the New England field station programming reaches rural teachers who live close to the site and some from the metropolitan suburbs according to anecdotal comments from the administrator questionnaire. Teachers are generally self-selected and recruited at science education conferences, through listservs and websites. Teachers who are generally comfortable in natural environments are the ones who choose to participate in this program, according to the administrator. Usually participants are in at least their third year of their teaching career; few brand new teachers participate.

**Implementing assessment and evaluation of programming.** The New England field station asks teachers to complete workshop surveys after each workshop. The site has not completed a comprehensive programmatic evaluation. Teachers are asked to complete an online survey before leaving the workshop. The program has numerous
online survey data due to over half of the participants completing a workshop survey, but does not have a cumulative summary of this data.

The spring workshop includes a program evaluation piece through the mechanism of teacher presentations. Self-selected teachers share 15 minute presentations of their work with students, success with research tools, and innovative ideas generated from the schoolyard ecology program. These presentations are a representative sample of the learnings of the teachers and impacts of the program on their students.

**Implementation structure for transference back to classroom.** The New England field station’s schoolyard ecology program structures most of its workshops to allow for teachers to both do extensive hands-on practice with the science tools as well as spend quality time sharing and celebrating the success of the teachers and their students. The program promotes and encourages the sharing the teacher-developed resources and tools across the entire teacher network through a blog and regular emails. According to the program coordinator, she works to “[encourage] the teachers by sharing their accomplishments and successes with the entire network, which keeps everyone’s aim upward and forward, and accessible to all”.

Teachers are celebrated and well supported in the schoolyard ecology program in many ways. During the spring workshop, teachers are invited to share presentations of what they have learned and how they have implemented the schoolyard ecology program with their students. The teachers also share and highlight the program through external workshops at professional conferences around the country. Teachers are encouraged to share photos, comments, lesson plans, graphs, and other notable pieces with the
coordinator to post to a blog. Teacher-developed lesson plans are shared on the program website. The schoolyard ecology program is supplementing their program with a project coach in 2016-2017 to visit new teachers’ schools to help them set up their schoolyard plots and will be available to help manage their data collection process with students for one or two visits. Teachers are also given many additional resource books to inspire their own local natural history and science curiosity and share their renewed enthusiasm with students.

**Planning and logistical strategies.** The schoolyard ecology program is a long-term program and does not offer one-time workshops for teachers. The administrator explained in the questionnaire that the program is most successful in spreading workshops out over the calendar year with one-day weekday workshops during the summer, the mid-spring, and mid-autumn. The program has not continued to offer graduate or continuing education credits as in the past because teachers are no longer seeking out the credits nor are they motivated by the credits to attend, according to the administrator questionnaire. The 5 teachers who completed the questionnaire report that they do prefer continuing education credits over graduate credits if offered. The introductory workshop is $50, and the following workshops are free for teachers and also include lunch.

**Summary of New England Field Station.** This long-term program for teachers is built upon strong relationships between the teachers and the field station scientists as well as among the entire teacher network. Priority is given to teachers getting their hands dirty while learning how to conduct protocols and work with collected data during multiple
workshops throughout the year according to the site administrator. The scientists work alongside the teachers, validating them and supporting them as they develop their own schoolyard research plots as observed during my site visit. One teacher sums it up: “Real Science; Real Scientists; Real Issues.” The detailed data can be read in Appendix G.

**Case Study 2: Upper Midwest Field Station**

The Upper Midwest field station is a land-grant state university’s off-campus site that includes an experimental forestry, aquatic studies, and agricultural research. The entire field station is over 4,000 acres in size. Part of the field station is utilized as a Long-Term Ecological Research (LTER) site and receives funding for some of its teacher outreach programming from the National Science Foundation who funds the LTER program along with other grants and partnerships. The university funds a Science Education and Outreach Coordinator at the biological field station to run and oversee the K-12 teacher outreach program.

The focus of the Upper Midwest field station’s K-12 teacher outreach program is to provide resources and professional development for local teachers by sharing the love of science through the creation and sharing of many resources and innovative programs according to the description of their programming on their website. The NSF funding is used to cover the expenses of five professional development days a year in science education for local teachers. Each professional development day includes a plenary with scientists and sessions provided by field station faculty and graduate students. Teacher outreach programming includes Research Experiences for Teachers (RETs), elementary
teacher outdoor science teaching institute, and the GK-12 teacher partnership summer institute that is coupled with a spring one-day workshop.

**Bringing teachers and scientists or researchers together.** The Upper Midwest field station provides RETs for teachers, creates data nugget lessons for teachers, and works directly with local teachers through the GK-12 teacher partnership. The GK-12 teacher partnership relies mostly on Ph.D. graduate student fellows to facilitate teacher professional development experiences and serve as a resource for teachers throughout the school year. During the GK-12 partnership program, field station faculty and scientists share their research during plenary talks.

Although scientists are not generally aware of what is happening in the science K-12 education community, according to the administrator, the Upper Midwest field station has a unique culture of scientists and Ph.D. graduate students wanting to be better science communicators. The graduate fellows serve as interpreters of the science at the field station for local science teachers. The teachers appreciate learning new content that is directly connected to the researchers’ inquiries, according to comments made by teachers during my site visit and in the teacher questionnaires. One teacher stated in the questionnaire:

> I was able to experience real research first hand, something that few teachers ever do. Some things turned out as expected, while others did not. The researches took it all in stride, something that was a valuable lesson for me as I conduct research with my students.
Another teacher noted in the questionnaire that it is important to ask a lot of questions because the researchers sometimes forget that the teachers do not always have as much background on the topic as the researchers do.

Through Research Experiences for Teachers (RET), university faculty and postdoctoral students mentor teachers through summer research projects. Projects vary from independent research projects to serving as a lab technician on a variety of projects and tasks. One teacher commented in the questionnaire that the value of the RET program is working with researchers during RET programs, allowing them to be a partner and not just a helper. Doing the real research allows teachers to take science back to their classrooms and become better teachers.

**Implementing outdoor field-based programming.** Outdoor field learning is not historically the culture of the Upper Midwest field station’s teacher professional development programming. The administrator explained in the questionnaire that she believes it is difficult to influence teachers during professional development workshops to change their practice and begin teaching their students in outdoor settings. However, many components of the teacher workshops are taught outdoors, utilizing outdoor spaces at the academic campus of the field station, the bird sanctuary, along the lake, and at the dairy. These outdoor spaces are utilized less during teacher professional development to conduct investigations, and more so, they are implemented for tours, demonstrations, and sunny comfortable learning spaces. It is important to the administrator that the field station visits show teachers the variety of spaces available for student field trips. The
administrator has found it helpful to share these areas (i.e. dairy, bird sanctuary) during professional development workshops and encourage return visits with their students.

**Implementing inquiry-based learning and instruction.** The Upper Midwest field station strives to model inquiry-based instruction during all teacher outreach programming, yet models it best during RETs and the outdoor science teaching institute, according to the administrator questionnaire. Modeling inquiry is tough during one-day workshops because they are only one hour long. Also, according to the administrator interview, teachers are uncomfortable with investigations and have to be taught how to be investigators. During RETs teachers get to be scientists, ask a question, and see it through, often by designing an experiment. During the week-long elementary teacher outdoor science teaching institute, the program walks teachers through the process of science. Even though there was only an hour available during the spring GK-12 teacher partnership workshop sessions, inquiry was modeled with the use of innovative smartphone microscopes.

**Increasing environmental literacy for teachers and students.** Middle and high school teachers have strong science literacy content background, according to the Upper Midwest field station administrator. The administrator also explained that elementary teachers who have had previous experiences with science tend to like science. Some elementary teachers do not identify as scientists as they claim that they teach elementary school so they do not have to teach science according to the administrator during our interview. Elementary teachers often lack the general natural resource knowledge simply
because they have a small interest in nature and they are not required to take many, if any, science courses during college, according to the administrator questionnaire.

Climate change and evolution are two topic areas in particular that middle and high school teachers have limited capacity to teach and they appreciate learning more about, according to the teacher questionnaire. During the teachers’ undergraduate courses and other professional development little time has ever been spent on this content area, which indicates the need for enrichments in these content areas. The field station has tailored their professional development offerings to include these content areas in addition to carbon cycling in response to teacher interest.

**Implementing STEM education.** The Upper Midwest field station has always been teaching STEM content, but was not using the STEM label. It was “in the 1990’s [when] the National Science Foundation married science, technology, engineering, and math with the acronym ‘STEM’” (Woodruff, 2013, para. 6). Now, the language used has been adapted to describe the workshops state that STEM is included during the Upper Midwest field station’s workshops. Much of the funding for science education in America currently is dependent on the inclusion of STEM according to discussions with the administrator during the site visit. Many applications of science, technology, and engineering were demonstrated during the observed teacher workshop including the use of smartphone apps for citizen science data collection, 3D printing, genetics and evolution computer simulation tools and a smartphone microscope.

**Increasing diversity and inclusion.** The Upper Midwest field station’s teacher outreach programming reaches rural teachers from the local region near the field station
according to the administrator. Instead of marketing the outreach programming, the program relies on established relationships with school districts. Teachers are self-selected veteran teachers and sometimes recruit others from their schools. The field station is concerned that many of the well established veteran teachers will be retiring in the next ten years according to the administrator interview. The administrator recognizes the need to build relationships with a new cohort of younger teachers.

**Implementing assessment and evaluation of programming.** Satisfaction surveys are completed by teacher participants as well as pre-workshop questionnaires at the Upper Midwest field station. The administrator stated in the questionnaire that it is really hard to gather data on changes in teaching practice and knowledge gained during teacher professional development workshops. Teachers are asked to complete a workshop survey before leaving each workshop. The site administrator did not indicate the completion of a comprehensive programmatic evaluation.

**Implementation structure for transference back to classroom.** The Upper Midwest Field Station has found that it is difficult, expensive, and time consuming to measure how teachers are implementing the content and skills learned through professional development back in their classrooms. Yet, programming typically includes structured time for teachers to discuss and brainstorm how to implement their new content and learnings according to the administrator questionnaire. The focus of the Upper Midwest field station is on introducing teachers to tools and resources they can use back in their classrooms and less on specific lesson plans according to my observations and discussions with staff during my site visit. Even with week-long professional
development workshops, without support throughout the year, teaching practice does not change, according to the administrator.

**Planning and logistical strategies.** The Upper Midwest field station has found that a three-day summer institute followed by spring and fall one-day weekday workshops works well for teachers according to the administrator questionnaire. The workshops are funded by the NSF LTER program and have enough funding to pay teachers to participate and cover their substitute teacher expenses in addition to offering lunch and teaching resources to take home. The institute also offers continuing education units through their university’s education department and the state department of education. Three of the four teachers who completed the teacher questionnaire prefered continuing education credits to graduate credits. The fourth teacher indicated that either graduate or continuing education credits were good and did not have a preference.

**Summary of Upper Midwest field station.** What makes the Upper Midwest field station unique is the long lasting extensive program scope and depth. The field station has been working with teachers since the 1950s in varying capacities and programming. Graduate fellows have been going into classrooms to provide science support for teachers for over 14 years. Strong relationships have been formed between teachers and graduate fellows from the field station, which is valuable to the entire program and network of teachers. The program has created a pool of teachers whom scientists can rely upon for their necessary outreach efforts when conducting NSF funded research that is required to create broader impacts. The program has been successful in retaining teachers because of its variety of ever-changing new content topics. This
longevity and the program’s reputation results in the continuation of interested teachers and reliable grant funding. The detailed data can be read in Appendix H.

**Case Study 3: Big River Field Station**

The Big River field station is small riverside classroom and research facility associated with a small private liberal-arts college. The field station infrastructure is funded by the college and the programming is funded through grants from large corporations and partnerships with local organizations and agencies. The field station director is a tenured faculty who spends a quarter of his time as the field station director and the rest of his time as teaching faculty. The field station is utilized by high school teachers during a week long summer STEM professional development workshop. Teachers visit the field station for half a day during the STEM workshop to introduce them to the place and invite them to come back with their students for field trips during the school year.

**Bringing teachers and scientists or researchers together.** The teacher professional development at the Big River field station allows teachers to interact directly with college faculty and laboratory scientists at the field station. It was apparent through the administrator and teacher questionnaires, administrator interview, site visit, and the teacher focus group that it is a priority of the program to foster strong relationships between the college science faculty and the high school teacher network. During the initial year of the multi-year professional development program, the college science faculty facilitated a bus tour with the network high school teachers to visit each of their
science classrooms and gain a stronger understanding of their setting, available resources, and a baseline understanding of what they have to work with.

The college faculty work with the high school teachers throughout the school year, offering to visit their classrooms and loaning specialized science equipment. The college faculty are accessible to the high school teachers, answering questions over the phone or in email. The college faculty-high school science teacher relationship is one of equals, according to the teacher focus group participants.

Also, the field station works with college pre-service teachers during the month of May each year. Students from the school of education are paired with a field station science undergraduate intern to work together to facilitate K-12 field trips for local students.

**Implementing outdoor field-based programming.** During teacher professional development workshops the Big River field station outdoor spaces are utilized to do water quality investigations and sample fish populations according to the site administrator. The station has a fleet of boats to get teachers out on the river doing science. The station also has a river-side riparian interpretive trail it utilizes with teachers and students. During my site visit I observed the field station’s wet lab, water quality lab, and classroom all house living creatures in fish tanks and aquariums, which effectively bring the outdoors indoors.

**Implementing inquiry-based learning and instruction.** The Big River field station models structured inquiry through its demonstrations and activities during teacher professional development workshops according to the administrator. The teachers
participate in activities and demonstrations as if they were students visiting the field station. The intention is that they will better understand what to expect when they bring their students for a field trip, according to the administrator. The field station scientists show the teachers how to take the lessons they model and scaffold them to different levels of inquiry according to a teacher participant in the focus group.

**Increasing environmental literacy for teachers and students.** The teachers who participate in the Big River field station teacher professional development have varying levels of environmental and scientific knowledge and literacy, according to the administrator questionnaire. Indirectly, the field station program addresses environmental literacy and science topics through the subject matter related to its research and outreach programs according to my site observations. Nearly all the programming for teachers is local and place-based; sampling and species identification, environmental issues, and river ecology is all focused on the local system according to the administrator. Teachers claimed during the focus group discussion that they do learn new science content that makes them more confident in their classrooms. Through my discussions with the administrator during my field site visit and the focus group it was clear that this teacher professional development program changes the way the teachers identify themselves not only as science teachers but also as scientists. They come to believe they are important in the scientific community according to their comments during the focus group.

**Implementing STEM education.** The Big River field station is utilized during a broader summer professional development STEM program for high school teachers that includes faculty from a variety of disciplines according to the program website.
Interdisciplinary and multidisciplinary subjects are of great interest to the teachers, according to those in the focus group.

**Increasing diversity and inclusion.** The Big River field station targets underserved schools and teachers. When the program began the college faculty met with school administrators and visited the schools to get buy-in and generate interest in the program. Since the program’s inception, there has been high retention rate with teachers from inner city urban schools, suburban public schools, and private parochial schools as well as with veteran teachers and new teachers, according to the administrator.

**Implementing assessment and evaluation of programming.** The Big River field station teacher professional development program has conducted an external evaluation. The site administrator shared the final report and there are a few of the findings relevant to the field station from it:

**General Results**

- Teachers reported the Biology Field Station experience gave them tools to analyze and explain the basic components of an ecosystem
- Teachers reported that visiting schools gave them a better understanding of the teaching and learning environments of the other teacher participants
- All teachers want faculty to visit their classrooms

What was most useful . . . In the teacher’s words

- I found nearly every part of this training to be useful, but I particularly appreciated the visits to the possible field trip locations (observatory, labs, and field station) as well as the individual classroom visits.
The field trip location visits allowed me to truly visualize how I might utilize these sights with my own students and curriculum, and the classroom visits were enlightening in that they allowed me to understand the resources and environments that the other group members have available for teaching.

What was most interesting . . . In the teacher’s words

- I was surprised and very glad to see how involved and interested the college professors were to the needs of the high school teachers. It shows how invested the school is and that they really want to see this work. I was very excited to see this.

- The amount of resources (faculty from the college, materials from the college, and also the willingness of the other participant teachers to share what they know.)

The site administrator stated in a personal communication that this report was insightful and helpful to future program design.

**Implementation structure for transference back to classroom.** The professional development program at the Big River field station does include structured time for teachers to work collaboratively and make plans about how to incorporate their new learning into their teaching environment back home, according to the administrator questionnaire. In the past, the program used an online reporting form tool for teachers to report how they implemented lessons in their classrooms; it was discontinued due to insufficient funding. The teachers are more likely to implement activities when the
college faculty visit their classrooms to provide support or if they borrow equipment and supplies from the college for the activities, according to the administrator. In most cases the teachers reflect on their time at the field station as an opportunity to be re-energized and renewed with excitement about teaching science according to their comments from the focus group.

**Planning and logistical strategies.** The Big River field station teacher professional development program works best during multi-day summer weekday workshops, according to the teachers and administrator. The teachers are paid a stipend as an incentive for participating. The college faculty are also compensated for their time working with the teachers both during the workshops and throughout the school year. The teachers stated that they like both the option for continuing education credits and graduate credits.

**Summary of Big River field station.** The Big River field station is much smaller than most field stations in the United States, yet builds incredibly strong relationships with local high school teachers through its proven professional development opportunities. The college faculty are sincerely interested in the success of the high school teachers and work with them throughout the year according to my site visit observations and the comments from teachers in the focus group. The college faculty intentionally created the opportunity to understand what resources and teaching spaces each individual teacher has access to and how that determines the real possibilities of what teachers can do with their students. Utilizing the Big River field station for teachers
has been effective in creating efficacious science teachers. The detailed data can be read in Appendix I.

**Case Study 4: Pacific Northwest Field Station**

The Pacific Northwest field station is operated in partnership with a large land-grant public university, the local USDA Forest Service Research Station, and the local National Forest. The field station is a Long Term Ecological Research (LTER) site and receives funding from the National Science Foundation, university, and US Forest Service along with other sources. It is a 15,800 acre field station that is used for forest ecology and watershed science research. A partnership between the university and state forestry and natural resources extension office provides teacher professional development experiences for teachers. It provides 0.7 time of one staff to coordinate teacher professional development. This case study explored a teacher-scientist partnership data literacy program. The intent of the program is for students to: become inspired and adept enough to continue the pursuit of STEM endeavors, foster citizens who are math and science literate, and develop a better understanding of contextualized curriculum implementation and outcomes according to the administrators’ introduction during my site visit.

**Bringing teachers and scientists or researchers together.** Opportunities for teachers and scientists to come together and leverage each other’s experience and expertise is the primary premise of the Pacific Northwest field station’s teacher professional development programming according to the administrator questionnaire and interview, and site website. The field station hosts RET teachers as well as
teacher-scientist partnership programs. The scientists were invited to join the teachers in planning and designing the data literacy teacher summer institute during the May planning retreat. The scientists shared their research projects and the teachers shared their need for relevant data and support in teaching data literacy. During my site visit observations both the teachers and scientists were very engaged and excited to work together, bringing a voice to science research and data literacy for teachers.

Implementing outdoor field-based programming. Outdoor field sites are utilized during teacher professional development experiences. The scientists share their research plots and field sites with the teachers regularly, according to the administrator. During the May planning retreat one of the program coordinators shared the importance of modeling teaching “in context with context,” meaning that it is important to teach relevant authentic content in the place from which that content is generated (e.g. forest), when possible. During our phone interview, the administrator stated her strong intention to get teachers outside almost immediately upon their arrival at workshops.

Implementing inquiry-based learning and instruction. Much of the focus on inquiry is aimed at instructor-centered investigations instead of participant-centered ones, according to the administrator questionnaire. The administrator begins programs by facilitating and modeling curiosity and wonder-inspired introductory hook activities which teachers can then use back in their classrooms according to the site administrator. She explained that the professional development workshops are limited by time, just as time is limited in teachers’ classrooms, to fully explore a scientific question. The
administrator also explained that teachers have varying capacities and comfort for facilitating inquiry-driven lessons with their students.

During the summer institute planning retreat, the focus was more on data literacy (using, understanding, and analyzing data) and less on data investigations. One part of this included exploring opportunities for teachers to incorporate inquiry into mathematics education as well as science curriculum. Often opportunities for inquiry were identified within the Next Generation Science Standards (NGSS) (National Research Council, 2013) and Common Core State Standards for Mathematics (CCSSM) (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) Practices throughout the planning retreat. The Scottish Storyline Method was incorporated into the planning retreat to facilitate the process of identifying storylines within the data in order to make it meaningful to the learners.

**Increasing environmental literacy for teachers and students.** Throughout most of the teacher professional development at the Pacific Northwest field station, more focus is spent on the process of science and less on particular content, according to the administrator. It was made clear during the site visit observations that it is important to this program to share stories of the place through reflective outdoor activities, interacting with current research on the ground, and writings from the writer in residence program according to the teachers and site administrators.

Climate change and data literacy are two content areas the field station has recognized as areas for growth among local teachers. In fact, the field station received a grant of $135,000 to conduct a data literacy summer teacher institute as a means to help
teachers become more comfortable with data analysis, management, and understanding. This includes teaching them to use and become comfortable with data tools such as google sheets and Excel. The areas of data literacy and understanding climate change are also front and center in the field station’s teacher professional development. One scientist noted during the site visit that “veteran teachers were not trained in climate science as it was not taught when they were in school; so in-service programs are essential.”

**Implementing STEM education.** The Pacific Northwest field station’s teacher professional development coordinator is housed in the university's STEM research center. The teacher professional development programming addresses interdisciplinary topics such as climate change whenever possible. It also makes connections between math and science by working with long-term ecological data sets. It recruits science-math teacher teams to attend workshops together in order to foster and encourage interdisciplinary implementation back at their schools.

The current data literacy program includes science concepts and understanding, mathematics practices, and the use of technology to access and manipulate data. During the planning retreat that I observed during my site visit the NGSS and CCSSM were identified to be critical in the program planning as well. The NGSS and CCSSM were thoroughly explored during the planning retreat to ensure that the scientists and teachers were appropriately introduced and on the same page with the language of academic standards. It is a goal of the data literacy program to create math and science literate citizens, according to the stated goals and outcomes of the program overview.
**Increasing diversity and inclusion.** The Pacific Northwest field station is in a rural region and primarily works with the local rural, caucasian, teachers of low socioeconomic status and sometimes recruits teachers from a much broader geographical reach which then includes much more diversity. Specifically, the program recruits teachers who work in Title I and “high-need” schools and school districts by giving them priority in the application process according to the program introduction during the planning retreat I observed during my site visit. No effort is made to recruit diverse populations of teachers except if the teacher's content area is considered, the types of schools where they work, and how many years they have been teaching, according to the administrator.

**Implementing assessment and evaluation of programming.** The Pacific Northwest field station has found that the best way to get evaluation data is when teachers are taking the workshop for credit; otherwise it is difficult to collect implementation and evaluation data from teachers according to the administrator. The program conducts surveys after workshops, uses logic models to identify clear intended outcomes, and implements other strong evaluation plans that are then useful in applying for grants and other funding sources.

**Implementation structure for transference back to classroom.** The professional development programming always includes time at the end of each workshop for planning in small groups or individually using a provided guide to structure thinking and planning. When teachers opt for graduate credits, their assignment is to
implement their new knowledge and then report how it went and how they might improve or refine their practice.

During my field observation of the data literacy planning retreat, the intent was to develop ways for teachers to experience the data to then create a lens or framework through which teachers can teach. The program facilitators believe that just handing teachers a new curriculum does not automatically translate to implementation with students. New curriculum is created by and through this program; however, it is not the only approach to getting teachers to implement new ideas and practices in their classrooms.

**Planning and logistical strategies.** The Pacific Northwest field station has found that teacher workshops work best in October and early April in addition to summer months on weekdays according to the administrator questionnaire. The free workshops are always multi-day experiences from two days to four weeks. The data literacy workshop was funded by a significant United States Department of Education grant.

During the data literacy planning retreat I observed many logistical components that led to its success. A very clear agenda with articulated project outcomes was emailed to all participants in advance. Upon arriving at the planning retreat, group norms were established to encourage strong participation and an equal playing field for teachers and scientists alike. The master teachers and scientists were asked in advance to prepare a five minute introductory presentation to share as a means to build a common understanding of the perspectives and experiences each brought to the retreat. The master teachers received compensation or a stipend for their time planning and facilitating the
four day summer teacher institute. Along with the teachers, the master teachers also receive six graduate credits for their participation in the program. The teachers prefer graduate credits to continuing education credits because the graduate credits allow them to climb the pay scale in their school districts as it was explained to me by a teacher during my site visit. Finally, a strong intention was made by the planning retreat facilitators to avoid too much “sit and get” style of information dumping on the teachers and scientists and, instead, to facilitate many partner and small group discussions and engaging interactive activities.

**Summary of Pacific Northwest field station.** A number of things make the Pacific Northwest field station teacher professional development programming innovative. The program incorporates facilitators and coordinators from both the university’s school of education math and science departments as well as the school of natural resources, university extension, and STEM research center, which together creates a strong team to conduct teacher professional development workshops. The strong teacher-scientist partnership program is dynamic and fosters an opportunity for the teachers to be scientists and the scientists to feel that their work matters and is important to others. Master teachers are invited along with scientists to design and plan teacher professional development experiences, which fosters programming that is relevant to teachers. The focus on data literacy is cutting edge with science and math teachers and is much needed to meet NGSS and CCSS Mathematical Practices. Finally, introducing teachers to the lens and framework of teaching through the contextualization continuum spectrum is also notable. The professional development encourages teachers to teach
“with context in context” within their capacity. The complete detailed data can be read in Appendix J.

**Summary**

In each of the four case study sites there was varying evidence of my nine criteria for innovative teacher professional development programming at biological field stations. This chapter presented summaries of the data collected at the New England field station, Upper Midwest field station, Big River field station, and Pacific Northwest field station.

**Considering the Criteria**

The nine criteria identified for this study were critical to the development of the study and created common ground upon which to collect data from each of the field stations. It was evident throughout this study that these criteria are important to science teacher professional development in the broad context. Throughout the course of completing this study, using the nine criteria as a starting point of investigation began to unearth six new additional criteria or themes that I further explore in Chapter Five. The six new themes are tangible and applicable in ways that complement the previous nine and if implemented, can create effective science teacher professional development according to my major findings in Chapter Five.

**Introduction to Chapter Five**

Chapter Five presents a discussion of my interpretations and conclusions of this research study. I draw conclusions and interpretations from the major themes discovered and synthesized from my questionnaires, interviews, focus group, and field observations conducted during site visits. I discuss major findings in terms of themes that emerged,
then identify and explain the implications and limitations of the research as well as potential future research recommendations. The chapter concludes with my personal plan for future use of this research study and how I plan to implement and bring it to life within my professional sphere.
CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Introduction and Research Question

This capstone research study was motivated by my desire to find ways to soften the relationship gap between scientists and educators, creating avenues for cross communication and access for both professional communities to each other. I set out to investigate this idea with the question: *What are the innovative practices of existing teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators?* The overall purpose of this qualitative multiple case study was to look at programmatic goals, designs, strategies, and core teaching and facilitation philosophies to help inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

In Chapter Four, I presented the results of my research and the supporting qualitative data gathered through my case study research. In Chapter Five, I draw conclusions and interpretations from the major themes discovered through my questionnaires, interviews, focus group, and field observations conducted during site visits. The first section will discuss major findings in terms of themes that emerged. The second section identifies and explains the implications and limitations of the research as well as potential future research recommendations. The chapter concludes with my personal plan for future use of this research study and how I will utilize the study findings in my professional career.
Major Findings

Throughout this case study research process, themes began emerging, some of which complemented my study criteria and some of which were new ideas not previously encountered in the literature review. The themes were synthesized from the data collected through observations, questionnaires, and interviews based on the nine criteria. These new ideas were more subtle at times; however, I found them critical to effective teacher professional development in the context of this study. I will argue that these themes may be more important and innovative than my original criteria. Here I will explore deeper into these six themes.

Create scientist identity in teachers

Throughout the multi-case study and as identified in the literature (Moreno et al., 2001; Musante, 2006), science teachers do not always identify themselves as scientists or know how to embrace and feel confident teaching the scientific process, let alone teach it through methods of inquiry. The professional development programs that find ways, subtle and not so subtle, to value and affirm teachers in their identity as scientists and give them tools and allow them to practice the process of science offer teachers a stronger identity as scientists and as members of the scientific community. Part of this strategy includes giving teachers permission to conduct investigations and experiments that may fail and allowing them to not know the pre-determined outcome of every investigation or experiment. From my research, this is best done by allowing teachers to practice protocols (as they do at the New England field station), hear from scientists and researchers that science is messy with unknown outcomes (as occurs at each of the case
study sites), and providing enough time for teachers to fully explore scientific questions and investigations during professional development workshops (which is difficult to implement at each field station due to scheduling and time constraints).

**Leverage master and veteran teachers in program design**

Experienced master and veteran teachers have tremendous insight and understanding of school culture and teachers’ needs. They feel valued by being part of the design and planning of professional development experiences. Creating a structure to leverage the expertise of teachers leads to strong buy-in, advocates for the program, and also gives other teachers a relational entry point among the field station experts (scientists, researchers, program coordinators) to the professional development program.

This was demonstrated by the Pacific Northwest field station during their planning retreat. Experienced master teachers sometimes serve as mentors to other teachers who are in the early stages of adopting new curricula or trying on new teaching practices learned during professional development experiences. The Pacific Northwest field station also actively incorporates teachers and scientists into the planning, and it seemed to me to have an incredible impact on the overall program.

The New England field station leverages its veteran teachers to share their best practices and learnings through presentations during the spring workshop as well as sharing through e-newsletters and website and blog posts.

At the Upper Midwest field station, experienced teachers not only are advocates for the field station professional development, but also contribute to the education of the graduate fellows who are learning to be more effective science communicators.
**Build and foster ongoing communities of practice**

In order to influence teachers’ practice of teaching science, continual support from the field station professional development coordinators as well as the scientists and researchers is necessary. Building collegial communities of practice among mixed groups of master teachers, less experienced teachers, scientists and researchers, and the professional development coordinators can serve as a powerful mechanism to supporting teachers in trying on new teaching practices and improving their science teaching skills. These networks can be any size, yet in my observations, I noticed that networks of 20-30 teachers seemed to work well; groups of more than approximately 30 teachers do not easily foster the close relationships necessary to build strong long-term communities of practice. I noticed that it is the shared journey of the teachers learning together with the scientists and researchers, and not so much the final piece of curriculum that may be created through the process, that is most impactful and offers the most learning for the teachers and scientists alike. Each of the case study site administrators acknowledged the need for sustained support in order for their teachers to have higher chances of implementation and changes in their teaching practice. My research affirms the work of Moreno et al., (2001): In the case of teaching science, as with any situation, strong relationships build strong communities and safe, transformative spaces.

**Take care of your people**

In addition to creating strong relationships, the most successful professional development programming at field stations takes into account the importance of thoughtful care of and the feasibility and ease of participation of everyone involved:
teachers, university faculty and staff, scientists, and researchers. Teacher professional
development is an extra requirement or responsibility for those involved in most cases. At
each of the case study sites, program coordinators offer one or more of these incentives: a
stipend or some form of compensation to the teachers who participate, offer to pay for
substitute teachers at the teachers’ schools, set up necessary travel details for the
scientists and researchers, offer compensation to the scientists and research partners, feed
everyone lunch, and make it as easy for people to participate as possible. This is a priority
Big River field station where the college faculty involved are given a stipend on top of
their salary to participate in teacher outreach. The teachers were also compensated for
their participation in the professional development. It was clear that offering compelling,
well-organized, and well-executed professional development is key to attracting teachers
to participate and to foster a high retention rate. Incentivizing teachers does not always
necessarily imply a high level of engagement, yet it does create a stronger likelihood that
they will attend. The New England field station did not compensate its teachers for the
day, yet the teacher buy-in and engagement was high according to my site visit
observations. Yet, at the Upper Midwest field station substitute teacher costs were
covered by the field station, lunch was provided, and multiple teachers were much less
engaged in the professional development workshop according to my observations during
the site visit.

**Embrace the place**

The professional development programs at each field station focused on that field
station’s place, stories, data, and giving teachers direct experiences with the place,
creating compelling, meaningful, and memorable opportunities for teachers. It is these experiences that reinvigorate and rekindle the flame of passion for teaching. I was introduced to the concept of teaching with context in context, or contextualization (Giamellaro, 2014) during my field observation of the Pacific Northwest field station and would like to do further research into this topic. It is important to use the physical place and its stories to teach science as opposed to doing activities that could just as easily be done indoors. During my observations of one case study site, one teacher advocated for more place-based learning to be included in the upcoming workshops. She wanted to ensure that more teachers have a chance to learn the stories of the place and form a personal relationship with the forest field station. This affirms the work of Dresner and Moldenke (2002) who stated that teachers need to conduct meaningful science projects themselves in order to become capable of providing a similar quality experience for their students.

All four field stations I observed have a strong commitment to getting teachers out into the field interacting with the place, its current research, and engaging in the stories of the place. The Upper Midwest field station administrator stated she is becoming more intentional about having place-based field trips and sessions that highlight what is unique about their site and region of the state. One teacher there commented that the professional development site had exemplary settings for teaching; so much so that she wants to replicate some of these settings for students at their schools. It gave the teacher context for getting started to improve the school’s outdoor learning environment. This confirms my claim that teachers need to be shown how to embrace their places and teach
Find the stories in the data

Three of the four field station case study sites effectively brought their current science research to life and made it accessible to teachers through multiple mediums. Each field station was administered by a college or university and utilized the expertise of faculty, graduate fellows, researchers, and scientists from their institutions. This created opportunities to get hard science data out of the journals, put it into context, and made accessible to teachers to then carry forward into their classrooms. Three of the field stations strongly recognize the need to increase data literacy among teachers and students, which is also exemplified by the language of the Next Generation Science Standards (National Research Council, 2013). The NGSS state within each grade level a performance expectation for students to demonstrate grade-appropriate proficiency in analyzing and interpreting data. These three field stations have created multi-year teacher professional development programs to address data literacy by using hard data from their scientists, making the data come to life through analysis, and understanding the story of the data.

However, the primary emphasis of the field stations was to help teachers analyze and understand hard scientific data relevant to their sites so they can then do the same with their students. The professional development programs focus less on science leading to action and the “so what?” question at the end of a lesson or activity, which is a key component of environmental education (The Global Development Research Center, 2016). None of the four field stations put much emphasis on creating the opportunity to
model for teachers how to first understand the stories in the scientific data and then relate it to the lives of learners. The *Excellence in Environmental Education Guidelines for Learning (K-12)* (North American Association for Environmental Education, 2010) included first the need to question, analyze, and interpret information, second the goal to gain knowledge of environmental process and systems, third, the necessity for students to gain skills for understanding and addressing environmental issues and finally the need for students to understand that they can take actions that can make a difference individually and collectively in groups to address the issues. The last two components were not actively demonstrated by the case study sites.

**Revisiting the Literature**

Much of my research confirms the very good work of many who have done research on this topic as described in my Literature Review. Dresner and Worley (2006) claimed that the three most influential, longest lasting, and impactful pieces of the program they researched have been: partnerships with scientists, teacher networks, and the strong emphasis on direct experience. This is reflected in my major findings as well with fostering strong relationships, sustaining communities of practice, and embracing the place.

Two of the field station administrators emphasized the importance of a teacher’s long term commitment to improving upon their teaching practice as a means to improve learning outcomes of their students. This is echoed by Dresner and Worley’s (2006) research which included a section regarding creating significant change in teaching practice through professional development experiences as a long term process occurring
over a teacher’s career. This supports my findings while gathering data from my case study sites.

The work of Martin (2001) also reaffirmed much of my research with his career in environmental education in Oregon. He claimed that after 30 years of experience he has learned:

- The vast majority of teachers want to be comfortable with what they teach. They feel strongly about knowing what they are presenting to their students, and need a lot of experience before they’ll be willing to say to them, “I don’t know. How can we find out?”

- Most teacher training for developing experiences and curricula outside the classroom does not supply adequate practice and support. These trainings, institutes and workshops rarely teach for understanding and mastery, and practically never provide on-going support while teachers are learning to use the content of their training.

- Practically all teachers could actively engage the world outside the classroom and deliver an effective education to their students. I am certain of this. They have the capacity, but need effective training and support.

- Teachers who persist in their efforts to try [community/environment based learning] with their students take about five years to become confident and effective. (Martin, 2001, p. 2)

My research study complements and adds to the broad collection of research qualifying the importance of science teacher professional development that narrows the
gap between scientists and teachers through innovative methods of building relationships, fostering a sense of scientist identity in teachers, connecting to places through stories, and ultimately creating more effective teachers.

**Implications of Research**

This research study has the capacity to be influential to any institution or organization that currently conducts science teacher professional development or is planning to do so in the future. The findings are not limited to biological field stations or marine laboratories. Many of the major findings could quite easily be applied to any organization or institution that is working to develop or improve its teacher professional development programming capacity.

It was clear from my research that it takes significant financial investment from an institution to prioritize, facilitate, and sustain high quality teacher professional development programs. Each of the case study sites were funded by large stable grants from international corporations or federal programs such as the National Science Foundation. A lack of significant stable funding decreases the capacity to create, develop, and sustain strong long-lasting programming.

The major findings of this research could be included in a framework for designing and developing science teacher professional development. There are numerous education leadership associations and organizations that publish best practices and guidance standards of excellence; my major findings could be incorporated into their standards. Some examples include the North American Association for Environmental Education’s *Guidelines for the Preparation and Professional Development of*
Environmental Educators (2005), the Organization for Biological Field Stations’ publications, and documents such as Lohr’s (2001) *An Operations Manual for Field Stations and Marine Laboratories.*

**Limitations of Study**

Upon completion of this research study, I discovered three potential limitations that may have influenced the outcomes. These include: rethinking the case study criteria, considering varying definitions of concepts, and designing of my data collection tools.

**Rethink Case Study Criteria**

Upon completing the Chapter Two Literature Review, I designed my case study research plan using nine criteria for innovative teacher professional development programming at biological field stations. Once I began to conduct my research and collect data, I quickly realized that I had too many criteria, and some of the criteria did not fit my research study; instead they expanded the scope too wide limiting my ability to focus. Specifically, the following criteria were appropriate for the study because all of them were researched, referenced, and included in some fashion in my literature review:

- programming focused on bringing teachers and scientists or researchers together,
- programming was outdoor field-based,
- programming focused on inquiry-based learning and instruction,
- programming worked toward increasing environmental literacy for both the teachers and their respective students and,
• programming included a programmatic structure for implementation and
  transference back into the K-12 classroom or field experience.

My other four criteria points were added to the research study design due to my
professional experience in environmental education and not from my literature review.

These less critical criteria included:
• programming focused on STEM education,
• programming included a strategy for increasing diversity/inclusion as a
  means to attracting minorities to the science and natural resources field,
• programming included data-driven assessment and evaluation of efficacy
  of teacher/scientist partner programs and,
• programming planning and logistical strategies.

These criteria are important in the professional environmental education field, but most
were not as critical to this research study. The criteria regarding programming planning
and logistical strategies are probably the most useful to professional development
 coordinators in planning or restructuring how and when they conduct experiences for
science teachers.

**Reconsider Concepts and Definitions**

The lack of clarity in definitions may have affected the outcomes of the
administrator and teacher questionnaires and interviews. As in most professions, a fair
amount of jargon is used, some of which the field agrees upon and some for which there
are many varying definitions. This is also true in the environmental education and science
education fields. Two examples of this included the use of the word *inquiry* as well as
environmental education or literacy versus science education or science literacy. Inquiry is a word that means different things to many people. Alberts (2000), the President of the National Academy of Science stated: “Teaching science through inquiry allows students to conceptualize a question and then seek possible explanations that respond to that question” (as cited in National Research Council, Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry and Center for Science, Mathematics, and Engineering Education, p. xii). However, I also learned that there is a inquiry spectrum or continuum with four distinct levels, including: confirmation, structured, guided, and open inquiry. I did not make these distinctions in my literature review or data collection tools. There are also varying definitions, distinctions, and interpretations of environmental education, science education, science literacy, and environmental literacy. Clearer definitions may have been helpful to the administrators and teachers.

Redesign Data Collection Tools

In my preparations for conducting case study research, I created multiple data collection tools: two questionnaires, interview questions, an artifact and document data collection form, and a field observation form. After realizing my criteria was too broad, I also realized that my administrator Questionnaire was too long, causing administrators to take an hour or more to complete it. Also a few of the questions were not directly pertinent to the established study criteria, and the data was not used in the results of the study. Also, due to the robustness of the data gathered in this multi-case study, it was not necessary to collect data from artifacts and documents.
Future Research Recommendations

Future research recommendations include investigating further into modeling inquiry and teaching teachers to teach through the inquiry continuum as well as looking into field stations that conduct environmental education more so, or in addition to science education.

It would be interesting to look closer at the four stages of inquiry and how these are implemented and modeled during science teacher professional development programming with scientists. The Materials World Modules, an Inquiry and Design-Based Science, Technology, Engineering, and Mathematics (STEM) Education Program (2016), described the inquiry continuum with the figure below.

![Inquiry Continuum Diagram](http://www.materialsworldmodules.org/index.php/modules-and-user-support/mwm-pedagogy/inquiry-design)

Investigating field stations that incorporate more environmental education strategies could be of interest. The relevancy “so what?” action piece was not prevalent in the programming at my four case study sites. The 1978 Belgrade Charter established
three goals of environmental education including “To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment” (North American Association for Environmental Education, 2004, p. 2). Incorporating the three “so what?” questions (So what is happening? So what does this mean to me? So what can I do?) generates awareness, stimulates reflection, and leads to action (The Global Development Research Center, 2016). The field stations did provide opportunities for gaining scientific knowledge, but did not actively address opportunities for values, attitudes, nor skills to take action to protect and improve the environment.

**Plan for Utilizing and Sharing Findings**

This research study fit perfectly into my current professional path. In addition to exploring the potential field station concept for a private landowner, I am currently designing and growing the Water Educator Network at the Colorado Foundation for Water Education with the development of educator workshops, relevant resources, and trainings. If the field station concept becomes a reality in the coming years, the results of this study will influence the creation of teacher outreach programming at the site. I also serve on the board of directors for the Colorado Alliance for Environmental Education where I volunteer in multiple capacities to support the broad reach and collective impacts of environmental educators across the state through professional development, workshops, and networking opportunities. This research study will inform and support all of these projects.

I plan to share my findings with my broader professional community through
conferences and publication. I have been asked to share the results of my research at two upcoming professional conferences, the Organization of Biological Field Station’s Annual Meeting and the Colorado Alliance for Environmental Education’s West Slope Conference. I have submitted a proposal to present at the North American Association for Environmental Education Annual Conference as well. I am also considering submitting an article to *BioScience* and *Clearing Magazine*.

More importantly, this journey of completing this capstone study has opened my horizons to some incredible teacher professional development programs facilitated by amazing program coordinators, scientists, researchers, and staff. Having the opportunity to visit each of the four case study sites provided a great opportunity to see workshops in action, watch how teachers embraced the programming, experience different styles of presenting workshops, and create new relationships with professional colleagues across the country. I have gained a much wider perspective than I had before of how teacher professional development programming can be developed, structured, and executed. This experience will influence my teaching practice and professional career well into the future.

**Relevancy to Hamline’s School of Education Conceptual Framework**

This capstone study fit well in Hamline’s School of Education Conceptual Framework. The most obvious connection is through the framework of building communities of teachers and learners. My initial underlying goal was to research ways to bridge the large gap between teachers and scientists. Through my research process it became clear that creating strong communities of practice including teachers and
scientists is key to bridging this gap.

My study also addresses the concept of constructing knowledge, as much of my work was focused on increasing science and environmental literacy among teachers as well as implementing this new knowledge back into their classrooms through their teaching practice. Attention was also given to the importance of inquiry and finding ways to help teachers improve their practice of teaching science.

**Chapter Summary**

Multiple themes emerged from this multi-case study that are helpful in the planning and development of science teacher professional development intended to bridge the gap between scientists and teachers: create scientist identity in teachers, leverage master and veteran teachers in program design, build ongoing communities of practice, take care of your people, embrace the place, and find the stories in the data. I set out to answer the question: *What are the innovative practices of existing teacher professional development programming at biological field stations and how do they inform future programmatic development and learning outcomes for educators?* I learned that there are many components of innovative programs worthy of exploring, trying on, and implementing. My research study quickly grew into a much larger study than initially intended when I was given the opportunity to visit and observe each case study site. I would reconsider the criteria and data collection mechanisms if I were to conduct the study again. This research study is very relevant to my current professional activity and the results are already influencing my educator professional development program design strategies.
The core take-away from this research study is that trusting, safe relationships must be fostered between teachers and scientists to establish common ground and break down any barriers. Then, once teachers realize that they too are scientists capable of conducting investigations, they can more comfortably embrace a place such as a field station and begin to explore the stories captured in the researcher's data. These experiences rekindle their passion and love for teaching science and reinvigorates them to share all their new learning and teaching practices with their students, ultimately increasing science and environmental literacy among themselves and their students.
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Appendix A. Case Study Site Questionnaire - Science Teacher Professional Development at Biological Field Station

Case Study Site Questionnaire - Science Teacher Professional Development at Biological Field Stations

Consent for Participation in Research Study

CASE STUDIES OF SCIENCE TEACHER PROFESSIONAL DEVELOPMENT PROGRAMMING AT BIOLOGICAL FIELD STATIONS

Informed Consent:
Thank you for participating in this questionnaire, follow up interview, and possible site visit. Your answers are important. Please answer the following questions as honestly and detailed as possible.

I am a graduate student working on a MAEd: Natural Science and Environmental Education degree at Hamline University in St. Paul, Minnesota. The intention of my research is to study innovative teacher professional development programming at biological field stations with the following question: What are the goals, designs, strategies, and core teaching and facilitation philosophies of teacher professional development programming at biological field stations? The intent of this qualitative multiple case study research is to inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

Upon completing this questionnaire, I plan to follow up with you for a video conference interviews that will last an 1-2 hours. These interviews will be recorded. The interview questions will be provided ahead of time. In addition, I plan to do a site visit and observe your site's teacher professional development programming in April 2016. Finally, I will also analyze documents such as your program's website, curriculum files, professional development program evaluation data. After completing the capstone, I will summarize the findings in a report to be distributed to questionnaire and interview participants and to their respective organizations.

I do not anticipate that taking participating in this questionnaire, follow up interview, and possible site visit will contain any risk or inconvenience to you. Furthermore, your participation is strictly voluntary and you may withdraw your participation at any time without penalty.

All information collected will be used only for my research and will be kept anonymous. Everyone in the study is being kept anonymous by using pseudonyms throughout the study. There will be no connection to you specifically in the results or in future publication of the results. Once the study is completed, I would be happy to share the results with you if you desire.

This research is public scholarship the abstract and final product will be cataloged in Hamline's Bush Library Digital Commons, a searchable electronic repository and that it may be published or used in other ways.

Contact Information:
Sarah R. Johnson, Hamline University MAEd: Natural Science and Environmental Education student sjohnson120@hamline.edu, 970-510-8897.

You may also contact my advisor: Trisha Harvey tharvey03@hamline.edu Assistant Professor, Advanced Learning Technologies, Hamline University 650 Drew Residence Hall MS-A1790
The Hamline University Institutional Review Board may be contacted via Matthew Olsen, chair mholson@hamline.edu.

By clicking NEXT you are verifying that you have read the explanation of the study, and that you agree to participate or are giving agreement for a minor that you are parent/guardian for to participate. You also understand that all participation in this study is strictly voluntary.
* Required

1. Field Station Name *

2. Your Name *

3. Your Title

4. Your Email *

5. Best phone number

Bringing Teachers and Scientists/Researchers Together

6. Does your site host long-term research studies? *
   Mark only one oval.
   - [ ] Yes, we host long-term research studies.
   - [ ] No, we do not host any long-term research studies.
   - [ ] Other: ________________________________

7. If you host long term research studies at your site, describe how you incorporate them into your teacher professional development programming? *

   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________
8. Describe any significant insights, learnings, successes, or failures with incorporating long-term research studies into teacher professional development programming.

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9. Are any of your long-term research studies citizen science research? *
   i.e. Project BudBurst, iNaturalist, Picture Post, Frog Watch, CoCoRaHS, eBird, Stream Team, etc.
   Mark only one oval.
   ☐ Yes, our long-term research studies are include citizen scientists
   ☐ No, our long-term research studies do not include citizen scientists
   ☐ Other: ________________________________________________________________

10. If you do have citizen science research projects at your site, describe how you incorporate your citizen science research studies into your teacher professional development programming? *

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11. Describe any significant insights, learnings, successes, or failures with incorporating citizen science research projects into your teacher professional development programming. *

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12. Do you have scientists and researchers on site? *
   Mark only one oval.
   ☐ Yes, we have scientists and researchers on site
   ☐ No, we do not have scientists or researchers on site
   ☐ Other: ________________________________________________________________
13. Describe how you incorporate teachers working/learning alongside scientists and researchers at your site. *

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________________________________________________________________________

________________________________________________________________________

14. Describe any significant insights, learnings, successes, or failures with incorporating scientists and researchers into your teacher professional development programming. *

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Outdoor Field Based

15. Describe how you use outdoor field spaces/sites to facilitate teacher professional development programming.

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16. Does your teacher professional development program require outdoor field sites in order to facilitate the program? *

Mark only one oval.

☐ Yes, our teacher professional development programming requires outdoor field sites to facilitate the program.

☐ No, our teacher professional development programming does not require outdoor field sites to facilitate the program.

☐ Other: ________________________________
17. Describe if and how you can just as easily facilitate your teacher professional development programming indoors? 

______________________________________________________________________

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18. Describe any significant learnings, insights, successes, or failures while teaching teacher professional development programming out at field sites/spaces.

______________________________________________________________________

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Inquiry-Based Learning and Instruction

19. Do you model inquiry-based instruction through your teacher professional development programming?
   Mark only one oval.
   ○ Yes, we model inquiry-based instruction through our teacher professional development programming
   ○ No, we do not model inquiry-based instruction through our teacher professional development programming
   ○ Other: ____________________________________________________________

20. If you do, describe how you model inquiry-based instruction through our teacher professional development programming.

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21. Describe any significant learnings, insights, successes, or failures while modeling how to use inquiry-focused instruction during your teacher professional development programming.

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Environmental Literacy

22. What environmental literacy and science topics have you recognized that teachers could use more training in?

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___________________________________________

23. How does your professional development programming work to address these environmental literacy and science topic needs?

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___________________________________________

24. Are you designing teacher professional development programming to meet the recommendations of an environmental literacy plan from your state, region, or country? If so, please explain. *
25. Do you use the North American Association for Environmental Education’s Standards of Excellence Guidelines when designing your teacher professional development programming? If, so please explain.

26. To what other standards or plans are you correlating your programming?

27. In your experience, how important has it become that your teacher professional development programming incorporates local place-based naturalist content?

   Mark only one oval.

   1 2 3 4 5 6 7 8 9 10

   Not very important that local place-based naturalist content is incorporated

   Very important that local place-based naturalist content is incorporated

28. Describe how your professional development programming incorporates local place-based naturalist content.

   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________
   __________________________________________

STEM (Science, Technology, Engineering & Math)
29. In your experience, how important has it become that your teacher professional development programming incorporates STEM topics? *  
Mark only one oval.

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30. Describe how your teacher professional development programming incorporates STEM topics.

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31. Describe any significant learnings, insights, successes, or failures you have had regarding STEM for your teacher professional development programming.

______________________________________________________________________________

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**Diversity and Inclusion**

There have been significant initiatives in environmental education recognizing the value of diversity and inclusiveness to advance environmental education by working to ensure that everyone has the opportunity to learn about the environment and experience quality environmental education.

32. Describe the population of teachers who live within the geographic region of your field station. *  
Nationality, race, languages spoken at school, urban, rural, suburban, etc.

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________
33. Describe the population of teachers who your professional development programming has reached in the recent past. *
   Nationality, race, languages spoken at school, urban, rural, suburban, etc. Provide any available data statistics here or by emailing them to sokinson120@hamline.edu upon completing this questionnaire.

34. Describe any methods you use to market and attract diverse populations of teachers to attend your professional development opportunities.

35. Describe any significant learnings, insights, successes, or failures you have had regarding diversity and inclusion for your teacher professional development programming.

Programmatic Evaluation

36. Do you currently implement any form of evaluation for your teacher professional development programming? *
   Logic models, focus groups, pre/post surveys, etc...
   Mark only one oval.
   ☐ Yes, we implement evaluation practices into our teacher professional development programming
   ☐ No, we do not implement evaluation practices into our teacher professional development programming
   ☐ Other: __________________________________________
37. Do you have program evaluation analysis you can share with the researcher? 
   Please email any any analysis or reports to sjojohnson1720@bu.edu.
   Mark only one oval.
   ☐ Yes, we have program evaluation data analysis to share.
   ☐ No, we do not have any program evaluation data analysis to share.
   ☐ Other: ____________________________________________

38. Describe any significant learnings, insights, successes, or failures you have had regarding incorporating evaluation techniques into your teacher professional development programming.

   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

Transference and Implementation

39. Do you structure your professional development programming to include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home? 
   Mark only one oval.
   ☐ Yes, we do include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home.
   ☐ No, we do not include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home.
   ☐ Other: ____________________________________________

40. Describe how you structure your professional development programming to include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home?

   ____________________________________________________
   ____________________________________________________
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   ____________________________________________________
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   ____________________________________________________
41. Do you have any accountability mechanisms in place to ensure teachers are implementing their new knowledge and learnings into their teaching environments? If so please explain how these mechanisms work.

42. Describe any significant learnings, insights, successes, or failures you have had regarding incorporating opportunities into your programming for teachers to transfer and incorporate their learnings back into their teaching environments.

Planning and Logistics of Teacher Professional Development Programming

43. What time of year have you found works best for scheduling teacher professional development? Season, month, etc.

44. Is your teacher professional development programming a single or multi-day event? If multi-day, how many?

45. Do weekdays or weekends work best to host teacher professional development?
Mark only one oval.

☐ Weekends
☐ Weekdays
☐ Other: ________________________________
46. Do you charge a fee for your professional development programming?

Mark only one oval.

☐ Yes, we charge a fee
☐ No, we do not charge a fee; our programs are FREE
☐ Other: ______________________________________

47. Briefly describe how you fund your teacher professional programming.

________________________________________________________
________________________________________________________
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________________________________________________________

48. Do you offer graduate credit or continuing education credits for participants? If so, briefly describe.

________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

49. Approximately how many teachers do you reach annually through professional development programming?

________________________________________________________

Final Section - Your Impression of Your Site's Programming

50. What are teachers saying about you programming?

________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________
51. What makes your programming unique and valuable to teachers?

52. Is there anything else you would like to share about your professional development program that may be helpful to the researcher? Please do so here.
Appendix B. Case Study Teacher Questionnaire - Science Teacher Professional Development at Biological Field Stations

Case Study Teacher Questionnaire - Science Teacher Professional Development at Biological Field Stations

Consent for Participation in Research Study

CASE STUDIES OF SCIENCE TEACHER PROFESSIONAL DEVELOPMENT PROGRAMMING AT BIOLOGICAL FIELD STATIONS

Informed Consent:

Thank you for participating in this questionnaire and possible follow up phone interview. Your answers are important. Please answer the following questions as honestly and detailed as possible.

I am a graduate student working on a MAEd: Natural Science and Environmental Education degree at Hamline University in St. Paul, Minnesota. The intention of my research is to study innovative teacher professional development programming at biological field stations with the following question: What are the goals, designs, strategies, and core teaching and facilitation philosophies of teacher professional development programming at biological field stations? The intent of this qualitative multiple case study research is to inform the future development and facilitation of science teacher professional development programming at biological field stations across the country.

In addition to conducting case studies of biological field station teacher professional development programming, I am gathering data from teachers who have participated in the said teacher professional development programming. I do not anticipate your participation in this questionnaire or possible follow up phone interview will contain any risk or inconvenience to you. Furthermore, your participation is strictly voluntary and you may withdraw your participation at any time without penalty.

All information collected will be used only for my research and your identity will be kept anonymous. There will be no connection to you specifically in the results or in future publication of the results. Once the study is completed, I would be happy to share the results with you if you desire.

This research is public scholarship the abstract and final product will be cataloged in Hamline’s Bush Library Digital Commons, a searchable electronic repository and that it may be published or used in other ways.

Contact Information:
Sarah R. Johnson, Hamline University MAEd: Natural Science and Environmental Education student sjohnson120@hamline.edu, 970-510-0697.
You may also contact my advisor: Trisha Harvey tharvey03@hamline.edu Assistant Professor, Advanced Learning Technologies, Hamline University 69O Drew Residence Hall MS-A1790
The Hamline University Institutional Review Board may be contacted via Matthew Olsen, chair mboesen@hamline.edu.

By clicking NEXT you are verifying that you have read the explanation of the study, and that you agree to participate or are giving agreement for a minor that you are parent/guardian for to participate. You also understand that all participation in this study is strictly voluntary.

* Required

1. Your Name *
   
   Your identity will be kept anonymous for this study. However, please include your name should the researcher need to follow up for any clarifying information.
2. Best phone number *

3. Your Email *

4. Subject and grades you teach *

5. Field Station where you participated in professional development programming. *

6. Name of professional development program(s) you attended.
   This is the program(s) you will be referencing throughout the remainder of this questionnaire.

7. When did you participate in this professional development program? *
   month and year

8. Could you be available for a follow up phone call interview in the coming month? *
   Mark only one oval.
   - Yes
   - No
   - Other: __________________________________________

Bringing Teachers and Scientists/Researchers Together
9. How important is it to you that professional development programs offer the opportunity to work alongside scientists and/or researchers?
Mark only one oval:

1  2  3  4  5  6  7  8  9  10

- Not very important that professional development programs offer the opportunity to work alongside scientists and/or researchers
- Very important that professional development programs offer the opportunity to work alongside scientists and/or researchers

10. Did you participate in a long-term research study(s) while participating in the professional development program?
Mark only one oval:

☐ Yes, I participated in a long-term research study(s) while participating in the professional development program
☐ I'm not sure if I participated in a long-term research study(s) while participating in the professional development program
☐ No, I did not participate in a long-term research study(s) while participating in the professional development program
☐ Other: __________________________________________

11. If you did, how meaningful was it to you to participate in a long-term research study(s) while participating in the professional development program?
Mark only one oval:

1  2  3  4  5  6  7  8  9  10

- Not very meaningful to participate in a long-term research study(s) while participating in the professional development program
- Very meaningful to participate in a long-term research study(s) while participating in the professional development program
12. Describe any significant insights, learnings, successes, or failures while participating in long-term research studies during the teacher professional development program.

________________________________________________________________________

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13. Did you participate in any citizen science projects while at your professional development program?  
   i.e. Project BudBurst, iNaturalist, Picture Post, Frog Watch, CoCoRahs, eBird, Stream Team, etc.  
   Mark only one oval:  
   ☐ Yes, I did participate in citizen science projects.  
   ☐ No, I did not participate in citizen science projects.  
   ☐ Other: ____________________________________________________________

14. If you did, how meaningful was it to you to participate in a citizen science project while attending your professional development program?  
   Mark only one oval.

   1  2  3  4  5  6  7  8  9  10
   Not very meaningful to participate in a citizen science project while attending in the professional development program
   ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

   Very meaningful to participate in a citizen science project while attending in the professional development program

15. Describe any significant insights, learnings, successes, or failures while participating in citizen science during your teacher professional development program.  

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
16. If you did participate in a citizen science project, how did you incorporate and transfer your learning from the project back to your students?

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

17. Did you work alongside any scientists or researchers while participating in your professional development program?
   Mark only one oval.
   
   ○ Yes, I worked alongside any scientists or researchers while participating in my professional development program
   
   ○ No, I did not work alongside any scientists or researchers while participating in your professional development program
   
   ○ Other: ____________________________________________________________

18. Describe what worked and didn’t work while working alongside scientists or researchers during your professional development program.

______________________________________________________________

______________________________________________________________

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______________________________________________________________

19. How meaningful was it to you to work alongside scientists and researchers while attending your professional development program?
   Mark only one oval.

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Not very meaningful to you to work alongside scientists and researchers while attending the professional development program

Very meaningful to you to work alongside scientists and researchers while attending the professional development program
20. Describe any significant insights, learnings, successes, or failures while working with
scientists and researchers during your teacher professional development program.


Outdoor Field Based

21. Describe how outdoor field spaces/sites were used in the facilitation of your teacher
professional development program.


22. Describe how significant or not significant it was that your professional development program
was facilitated outside in the field as opposed to in an indoor space.


23. Could the teacher professional development programming just as easily been facilitated
indoors?
Mark only one oval.
☐ Yes, it could have been facilitated in either setting: indoors or outdoors.
☐ No, the programming required being out in the field.
☐ Other: ________________________________

24. Describe any significant learnings, insights, successes, or failures while learning in the field
during your teacher professional development program.


Inquiry-Based Learning and Instruction
25. **Was inquiry-based instruction modeled throughout your teacher professional development program?**
   *Mark only one oval.*
   - [ ] Yes, inquiry-based instruction was modeled throughout your teacher professional development program
   - [ ] No, inquiry-based instruction was not modeled throughout your teacher professional development program
   - [ ] Other

26. **On a scale of 1 to 10 rate your ability and confidence to teach through inquiry BEFORE you attended the professional development program.**
   *Mark only one oval.*

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   Not very strong ability or confidence in teaching through inquiry | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |

27. **Now, AFTER the professional development program rate your ability and confidence to teach through inquiry at your home teaching environment.**
   *Mark only one oval.*

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   Not very strong ability and confidence in teaching through inquiry | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |

28. **Describe any significant learnings, insights, successes, or failures while learning how to teach with inquiry-focused instruction during your professional development program.**

   ..........................................................................................................................
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**Environmental Literacy and Scientific Knowledge**
29. What environmental literacy and science topics do you feel you need the most help with?

_________________________________________________________________________

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_________________________________________________________________________

_________________________________________________________________________

30. How did your professional development program address improving your comfort and knowledge of these environmental literacy and science topics?

_________________________________________________________________________

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31. How important is it to you that professional development programs incorporate local place-based naturalist content?

Mark only one oval.

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<td>Very important that local place-based naturalist content is incorporated</td>
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32. Describe how the professional development program incorporated local place-based naturalist content.

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_________________________________________________________________________

STEM (Science, Technology, Engineering & Math)
33. How important is it that teacher professional development programs incorporate STEM?

   
   Mark only one oval.

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   Not very important that STEM is incorporated

   Very important that STEM is incorporated

34. Describe how the professional development program incorporated or did not incorporate STEM into the program.

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

35. Describe any significant learnings, insights, successes, or failures you have had regarding STEM during your professional development program.

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

   ____________________________________________________________

Diversity and Inclusion

There have been significant initiatives in environmental education recognizing the value of diversity and inclusiveness to advance environmental education by working to ensure that everyone has the opportunity to learn about the environment and experience quality environmental education. This section of this questionnaire is optional.

36. What is your nationality?

   ____________________________________________________________

37. What is your race?

   ____________________________________________________________
38. **What is your age?**
   Mark only one oval.
   - [ ] 18-25
   - [ ] 26-45
   - [ ] 46-55
   - [ ] 56-65
   - [ ] 66-75
   - [ ] over 75

39. **What is your primary language?**

40. **How do you best describe the geographic area where you live?**
    Check all that apply.
    - [ ] Urban
    - [ ] Suburban
    - [ ] Rural - Public Lands
    - [ ] Rural - Agricultural
    - [ ] Small town (under 20,000 people)

41. **Did you feel like you were a minority in the group of teachers participating in the professional development program? If so, describe.**

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
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   __________________________________________________________

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**Programmatic Evaluation**

42. **Do you remember completing any type of survey, feedback form, or evaluation after attending your professional development program?**
   Logic models, focus groups, pre/post surveys, etc.  
   Mark only one oval.
   - [ ] Yes, I did complete a program evaluation
   - [ ] No, I did not complete a program evaluation
   - [ ] I don't remember if I did or did not complete a program evaluation
   - [ ] Other: __________________________

---

**Transference and Implementation**
43. Did the program include structured time for you to work on a plan to incorporate your new learning and skills back home with your students?
Mark only one oval:
☐ Yes, the program included time to work on an implementation plan to use with my students.
☐ No, the program did not included time to work on an implementation plan to use with my students.
☐ Other: ..........................................................................................................................

44. Have you participated in any accountability measures to track how you are implementing your new knowledge and learnings with your students? If so please explain how these mechanisms have been implemented.
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45. Have you been able to successfully transfer and incorporate your new learnings and skills to your students? Describe how.
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46. Describe any significant learnings, insights, successes, or failures you have had while incorporating the new knowledge gained during the professional development back to your students.
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Logistics of Teacher Professional Development Programming

47. What time of year works best for teacher professional development?
Season, month, etc.
........................................................................................................................................
48. Do you prefer professional development programming to be a single or multi-day event?
   Mark only one oval.
   ☐ Single day
   ☐ Multi-day
   ☐ Other: _____________________________________________

49. Do weekdays or weekends work best for professional development?
   Mark only one oval.
   ☐ Weekends
   ☐ Weekdays
   ☐ Other: _____________________________________________

50. How much are you willing to pay for a single day of professional development?
    Check all that apply:
    ☐ less than $50
    ☐ $50 - $75
    ☐ $75 - $100
    ☐ More than $100
    ☐ Other: _____________________________________________

51. Do you prefer to be offered graduate credits or continuing education credits for completing professional development workshops?
    Check all that apply:
    ☐ Graduate Credits
    ☐ Continuing Education Credits
    ☐ Other: _____________________________________________

**Final Section - Tell us a bit more...**

52. Describe what made this professional development program memorable, unique, and valuable to you.

   _____________________________________________
   _____________________________________________
   _____________________________________________
   _____________________________________________
   _____________________________________________
53. Is there anything else you would like to share about the professional development program you participated in that may be helpful to the researcher? Please do so here.


Powered by
Google Forms
Appendix C. Interview Questions for Case Study Sites

**Field Station:** *(circle one)* New England field station, Upper Midwest field station, Big River field station, Pacific Northwest field station

**Administrator Name:** *(pseudonym)* ____________________________

**Administrator’s Title:** ____________________________

**Outdoor Field Based***

1. Describe how you use outdoor field spaces/sites to facilitate teacher professional development programming.

2. Describe any significant learnings, insights, successes, or failures while teaching teacher professional development programming out at field sites/spaces.

**Bringing Teachers and Scientists/Researchers Together***

3. Describe how you incorporate your long-term research studies into your teacher professional development programming?

4. Describe any significant insights, learnings, successes, or failures with incorporating long-term research studies into teacher professional development programming.

**Citizen Science***

5. Describe how you incorporate your citizen science research studies into your teacher professional development programming?

6. Describe any significant insights, learnings, successes, or failures with incorporating citizen science research projects into your teacher professional development programming.

7. Describe how you incorporate teachers working/learning alongside scientists and researchers at your site.

8. Describe any significant insights, learnings, successes, or failures with incorporating scientists and researchers into your teacher professional development programming.

**Inquiry-Based Learning and Instruction***

9. Describe how you model inquiry-based instruction through our teacher professional development programming.
10. Describe any significant learnings, insights, successes, or failures while modeling how to use inquiry-focused instruction during your teacher professional development programming.

**Environmental Literacy***

11. Describe the level of environmental literacy your teachers have when they first come to a workshop.
12. How does your professional development programming work to address these environmental literacy and science topic needs?
13. In your experience, how important has it become that your teacher professional development programming incorporates local place-based naturalist content?
14. Describe how your professional development programming incorporates local place-based naturalist content.

**STEM (Science, Technology, Engineering & Math)***

15. Describe how your teacher professional development programming incorporates STEM topics.
16. Describe any significant learnings, insights, successes, or failures you have had regarding STEM for your teacher professional development programming.

**Diversity and Inclusion***

17. Describe any methods you use to market and attract diverse populations of teachers to attend your professional development opportunities.
18. Describe any significant learnings, insights, successes, or failures you have had regarding diversity and inclusion for your teacher professional development programming.

**Programmatic Evaluation***

19. Do you have program evaluation analysis you can share with the researcher?
20. Describe any significant learnings, insights, successes, or failures you have had regarding incorporating evaluation techniques into your teacher professional development programming.

**Transference and Implementation***

21. Describe how you structure your professional development programming to include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home?
22. Describe any significant learnings, insights, successes, or failures you have had regarding incorporating opportunities into your programming for teachers to transfer and incorporate their learnings back into their teaching environments.

**Final Section - Your Impression of Your Site's Programming**

23. What are teachers saying about your programming?
24. What makes your programming unique and valuable to teachers?
25. Is there anything else you would like to share about your professional development program?

*Additional follow up questions may be used or not. More questions may be asked as needed.*
Appendix D. Artifact and Document Data Collection Tool

This data collection tool will be used to document evidence of the following innovative professional development facilitation and programming practices:

- bringing teachers and scientists or researchers together,
- teaching at outdoor field-based sites,
- using inquiry-based learning and instruction,
- increasing environmental literacy and science content for teachers,
- addressing STEM education,
- including a strategy for increasing diversity/inclusion,
- including data-driven assessment and evaluation,
- including structure for implementation and transference back to teachers’ students, and
- planning and logistical strategies.

**Field Station:** *(circle one)* New England field station, Upper Midwest field station, Big River field station, Pacific Northwest field station

<table>
<thead>
<tr>
<th></th>
<th>Evidence of supporting Study Criteria (describe)</th>
<th>Other notes</th>
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<tbody>
<tr>
<td>Website</td>
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<td>Brochure</td>
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<td>Flier</td>
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<tr>
<td>Curriculum and Program/Workshop Agendas</td>
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</tbody>
</table>
Field Station: *(circle one)* New England field station, Upper Midwest field station, Big River field station, Pacific Northwest field station

administrator Name: *(pseudonym)* ______________________________

Program being observed: ______________________________

Observation Date(s): ______________________________

<table>
<thead>
<tr>
<th>Elements to Observe</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Physical Setting:</strong> context, how is site utilized, what objects, resources, technologies are being utilized, how field site is utilized for learning</td>
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<tr>
<td><strong>Participants:</strong> who, how many, commonalities, who is missing that could be here, patterns and frequencies of interactions, signs of diversity and inclusion</td>
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<tr>
<td><strong>Activities and Interactions</strong> program agenda/flow, how do people interact with activity, how are people and activity related,</td>
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<tr>
<td>Activities and</td>
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<td>Activities and Interactions: Teacher/Scientist Relationships</td>
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<td>evidence of bringing teachers and scientists together for common learning</td>
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<td>evidence of facilitators incorporating inquiry into the program</td>
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<thead>
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<tr>
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<tr>
<th>Activities and Interactions: Transference</th>
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<tr>
<td><strong>facilitating implementation and transference back to teachers’ students</strong></td>
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</table>
| **Conversation**  
*what are people talk about and with whom* |
| **Subtle Factors**  
*informal or unplanned activities, nonverbal communications, what does not happen* |
| **Researchers behavior**  
*role, how is researcher affecting the scene, thoughts* |
Appendix F. Teacher Focus Group Outline

1. Thank teachers for coming.
2. Review the purpose of focus group, set the stage.
3. Share the flow of the meeting/agenda, ground rules, and set the tone.
4. Asked teachers to first respond to the questions by writing their responses on the notepad page numbered corresponding to the question number. Then, after writing, we discussed. I asked the teachers to add anything to their written response that came up for them during the discussion.

Questions

a. Why do you choose this professional development programming over other options? What experience and/or content drives you to attend.
b. What is our favorite activity at the field station during your professional development experience and why?
c. How do you interact with the scientist and researchers while at the field station? What role do they play in the professional development?
d. Describe how you interact with the scientists and researchers throughout the year.
e. How does the professional development help you teach through inquiry back in your classrooms?
f. How does the professional development affect your teaching?
g. How does this professional development cause you to feel about science and your role within the scientific community?
h. When is the best time of year, day of the week for teachers to participate in professional development?
i. Is there anything else you like to say about this professional development program and how it affects your teaching, your role in science, or the program in general?

5. Ask for any additional thoughts, feedback, or information.

6. Eat pizza and soda.
Evidence of bringing teachers and scientists or researchers together

Administrator Questionnaire:

- At our introductory workshop, scientists present background content indoors, including reviewing the scientific protocol that students will follow in collecting field data at their school field sites. Scientists then bring the teachers outdoors to practice setting up field sites, and collecting data using the same protocol and field sheets as students will eventually use. As questions arise, teachers can ask the scientists there in the context of doing the field study.

- At the data workshop, our information manager and one of our scientists present to teachers how to approach working with and looking at project data. Teachers choose to work at the level most beneficial to their educational goals. Depending on the level they choose, they spend half to 3/4 of the workshop time engaging in tasks such as inputting data onto our online database, using online graphing tools, or graphing by hand or using software such as Excel. In addition to the 2 presenters, 3-4 project ecologists, 2 education staff, and 2-3 grad student mentors are available to teachers as questions arise.

- At the spring workshops, teachers spend field time in small groups led by the project ecologist. Project ecologists point out seasonal changes in the forest that relate to project themes. They review parts of the field protocol that are specific to the spring field season. Teachers can ask questions about any aspect of this work along with the way, and should feel prepared to lead their students in spring field work after this workshop. Project ecologists then join the audience when experienced schoolyard ecology teachers formally present the ways in which they have integrated project themes into their teaching in the afternoon. Scientists, staff and teachers generally get inspired to see how this work is playing out in actual classrooms and schoolyard field sites.

- Teachers continually tell me verbally and in our written surveys how much they value having access to the scientists directly. We are very lucky to have an extremely dedicated group of scientists and data manager who have stayed with this program for over 10 years, primarily on a volunteer basis. One of our scientists is mostly retired, but continues to participate in every workshop and respond to numerous emails regarding schoolyard reach throughout the year.

Administrator Interview:

- The administrator does not conduct any training for the scientists before working with teachers as she believes they wouldn’t be up for that. She does have discussions with them to remind the to teach with hands-on techniques.

- Most ecologists and scientists in the program are parents of children and have a personal commitment to education at this level; they have an internal motivation as they do receive much credit for working with teachers. Also their National Science Foundation funding depends on them creating broader impacts which is an external motivation for the scientists.
This field station does a good job of hiring competent communicators or ‘people people’ which is fortunate to their education and outreach efforts.

Teacher Questionnaires:
- Teachers consider working with scientists important during professional development experiences.
- It has been very successful to learn about the project from the scientist who designed the study.
- The ecologist showed us the hemlock adelgid and helped us understand how they infect trees and what to look for-- he was great answering our questions and had a lot of patience.
- Sometimes professional scientists need help breaking down a process into manageable steps and/or translating jargon into more accessible terms.
- Initially I worked next to the scientists to learn the protocols, to practice it in the field. After these first workshops I worked with scientists in subsequent, ongoing workshops to learn how to make graphs, and to "tell the story" for the data from the graphs. First simple ones, then more complex.
- Teachers claim that it is very meaningful to work alongside scientists.
- There have been many times I have had questions that the scientist was able to answer.
- It is significant to know that my participation is valued and that my insights are worthy of sharing with colleagues.
- I went from not really knowing how to frame a question based on the data to asking questions and to figuring out how to use the data to ask more questions, to facilitating the question process with students, to transferring the techniques in other science applications.

Field Observation:
- Six ecologists were an active part in the teacher professional development programming instructing indoor presentations and hands-on forest walks to demonstrate how to conduct various protocols for schoolyard research projects.
- Ecologists were sincerely interested in the program and valued the teachers perspective and talent.
- Ecologists are viewed as the experts by the teachers; yet the teachers feel comfortable asking questions and the ecologists are accessible.
- The ecologists generally do not like public speaking.
- Talking with one of the ecologists, she said that if the education program director was to offer to teach the scientists how to teach that would cause lots of grumbling.
- Coordinator of the professional development demonstrated her authentic appreciation to her scientists for participating in the program.

Artifacts and Documents
- Ecologists serve as mentors, providing their expertise and enthusiasm to teachers. Staff educators support teachers and their students throughout the year, as needed.

Evidence of outdoor field-based programming
Administrator Questionnaire:
- We bring teachers outdoors into the forest for both the summer Institute and our Spring workshops in order to allow the teacher to be the student and to prepare them how to set up and execute outdoor field studies.
- I don't think the workshop would be as effective indoors. We often to large chunks of the work indoors, and that has its benefit for focussing on certain content, but I would not want to skip the outdoor portions altogether.
- Teachers continually tell us how much it helps to actually physically practice field site set up and data collection outdoors so that they feel confident doing it back at their schoolyards. I'm a big believer in learning by doing and these workshops continually reaffirm the importance of that. It can be a challenge to get teachers to certain field locations such as a vernal pool, which involved transportation by car...a little more time to and from the site has to be accounted for, but not a major issue.

Teacher Questionnaires:
- Once instruction was complete we went into the field to set up the site according to the directions that we would be giving our students. We were able to collect data and problem solve with the instructors.
- A hemlock forest plot used to collect data- we labeled trees and recorded location and then mapped locations of trees. We also keep a running log of health of trees.
- I'm not sure you could be successful with an outdoor project without being instructed in the field.
- We visited a site and were able to learn exactly how to tag trees for our own study as well as to observe spring bud burst.
- By being outside we could see the trees as they were in nature.
- Much more insight is gained from field experience; practical questions come up and are able to be answered onsite by the expert researcher.
- Based on protocol, we used trees near buildings, to walking down various trails to access other aspects of protocol.
- It is very significant to do this workshop outdoors. It is hard to show students if you don't do it yourself, so practicing in real settings is very good.
- I was able to take pictures of what we were doing to use for my own records and to use when instructing my students prior to going out into the field with the scientists.
- I gained practical knowledge about the study my students participate in.
- Problem solving in the field, what ifs, and practice makes you a better scientist and teacher.

Field Observation:
- The spring session for the teachers was primarily indoors with only 1-1.5 hours of the day spent outdoors freshening up on research project protocols.
- The setting was in a natural history-like museum with multiple forest dioramas.
- The program highly encourages teachers to use their school yards and neighboring parks as an extended classroom.

Artifacts and Documents
Outdoor learning is a critical piece of the professional development programs.

**Evidence of inquiry-based learning and instruction**

**Administrator Questionnaire:**
- Once again, you will need to define 'inquiry-based instruction" in order for me to best answer this question. Yes, I believe we model a structured inquiry approach. We provide the study question and the hypothesis for teachers, but we do review our process in developing those. We also engage them directly in helping to answer the question...using field data they and their students collect. We cannot know what their site data will look like season to season—there is much that is unknown and thus a discovery process. We did structure this quite a bit by developing the question, hypothesis and study methods.

**Administrator Interview:**
- We model structured inquiry; we don’t know the answer to the questions and the answers are variable. We help teachers understand that it's expected that field science will be messy and open ended.
- The scientists model inquiry by communicating uncertainty. The director of education says that most scientists are comfortable with uncertainty; yet the teachers generally are not ok with it. Teachers like to be write and are not comfortable with not knowing the answers. The scientists in this program model being ok with uncertainty through hands-on science.

**Teacher Questionnaires:**
- All teachers surveys claimed that their ability and confidence to teach through inquiry at your home teaching environment improved during professional development program
- The need to overcome student's desire to do things correctly, to risk failure. Many have limited ability to problem solve or think outside of the traditional cookbook lab experiences.
- Inquiry is really the process of science. I knew the basics, but this LTER Schoolyard gave me the tools to incorporate real science into my class.

**Field Observation:**
- Scientists designed and formulated research questions instead of the the teachers forming the questions.

**Evidence of increasing environmental literacy for both the teachers and their respective students**

**Administrator Questionnaire:**
- Working with and looking at data; data literacy, seems to be the science topic that teachers are least prepared to tackle on their own.
- That is why we offer a workshop dedicated to data literacy, and we have expanded it over time to incorporate 3 separate learning levels. We have also developed an online database to help with data management, online graphing tools to produce quick graphs of data, and help teachers learn to create graphs to answer individual questions. We have developed various tools on our website to
help with this as well, including a "biomass calculator" and a growing season
calculator. We share lesson plans and graphs developed by teachers related to
working with data.

● We use our field station as the setting for our training. Most of our teachers are
within commuting distance of our forest, and therefore, there woodlands are
similar. They will encounter many of the same tree species, invasive species, and
wildlife as they will see at the field station. Our scientists provide a good dose of
naturalist content that helps inform teachers of the relationships among living and
nonliving species that make up our regional ecosystems. Teachers can then bring
that understanding to their students in the context of their schoolyard.

Administrator Interview:

● Every teacher comes with a different level of knowledge; elementary teachers
typically have a very different level of science and ecology knowledge than high
school teachers. Many of our teachers are environmental science teachers and
fewer and fewer are biology teachers because biology teachers are teaching less
natural science in their classrooms than ever before.

Teacher Questionnaires:

● Topics teachers said they need more content knowledge in: carbon storage,
finding and sharing balanced sources of information on climate change as well as
hopeful solutions for the future; the NGSS Science Practices- phenology, various
aspects of tree topics
● The professional development confirmed what I already knew and how to make
links between topics
● Scientists were always there to answer questions, share papers, knowledge

Field Observation:

● During the workshop 4 teachers demonstrated their new confidence and
understanding of the science research projects they were facilitating with their
students through their formal presentations.
● One teacher said in regard to the program “It’s awesome! It taught me to do
science!”
● Important to teach teachers basic science content and not assume that teachers
know stuff.

Artifacts and Documents

● Teachers become teacher-scientists and some create academic posters and present
at professional conferences with other scientists.

Evidence of STEM education

Administrator Questionnaire:

● It is all science related. Technology plays an increasingly large role over time,
especially in data management and analysis. Mathematics is infused in the data
literacy piece which is integral to understanding the story these studies are telling.
The only piece we don't really use in our work, is engineering.
● Data literacy has been the most challenging and yet we still see it as integral to
understanding the studies themselves, so we continue to tackle it. I see lots more
success over time, and teachers will be sharing some of that at our upcoming Spring Workshop. Our blog features a bunch of this, as do the lesson plans on our website that teachers have contributed. Even our elementary teachers are tackling the graphing piece and feeling successful.

Administrator Interview:
- A tremendous amount of time has been put into teach teachers how to use and analyze data with their students.

Teacher Questionnaires:
- We used the data collected to graph and analyze with excel program
- We used technology and of course science is STEM!!!!
- There is a lot of data that needs to be submitted through computers and can also be accessed in the same way.
- The program incorporates data collection and analysis.
- NGSS science practices, data organization, graphing, analysis
- Science is a bumpy road. Sometimes it all goes well, sometimes, not, Working with different students each year can have a significant impact on each year's success. This program taught me it is OK to struggle, but not give up.
- I learned how to work with the data.
- I learned of my own shortcomings with excel

Field Observation:
- Much of the program involves science, math, and technology, but not much engineering. The program does not involve designing an experiment, but rather following predetermined protocols.
- The program teaches teachers to use data to make graphs, charts, and how to teach their students to understand what the date is telling them.

Artifacts and Documents
- Workshops led by site ecologists throughout the year help teachers build skills in field methods and data analysis.

Evidence of a strategy for increasing diversity/inclusion as a means to attracting minorities to the science and natural resources field

Administrator Questionnaire:
- We have a large range of nationalities, races, and urban students in our wider geographic region. We continually try to engage a range of underserved populations but most often, we are reaching the rural students who live closer to our field station, and students in suburbs of Boston and Worcester. We have very few financial resources supporting our K-12 education work. We tend to have a self selecting group of teachers recruited at science education conferences and Mass. Science teacher websites, and listservs. Individual teachers choose whether they'd like to participate or not. Largely, we find that teachers who themselves are comfortable in natural environments, are the ones who opt to do this work. Urban teachers have less interest and confidence overall in beginning this kind of work, and would require more staff support on the part of a field station and more
support from their school districts than we can offer. We had pursued some specific grants to reach these populations and were not funded for such.

Administrator Interview:
- A range of teachers participate in the professional development; they are self-selected. The site works with teachers who really want to participate and who are self motivated.
- Teachers who sign up to participate are comfortable learning and teaching outdoors.
- More public schools participate just because there are more public schools in the area; more private schools are beginning to participate; guessing it has to do with public schools test taking culture. Public schools are going less deep and are more so teaching to the test; private school teachers have higher retention rate than public schools teachers. Fewer and fewer elementary teachers are participating over time.
- Usually our participants are in their third year of teaching through well seasoned teachers.

Teacher Questionnaires:
- All teachers who chose to complete the survey were caucasian, english speaking, well seasoned careered professionals, from suburban communities

Field Observation:
- Of the 18 participants, 2 male and 16 female.
- Most participants were regional private, parochial school middle and high school teachers. Most were seasoned mid-late career teachers.

Artifacts and Documents
- Teachers from across the entire state are reached and some from neighboring states as well.

Evidence of data-driven assessment and evaluation of efficacy of teacher/scientist partner programs
Administrator Questionnaire:
- Currently, we use Survey Monkey surveys as an evaluation tool. Teachers complete surveys after each of our workshops. We combine multiple choice and open ended questions in our surveys and do find the feedback to be very helpful. At the same time, we find that teachers provide mostly positive feedback even if they then choose to drop out of the project. We feel we could use help in finding ways to keep teacher engaged in this work over time. We do find that a combination of time pressure and career transitions (retirement, subject changing, specializing, grade level changes) are mostly responsible for the high turnover rate in our projects. However, even with those who cite time as the constraint, we might find a way to get more specifically at what the line is for timing...and if there are ways we can address that.
- We have recently put out a survey to students in our undergraduate education program (REU) to see what kinds of experiences in their K-12 education might have led them to pursue ecology in higher education. We are still analyzing those
results and hope they might inform us, along with our funders, as to what experiences in K-12 have an impact in preparing students to pursue STEM fields in higher education and their careers.

Administrator Interview:
- The site has not completed a comprehensive evaluation for their teacher professional development program. The site does use an online survey tool at the end of each workshop.

Teacher Questionnaires:
- Teachers surveyed report completing surveys
- Teachers present success stories through presentations at spring workshop

Field Observation:
- Teachers were asked to bring a laptop to the workshop. At the end of the workshop they were requested to take time to fill out the evaluation survey. 15 participants, 83% filled out the online survey.
- Teachers are invited in advance of spring workshop to put together a short presentation to share at the spring workshop with other teachers. There were 4 presentations during the spring workshop by teachers who shared stories of their successes with students, new technology, and innovative teaching tools. These presentations were tremendous evaluation pieces for the field station as they demonstrated how the teachers are implementing their professional development and also how they identify as scientists. The excitement and engagement these presentations fostered for the entire group of teachers was influential.

Artifacts and Documents
- The program has numerous online survey data but not a cumulative summary document.
- Multiple workshop surveys are present.

**Evidence of programmatic structure for implementation and transference back into the 12 classroom or field experience:**

Administrator Questionnaire:
- At our Spring workshop, we put out a call for teacher presentations and usually include 5 or so teacher presentations in the afternoon. This has proven a very effective way of getting teachers to share what they have learned and accomplished with each other.
- I maintain a blog in which I continually encourage teachers to share photos, comments, lesson plans, graphs, etc. as a means of encouraging cross pollination among teachers in our network. I also post teacher-developed lesson plans on our website.
- At our Data workshop, teachers spend the afternoon, working on various pieces that they will then take back to their classrooms. For instance, some teachers, will spend the time organizing student field data sheets and inputting data onto our online database. They will practice downloading data, and using our online graphing tools to graph their student data. They then have those tools to share with their students. Second to third year teachers will create a series of graphs of a
preset Schoolyard dataset (not their own) using instructions developed by a team of field station staff. Those teachers will then have the knowledge of how to create similar graphs of their own students' data. Our most advanced teachers, will come to the workshop with individual data literacy/educational goals. They will spend 3/4 of the day working to meet those goals with the help of field station scientists and mentors who are available as needed. Several of our teachers come back year after year with new goals, and continue to build up their ability to work with data. They have a group of graphs and table stored up to use in a variety of ways as teaching tools. These teachers then share graphs and lesson plans on our website as resources for the entire network.

- Our best such mechanism is our online database. If a teacher inputs data, we can tell that the study is actually being implemented at their site. All the rest of their participation is on optional report back/share basis. Many teachers choose to send us lesson plans, choose to present at workshops, contribute student samples, photos, etc. and many do not.

- This year, we have supplemental funding to hire a project coach to visit new teachers who will be beginning our climate change in the forest project. This way, coaches will help teachers succeed in setting up wooded plots, and be available to help manage data collection with students for one to 2 visits. If we had additional funding, we might do this for all of our projects. Most years, we have not had funding for coaches for any of our projects.

- We feel we do not need to make any more such mechanisms given the constraints on our end and the constraints on schools/teachers.

- I hope you can tease out the MANY ways we do this throughout the year from above. All of our written materials are available as free downloads from our website. Ecologist created Powerpoint presentations are avail on website; teacher developed lesson plans on website... I also keep in contact with teachers by email throughout the year, sending updates to each project group frequently. I also include updates on the blog with links back to related resources on the website. A big part of what I do, is cheerlead for teachers, sharing their accomplishments and successes with the entire network, which keeps everyone's aim upward and forward, and accessible to all.

Teacher Questionnaires:

- In regard to successfully transfer and incorporate your new learnings and skills to your students: sort of but not enough time I teach phs science now so only do measurement with them not ecology; Yes. We participate in the project each year in the fall and spring; Yes. My students ask of me the same questions I ask of the researchers with whom I work. I am able to supply answers or guide them towards finding them on their own.; OH YES!

- access to technology makes it difficult to complete the data analysis with computer programs

- My students have learned how to reliably gather, record, analyze and share field data gathered at our study site. They have learned how to contribute to a broader long-term professional ecological research study aimed at shedding light on the effects of climate change on the length of the growing season in our region.
Some years went well. Some years we didn't get all the data correct. When dealing with lots of kids, I might not notice one group did not have it recorded correct, even though I spot check. I have the students keep their data in their journals, not on separate sheets for each day like elementary teachers do. So sometimes students lose it.

Field Observation:

- Teachers were not given structured time during the spring workshop to collaborate and design ways to incorporate their new learning back to their classrooms.
- They were given resource books and handouts to take back to their classrooms and use for make their curriculum more innovative.
- Teachers have clear protocol that is easily taught to students and also they were given ideas on how to add variation to their individual research studies.
- The program relies heavily on mentor teachers to help new teachers in the program be successful.
- The prestige of working with a private university helps to convince administrators and parents the value of the program.

Artifacts and Documents

- Teachers are setting up schoolyard plots and conducting long term research with their students.

Evidence of planning and logistical strategies

Administrator Questionnaire:

- Summer is great, maybe the easiest, but the problem is folks forget stuff they learned in summer, come November....if not sooner. That is why I opt to spread out workshops across the year.
- We charge $50.00 for the intro workshop and the rest are free.
- 3-4 single days throughout the year on weekdays work best
- GRANTS and private donations. LTER Schoolyard program, family foundations, individual donors. We have trouble finding enough funding to grow the program.
- Not any more. We tried that and found it was initially successful and then the number of teachers dropped so low that the income for us was not worth the time in administering it.
- Graduate Credit/Continuing Ed Credit - Not any more. We tried that and found it was initially successful and then the number of teachers dropped so low that the income for us was not worth the time in administering it.

Administrator Interview:

- Teachers are not motivated by continuing education credits nor graduate credits. The teachers are self motivated. They want to see themselves with this work and see the importance of it. The site offers continuing education credits and lunch, yet does not pay teachers to attend.

Teacher Questionnaires:

- Best time of year works best for teacher professional development: summer, mid-spring, mid-fall
● Weekdays are best
● Continuing education credits are preferred over graduate credits

Field Observation:
● Spring workshop was held on a Thursday during the school year. Teachers had to make substitute teacher arrangements in order to attend.
● Workshop was free to attend and participants brought their own lunch; snacks were provided.
● Pre-workshop logistical plans and expectations were clear through email communication.
● Teacher participants were given multiple resources as a gift; these included brand new natural history books and resource guides.

Artifacts and Documents
● The price for the summer institute is only $50 making this program very affordable for many.

Other pertinent data:

From Administrator
● I think the benefit of having done this work over time with at least some consistent funding from NSF, has allowed us to fine tune this work over time. We are continually adding to and revising our educational resources available to teachers. We see teachers develop their ability to understand and teach complex ecological themes grow each year. The dedication of science and information manager staff has been tremendous. I don't think I ever could have predicted that all of us would still be at it 11 years later. We have also benefitted greatly from collaborating with even more staff and other organizations.
● One teacher said it best on one of our old fashioned hand written evaluations: "Real Science; Real Scientists; Real Issues"
● The goal of our program is to engage students and teachers in the process of science through authentic field science investigation; we want them to experience first hand what it’s like to be a field scientist.
● We want to connect children to nature by getting kids outside and connect them with nature.

From Teachers
● It was a unique project that brought science alive to my students.
● This program allows me to introduce students to citizen science. Many students are thrilled to be a part of a long term research study that could influence future policy in an effort to mitigate the effects of climate change.
● Success and comfort. The field station scientists and staff have never made me feel less than they. They always encouraged and support and that gave me courage to try more.
● Great learning site, pleasant people to work with, nice facilities
● They changed how I teach. The skills I learned here made me fly. I don't like to do work half way. I want to understand and they always, always helped me. They
listen and are responsive to me needs. They make us teachers feel valued and appreciated.

From Site Visit

- Relationships! Relationships! Relationships! - teachers are highly valued, scientists are greatly appreciated
- There was no emphasis or time spent discussing how to take the science research and using it to discuss the ‘so what’ action or relevancy piece.
- Throughout the workshop teachers were engaged in high level scientific discussions and exhibited a general passion and excitement for science.
- Teacher comments during workshop:
  - “This is my recharge, where I find pools of excitement to take back to my students.”
  - “Knowledge does not come from books, it goes into books”
  - “This professional development is critical to my recharge”
Evidence of bringing teachers and scientists or researchers together
Administrator Questionnaire:

- Field station is an LTER site (Long Term Ecological Research) funded by the National Science Foundation. This grant includes funding for outreach, we use those funds to cover the expenses of 5 professional development (pd) days in science education a year for local teachers. Each pd day includes a plenary with a scientists and sessions provided by field station faculty and graduate students. The scientists involved are not always affiliated with our LTER site, we cover a wide array of biology and ecology.
- Data nugget lessons are worksheets designed for teachers to bring real data set from real scientists into the classroom. The idea for data nugget lessons was formed by our graduate students working with mentor teachers in middle and high school classrooms. There was need for authentic science data to help students understand the process of science and connect with real scientists.
- The teachers are really interested in what the scientists have to share during plenary talks. Sometimes it is hard for them to see a direct tie to the teaching in the classroom but they recognize that they are also gaining knowledge as an adult learner and are engaging/making connections with the scientific community.
- One of the best ways we incorporate teachers working/learning alongside scientists is through Research Experiences for Teachers (RET). Each summer we fund (using external grants/NSF or discretionary donations) between 2 and 8 RETs, we have had a combination of faculty mentoring and postdoctoral students mentoring the teachers. Sometimes the teachers have an independent research project and sometimes they function as a lab technician and work on a variety of projects and tasks. In summer 2015 we requested that the RETs get together as a cohort over the summer to share their experiences and to discuss how they were planning to bring their RET experience back to their classroom/students. These were really fruitful conversations and teachers created Data Nuggets and lesson plans based on their RET experiences. The RETs also presented to other teachers at our GK-12 summer Institute.
- With any type of position, we have had the occasional mismatch of personalities. I have also heard stories of teachers who were not as productive or engaged as their mentor would have liked them to be. But I have never observed this in the past two years.

Administrator Interview:

- In 1999 the field station scientists saw the need for a teacher workshop program. They had their own children and personally wanted to work with teachers. The GK-12 program paid PhD. grad students to go to partner middle and high school classrooms 1-2 days a week. The program targeted 13 rural school districts who have limited resources.
- The field station has a unique culture of scientists and PhD grad students wanting to be better science communicators.
• Graduate fellows (ecology students) serve as interpreter between the field station research and local science teachers.
• Teachers find it tough to find enough time to coordinate with graduate fellows due to school schedule limitations.
• Our pre-service teacher program was piloted for a couple years working with the university's teacher education program. A small group of pre-service high school science teachers spent 16 weeks at the field station. They now believe they are scientists and believe they can do this. Their identity of as scientists has shifted.

Second Administrator Interview:
• Scientists have no idea what is going on with the science education community; yet they need to know how science education works.
• Professional development for teachers is an extra responsibility for scientists resulting in extra work and is not the highest priority for most institutions.
• Some faculty do not speak English as their first language and are uncomfortable public speaking.

Teacher Questionnaires:
• I was able to experience real research first hand, something that few teachers ever do. Some things turned out as expected, while others did not. The researchers took it all in stride, something that was a valuable lesson for me as I conduct research with my students.
• I learned not only new things about biological organisms and systems, but new ways to think about how students learn. I learned more about the difficulties in maintaining a research and collaborative network of science educators too.
• It was nice to hear how what we were learning directly coincided with the researcher's inquiry.
• Looking into best practice for teaching was valuable, plus digging into the NGSS was very helpful.
• The researchers seemed to be appreciative that I was there helping them. I've found that it's important to ask a lot of questions, since the researchers sometimes forget that I don't always have a strong background like they do. I certainly have learned a good deal working with them.
• I learned more about ecology, biogeochemistry, water systems, biodiversity, mapping systems, biofuels, long term ecological research, evolution and how to teach it.
• It was very meaningful to teachers to work alongside scientists.
• It helps to see what scientists do and how they approach learning and research.
• Working with the researchers allows you to be a partner, not just a helper. That's the real value of the RET program. You actually do the research, and that's valuable information I can take back to my classroom. It's helped me become a better teacher.
• Really awesome to work with graduate fellows to bring their research into the classroom.

Field Observation:
● This program mostly connects teachers to PhD graduate fellows and not directly to the research scientists at the field station.
● Field station scientists do not seek out opportunities to reach K-12 audiences, but when invited they will go visit classrooms.
● Scientists want to educate young students in order to build a base of science in students.

Evidence of outdoor field-based programming
Administrator Questionnaire:
● Can I just say that our site is awesome! Our field station has a wide variety of habitats and they are fairly easy to get to. The main areas we utilize for learning with teachers our bird Sanctuary and academic campus along the shore of a large lake.
● The bird sanctuary features a collection of captive birds - birds of prey, upland gamebirds and waterfowl that are easy to observe and therefore are used for field trips to look at adaptations. The Sanctuary surrounds a 45 acre freshwater lake that is used for water quality studies by faculty labs and undergraduate courses. A 1.5 mile hiking trail surrounds the lake that is used by Sanctuary visitors for bird watching and exercise. The Sanctuary offers field trips for K-12 students, we share these experiences with teachers and a few bring their students during the school year (this is an area we are seeking to grow - onsite experiences for the students of our K-12 Partnership teachers). A guided field trip experience at the Sanctuary is the agriculture and ecology activity trail that is based on the research of the Long Term Ecological Research Program.
● The academic campus is a historic estate with modern and historic buildings throughout. Our academic buildings are, including our large auditorium, classrooms, computer lab, library and faculty labs. Our lake is one of the largest freshwater lakes in the state and makes a beautiful outdoor classroom for aquatic ecology. The grounds of the academic campus are highly manicured and have trees that are original to the 1927 estate, so it has a 'park like feel'. We use this to our advantage when presenting the elementary professional development program, elementary teacher outdoor science teaching institute, because we hope the manicured landscape has elements in common with school yards (ex. gardens, parking lots, hardscaping, mown lawns, etc.)
● The field station also has lots of agricultural lands and a pasture dairy center, which we have taken the teachers to observe and experience.
● We also use the nearby experimental forest for pd and field trips, it has a creek habitat and lots of forestry and maple syrup research that is interesting to teachers and K-12 students.
● Historically much of our teacher pd has happened indoors, but we have been getting more intentional about having place-based field trips and sessions that highlight what is unique about our site and our region of the state.
● We have been researching the implementation of what elementary teachers learn during the elementary teacher outdoor science teaching institute. The insight I have gained is that it is really hard for teachers to change their practice and if
taking kids outside for lessons has not been a normal part of their routine, it is really rare for a teacher to put it into practice. Even when they are really excited about it during professional development or in follow up interactions.

Administrator Interview:

- We’ve been adding more field trips to places of interest within our field station so that teachers can see it through the lens of a possible student field trip site.

Teacher Questionnaires:

- We were outside learning all day. It was nice to get ideas to take back to the classroom.
- Spaces were used often to connect what we were learning, plus modeling how to use outdoor learning spaces for teaching.
- Last summer I was out in the field every day, usually for the entire day. For my previous research experience, my time in the lab and in the field was about equal.
- as places to gather data, ask questions, set up experiments, observe, play
- It was very significant that my professional development program was facilitated outside in the field as opposed to in an indoor space.
- When dealing with plant and insect research, it's imperative that you do your investigation outdoors. It was a good experience most of the time.
- leave no teacher inside
- It was nice to have some time to think about the outdoors as a classroom. We so often think of it as a recess tool!
- Our site had some exemplary settings for teaching. We want to replicate some of these settings for students at our schools. It helped us get started with what we needed to do to improve our school outdoor environment for learning.
- One of the things I've learned is that much of the work can be physically demanding, especially if it's done all day, every day. Still, it was nice to be outdoors so much as opposed to being indoors all day.
- learned more about agricultural methods and their impact on climate and ecosystem services

Field Observation:

- A few presentations were done outdoors as well as a field trip to the site’s farm to see their innovative dairy operation.
- Natural stuff was collected outdoors by the teachers to then observe closely with microscopes back in the classroom.

Evidence of inquiry-based learning and instruction

Administrator Questionnaire:

- We strive to model inquiry-based instruction but are often limited by time, especially during 1 hour sessions. I think we model inquiry-based instruction best during the one week, elementary teacher outdoor science teaching institute program which is based on the Next Generation Science Standards and goes beyond inquiry-based instruction to help teachers understand and practice with their students the nature of science.
This is another one that is really difficult, so much instruction is teacher led and kit based. I think we are most successful with really place-based examples, but even then the questions are often provided and not student generated.

Administrator Interview:

- Inquiry is a loaded word. We model inquiry with students as investigators; however teachers are uncomfortable with investigations; teachers have been an investigator or taught how to do so.
- The RET teachers get the most experience with investigative inquiry as it is generally the first time teachers ever get to be scientists and actually ask a question. RET teachers gain pride in being a scientist and begin to look at science differently.
- The weeklong elementary teacher professional development program creates opportunities for teachers to be scientists. The program walks them through the process of science. However we have not seen much implementation back in their schools. A week long professional development program without any support throughout the year does not work to change teaching practice.

Teacher Questionnaires:

- My experience just sharpened my inquiry skill set and gave me additional ideas.
- All surveyed said their ability and confidence to teach through inquiry at your home teaching environment improved from PD experience.
- reinvigorate me to the difficult task of inquiry style teaching, which has been my love since I was a graduate student in science education 25 years ago

Field Observation:

- Modeling how to teach inquiry was the focus of one of the day’s breakout concurrent sessions through the use of smartphone microscopes.

Evidence of increasing environmental literacy for both the teachers and their respective students

Administrator Questionnaire:

- Climate change and evolution are two large topic areas that teachers have appreciated learning more about and stated that very little of this instruction happened during their undergraduate courses or during other professional development. Carbon cycling is another huge area that has been the focus of a professor from the College of Teacher Education)
- Luckily climate change and evolution are two areas that our scientists study, so we have been able to bring in plenary speakers on these topics and have graduate students create data nugget lessons and sessions with activities related.
- What we have found in our work with elementary teachers specifically is that they often lack the general natural resource knowledge - simply because they have a small interest in nature and they were not required to take many (if any) science courses during college. I often weave nature hikes and experiences into pd that allow teachers to have a positive experience outside and gain a little 'nature knowledge'. For example, this fall we took teachers on a field trip to the Bird Sanctuary, taught them to use binoculars and then to identify a few migrant
waterfowl on the lake. After this we had two classrooms request us to visit with the binoculars and help with a bird ID lesson in the schoolyard.

Administrator Interview:
- Middle and high school teachers have strong science literacy content. Elementary teachers who have had previous experiences with science like science. Some elementary teachers do not identify as scientists as they claim they teach elementary school so they don’t have to teach science.

Teacher Questionnaires:
- I could always use more ideas on conducting classroom research that matches with my curriculum (soon to be NGSS).
- It helped to a certain extent, but much of the research I did was above what my students are capable of doing. Still, I was able to adapt much of what I learned to use in the classroom.
- The research I did can have an impact on where I live, and therefore it makes it relevant.
- I want to know what the organisms are around me and how they work together, both for my own knowledge, but to increase the knowledge of my students

Field Observation:
- Science literacy and environmental literacy were not necessarily the primary focus or priority of the workshop. However, innovative local agricultural farming techniques were shared as well as land management strategies.

**Evidence of STEM education**

Administrator Questionnaire:
- All funding and emphasis is on STEM so it is always important.
- I think it is more difficult to get STEM education right, the new NGSS will be helpful in moving forward but when someone is new to them they are really overwhelming.

Administrator Interview:
- Our programming has not changed as it has always reflected STEM content, only now we have adapted our language to imply that STEM is included in our programming.

Teacher Questionnaires:
- all stem all the time and lots more of the E in STEM since it became "the thing"
- the sessions I attended that dealt with comparing and contrasting the practices of engineers to that of scientists helped me realized I CAN teach about engineering practices even though I was not initially trained as an engineer
- I need more information about STEM- am still uncomfortable with it.

Field Observation:
- Many applications of technology and engineering were shared during the one day professional development workshop including nature smartphone apps, 3-D printing, genetics and evolution computer simulation tools, and a smartphone microscope.
Science applications were included through a modeling workshop, an ecology research project, and the use of a rainfall simulator.

**Evidence of a strategy for increasing diversity/inclusion as a means to attracting minorities to the science and natural resources field**

Administrator Questionnaire:
- We mostly work with rural teachers from our region of the state. I don't know the demographics of our teachers but my guess would be they are not diverse.
- We don't market most of our programs, we rely on established relationships with districts. With that said, we have had a difficult time creating new relationships with urban districts. A lot of time goes into creating these relationships. When I do market programs I use social media, our website, word of mouth and the state Science Teachers Association listserv.
- Relationships with administrators is important, even though the teachers are the ones you will have a long term relationship with you have to start with principals, curriculum directors, etc.

Administrator Interview:
- Our in-service teachers are self-selected seasoned veteran teachers. They do recruit new teachers from their schools. We are concerned about the veteran teachers and need to create relationships with the administrators from their local school to formalize the relationship and ensure future relationships.

Second Administrator Interview:
- Motivated self-selected teachers participate in professional development programs; they are not being told by their administrators to participate.

Teacher Questionnaires:
- All who filled out the survey were caucasian, english speaking people
- A variety of geographic diversity was represented by those who chose to take the survey.
- All were between the ages of 26 and 55.

**Evidence of data-driven assessment and evaluation of efficacy of teacher/scientist partner programs**

Administrator Questionnaire:
- It is really hard to gather data on teaching practice and knowledge gained! I have lots of survey data that shows they enjoy attending and being compensated for PD!

Administrator Interview:
- We do basic pre and post surveys and evaluation.

Second Administrator Interview:
- We do satisfaction surveys and not much true evaluation to measure content learned, changes in teaching practice, or conducting classroom observations.

Teacher Questionnaires:
- Teachers remembering filling out a program survey.
Field Observation:
- Teachers were asked to fill out a survey before leaving the workshop.

**Evidence of programmatic structure for implementation and transference back into the 12 classroom or field experience:**

Administrator Questionnaire:
- Typically there is at least 1 hour of each day of professional development that is a structured conversation or brainstorm about how to implement what has been learned (sometimes we do this after the plenary speaker to come up with ideas on how to bring their science into the classroom).
- Regarding accountability mechanisms in place to ensure teachers are implementing their new knowledge and learnings into their teaching environments: “nope, this is the hard part...i have started asking on surveys, 'how have you implemented what you learned at previous workshops?'
- They really appreciate the time to network and steal ideas from each other.

Administrator Interview:
- With our elementary teacher professional development, we have not seen much implementation back in their schools. A week long professional development program without any support throughout the year does not work to change teaching practice.
- Elementary teachers who have had previous experiences with science are comfortable taking content and translating it back to their grade level and then get more excited and comfortable with investigative teaching with their students.
- Gathering data on effectiveness of transference and implementation is very difficult, expensive, and time consuming.

Second Administrator Interview:
- Teachers are casual integrators picking up bits and pieces throughout a professional development workshop.

Teacher Questionnaires:
- Yes, the program included time to work on an implementation plan to use with my students.
- Yes I have participated in accountability measures to track how I am implementing new knowledge and learnings with my students.
- Somewhat able to successfully transfer and incorporate new learnings and skills to my student - I feel more confident taking the students outside for learning, it's fitting it into our already packed schedule.
- Our students have been working outdoors for a variety of purposes in learning science.
- Yes. I've changed the structure of the scientific method template that I now use. I also edit the template depending on the experiment we are conducting. Those two things have been very impactful in my classroom. I also have been able to pass along a good deal of the content I've learned.
- One cannot succeed without failing many times--just don't quit trying!
I've learned to be flexible with regard to the scientific method format I use, but my basic structure has improved dramatically. There have been times when I expected a bit too much too fast, but I've learned to be more deliberate to begin with.

Students sometimes need a lot of support plus extra time to become oriented in an outdoor environment. This takes time and planning to do well.

Field Observation:
- Workshop introduced teachers to upcoming RET experience at the field station.
- Field station presenters encouraged teachers to consider the tools and resources they have readily available in their schools.
- Workshop introduced teachers to tools they could use back in their classrooms and not lesson plans by design.

Evidence of planning and logistical strategies
Administrator Questionnaire:
- Fall, spring and late summer (3 days) work best; spring 1 day; fall 1 day; summer 3 days
- Our teacher professional development is funded by grants, specifically the National Science Foundation's, Long Term Ecological Research program's 'schoolyard LTER' funds.
- We actually pay teachers to participate, in the school year we reimburse sub costs, in the summer each teacher earns a stipend
- Yes, we offer CEUs through our university and the state department of education

Teacher Questionnaires:
- Summer is the best time of year for PD
- Conducting sustained and on-going professional development is the only way to affect big changes
- Weekdays work best
- I prefer to BE paid; willing to pay less than $50
- Continuing education credits preferred more so than graduate credits

Field Observation:
- Workshop was held on an April Thursday during the school week. Approximately 50 teachers attended. The field station paid for the teachers’ substitutes back at school, fed them lunch, and offered them lots of free resources at the end of the day.

Other Pertinent Data

From Administrator:
- "Today's speakers and presentations inspired me to create a plan for bringing the outdoors to my students." Quote from teacher
- Connecting with real scientists and research that is happening right in our region of the state

From Second Administrator:
• Graduate fellows work on reflecting on practice as they learn how to teach in local classrooms and work with teachers.
• Graduate fellow training includes weekly meetings, training similar to a teaching assistant training, observing K-12 classroom teachers, and being mentored by K-12 teachers. The school of education has been a part of the fellow program to help them with pedagogy and such.
• What makes this professional development unique is its long lasting extensive program. The graduate fellows have been going into classrooms to provide support and follow up for a long time. Strong relationships have been formed between teachers and the graduate fellows from the field station.
  ○ The program has created a pool of teachers whom scientists can rely upon for their necessary outreach efforts to conduct NSF required ‘broader impacts’.
  ○ The program has been successful with its variety of ever changing new topics which is key in retaining teachers.
  ○ Don’t have to market the program; the longevity and reputation of the program pays off.

From Teachers:
• Being able to take time and think about how I deliver science curriculum, something that is often overlooked.
• I was able to participate with 2 other teachers at my school, so we helped one another with our projects and implementation of our learning.
• The RET program is a unique experience. It allows you to become a ‘real’ researcher. That's an opportunity that few teachers have. It also allowed me to forge lifelong friendships.
• the responsiveness to the needs of the teachers, the collaboration with both scientists and science education researchers really changed my professional path
• My students now get a better education because the RET program has helped me to become a better teacher. What can be better than that? :)
• The field station has a website and uses social media to keep us connected. This has been very helpful and has kept me from forgetting about what we planned. Sometimes it's easy to get back to school and routine takes over. It is helpful to stay connected and planning more things together moving forward.

From Field Observations:
• The concurrent sessions with more hands-on activities had more participants than those that were more lecture and discussion based. Most of the day was being talked-at presentations and demonstrations in and out of the classroom and there was little dialogue or discussion encouraged.
• Graduate fellows visit the teacher’s schools to help them identify potential ways to use their school yards to teach science.
• Many of the conversations throughout the day consisted of teachers sharing with each other building rapport and rejuvenating their interest in teaching science.
• There seemed to be a fair percentage of disengaged teachers during some of the presentations who were carrying on side conversations, some seemed to be
completely checked-out. The day was a free day for them and for some there was not necessarily a personal-investment for them to participate.
Evidence of bringing teachers and scientists or researchers together

Administrator Questionnaire:
- Two ways: During the summer PD workshops, we introduce the teachers to our research staff and research programs. Secondly, we encourage their students to develop Independent Study projects (i.e. "science fair-type" projects) either at the Field Station or on subject matter related to our research. Occasionally, we have had students take advantage of this opportunity.
- Unquestionably, the teachers (and students) enjoy learning about real science in their own backyard and like doing science. They often comment on how it makes them feel like a biology student themselves again.

Administrator Interview:
- PhD faculty and research interns teach the professional development workshop.

Teacher Questionnaires:
- No, I did not work alongside any scientists or researchers while participating in your professional development program
- It was really helpful and inspiring to see what the scientist was working on and hearing them explain how they were conducting their research and what they were researching helped me develop real world examples and labs that I can use in my classroom. Nothing we did was not helpful.
- It helps me understand the concept better which in turn makes me a better teacher. It also helped me develop lessons that were based on real world examples.

Site Visit:
- College faculty at the field station is dedicated to supporting local teachers enrolled in the continuous professional development program.

Focus Group:
- College faculty keeps learning ‘fresh’; faculty comes to my classroom during the year to conduct a lab; faculty makes themselves available for email/phone calls during the year. Faculty is a very valuable resource.
- Researchers explain what they are working on, how they are conducting experiments, and how you can be involved during tour of labs; researchers share programs that high schools can be a part of or apply for.
- The relationship between teacher and scientists is very good. The scientists are eager to explain what is going on and offers ideas to teachers for lessons. They are also very informative in answering questions and helping when and where possible.
- The majority of college faculty/researchers are excited to aid us in any way possible. There is a real sense of community because all are “scientists” in some way. They are all very open and honest with us.
- Relationships are built and in some cases, desperately sought out. Many privately funded research groups thrive to make their institutions educational to help establish a financial ‘need’ to educate. It becomes a self-sustaining system, which creates a community feeling.
The college faculty are always very welcoming and seem excited to be there. The relationships are very easy-going and they are not at all intimidating. They go out of their way to be accessible and answer any questions that we may have. Networking through other regional research institutions has also been made possible.

Evidence of outdoor field-based programming
Administrator Questionnaire:
- We utilize the River itself by taking teachers out on the water to collect water quality data and sample fish populations. We also have a nature trail that we hope to develop into interpretative learning stations with the teachers' input.
- For some of what we do with the teachers, it would be a challenge to offer the same type of programming indoors, given that one of the main appeals of our outreach program is actually sampling in the field. It's hard to simulate something similar indoors. We do other activities indoors from identification of organisms and molecular biology techniques, such as plating bacteria and electrophoresis.
- Consistently, teachers and their students remark on the setting of the Field Station and the unique experiences that they receive by being out in the field.

Administrator Interview:
- Field station gets used as a part of a larger week long teacher STEM workshop; teachers are only at the field station for part of a day.

Teacher Questionnaires:
- We were able to see how the field station is a host for many different on-going projects for multiple agencies and colleges or universities.
- It was very significant seeing how the health of the river is monitored
- Showed me what natural research projects were being conducted.
- Very significant, I don't learn and understand as well, unless I am seeing it or interacting with it.

Site Visit:
- The development of the nature trail through the riparian area indicates a priority to use the area for teaching.
- The extensive wet lab of the field station is shared with the teachers to demonstrate ongoing aquatic research projects.

Teacher Focus Group
- I enjoy biology and the outdoors; this is a fun professional development.
- This program has given me the ability to have free field trips for my students.
- It's very easy to schedule field trips throughout the school year.

Evidence of inquiry-based learning and instruction
Administrator Questionnaire:
- Many of the hands-on activities that we do with teachers are inquiry-based. Little to no lectures occur, rather the format we use with the teachers during the
workshops is the same we use with their students when they come back for a field trip.

- Given the resources at the Field Station, it makes less sense to engage in more traditional classroom activities, such as lectures. Inherently, our research and the related outreach programs are inquiry-based.

Administrator Interview:
- The field station does not yet have any RET programming.
- During the professional development, teachers play the role of student and do the activities that students will do on upcoming field trips to the field station.
- Teachers generate data by using water quality protocols to measure various parameters.
- Faculty facilitate scientific discussions about the process of science and the scientific method during the teacher professional development programming.

Teacher Questionnaires:
- Having a few lessons modeled was very helpful and gave me ideas to adapt some of my lessons or labs to be more inquiry based.
- No, inquiry-based instruction was not modeled throughout your teacher professional development program
- I just picked up some good hands on activities that I could give to my students to make them start asking questions.

Site Visit:
- When visiting the field station without a workshop currently happening, I could imagine how the wet lab, fleet of boats, and riparian trial are potentially utilized for investigations with teachers.

Teacher Focus Group
- The field station has helped me be more familiar with the river and what be there. During the year, I will ask the kids questions regarding the river; what’s in it, how clean do they think it is, etc. We then go to the river and take samples and observe the H20 and see what we find.
- Help create curiosity in students so students ask questions
- The faculty at the field station help with lesson and model some as to what level of inquiry I know I have a basic level and am not that confident teaching this way. The station helps with this giving me ideas and modeling lessons.
- Seeing research done at the field station models how inquiry is done.
- The college has been a model for asking essential questions that are skill based. Students can see the interactions between our community and the field station, which gives a real-life model of what/and how student expectations are, and should be at a higher level. Students who are not always the ‘science’ kids participate and engage at that higher critical thinking level.
- The professors show us how to take the lessons they model for us and scaffold them to different levels of inquiry.

Evidence of increasing environmental literacy for both the teachers and their respective students
Administrator Questionnaire:
- This varies widely from teacher to teacher; but in general, they are more literate in environmental and scientific topics than the general public. Like anyone else, they could always use training on the latest research, pertinent regulatory or legislative issues and the associated terminology.
- Indirectly our program addresses environmental literacy and science topics through the subject matter related to our research and outreach programs.
- Just about everything we do with the teachers is local place-based. From sampling to species identification to environmental issues, we focus on the local ecology.

Administrator Interview:
- Teachers learn plenty of content through teacher professional development workshop and less specific curriculum for their classrooms.
- Teachers come with high level of science literacy but very little environmental literacy.

Teacher Questionnaires:
- It gave me more confidence in teaching this in my classroom.
- Mostly just refreshed my memory, environmental topics are what I know best.
- Refreshed my memory and gave me some good ideas on lessons in my classroom.
- It makes the information relevant to my students, so helpful to me.

Site Visit:
- When visiting the field station without a workshop currently happening, I could imagine how the wet lab, fleet of boats, and riparian trial are potentially utilized for investigations with teachers to learn science and environmental literacy content.

Teacher Focus Group
- More so than science literacy this program changes the way teachers view themselves as a scientists and their identity as a scientist. They come to believe they are important to the scientific community.

Artifacts and Documents
- External program evaluation included:
  - Teachers reported the Biology Field Station experience gave them tools to analyze and explain the basic components of an ecosystem

Evidence of STEM education
Administrator Questionnaire:
- We are connected to a broader STEM teacher professional development program where faculty from a variety of disciplines participate in the summer PD workshops for high school teachers.
- Interdisciplinary and multidisciplinary subjects are of a great interest to the teachers. Further, most high school teachers with whom we work are teaching several subjects (BIO and CHEM or CHEM and PHY).

Administrator Interview:
The field station is utilized during the week long STEM workshop for teachers.

Teacher Questionnaires:
- We had an engineering aspect to almost every lesson seen.
- It was very nice to know that a lot of the stuff that I already do can be done with a little adaptation to be more STEM like.
- Gives you some ideas on labs or lessons that I can do with my students.
- Helped me develop some lessons and labs.

Site Visit:
- It was very clear that the teacher professional development program is part of a larger STEM education teacher workshop week.

Teacher Focus Group
- STEM is the focus of the larger week long teacher workshop.

Evidence of a strategy for increasing diversity/inclusion as a means to attracting minorities to the science and natural resources field

Administrator Questionnaire:
- Mostly White/Caucasian, English-speaking, equal mix of gender and mix of urban, rural and suburban areas
- Mostly White/Caucasian, English-speaking, equal mix of gender and mix of urban, rural and suburban areas
- Our marketing has been mainly directed towards recruiting their students into our STEM outreach programs. Here we attempt to obtain diversity of race, gender and socioeconomic backgrounds. We are limited in the diversity of the teacher demographics; but have had some success with increasing the diversity of our student participants.
- Diversity, particularly socio-economic diversity, has enhanced our student programs. Less so with the teachers.

Administrator Interview:
- Program continues to reach the same teachers over the years; we have to work to retain teachers year to year.
- The grant we received requires us to target underserved schools to reach teachers. We offer a stipend for the teachers. We’ve built a program that is now in year three by meeting with school administrators to invite teachers to participate. We also visited the schools to market the program to teachers. We have had a high retention rate.
- We have a diversity of seasoned teachers and new rookie teachers.
- We have inner city urban schools and parochial schools too.

Site Visit:
- When the original program was established, a handful of local school were identified to participate. Little work has been done to market to new additional schools.

Teacher Focus Group
Teachers are from local parochial and public high schools in the urban and suburban area.

Evidence of data-driven assessment and evaluation of efficacy of teacher/scientist partner programs

Administrator Questionnaire:
- For the past five years, we have contracted with an external evaluator at the University of Cincinnati. The external data we have received is very insightful and extensive. We try to adjust our programs based on this feedback.

Administrator Interview:
- For the yearlong, high school program, we contracted with the Evaluation Services Center at the University of Cincinnati. Two of the staff members would work closely with us to develop a variety of instruments. They then collected the data (quantitative and qualitative) from every aspect of the program: workshop, summer camp and any interactions with the teachers throughout the year. They come to the start of every workshop to explain to the teachers what they are doing and why they are doing it. We’ve received numerous reports from them.
- For the daylong grade school field trips at the Station, it’s done in-house and much less comprehensive.

Teacher Questionnaires:
- I don't remember if I did or did not complete a program evaluation

Evidence of programmatic structure for implementation and transference back into the 12 classroom or field experience:

Administrator Questionnaire:
- Yes, we do include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home
- A few ways we structure our professional development programming to include time for teachers to work collaboratively and make a plan on how to incorporate their new learning into their teaching environment back home: The first way is by conducting sessions together with all of our teacher participants, regardless of their subject matter. In other words, we hold STEM sessions, just as often as specific content sessions. Also, we schedule times to visit the high school teachers in their own classrooms and then invite them back on campus or to the Field Station with their students.
- Yes, we had an online reporting form for each lesson or activity that was implemented from our summer PD, that our external evaluators would monitor. Recently, we have discontinued this due to funding but document these anecdotally.
- Teachers are more likely to implement the activities when we visit their classrooms to provide support and/or when we loan them equipment and supplies for the activities. We have not been as good as we could be in following up with them.

Administrator Interview:
We do create a couple pre and post field trip activities for teachers to implement with this students. Only a handful of teachers have implemented these.

Teacher Questionnaires:
- No, the program did not included time to work on an implementation plan plan to use with my students.
- Yes, the program included time to work on an implementation plan to use with my students.
- No, I have not participated in any accountability measures to track how you are implementing you new knowledge and learnings with your students. No pressure is great, because schools mostly only care about test scores.
- Creating more engaging lessons and labs
- The majority of my students can't learn the basics and don't have enough knowledge or skills to conduct the labs and lessons. Most of my students don't care about learning and I have to trick them to learn.

Teacher Focus Group
- The field station gives me real-life experiences that I can share with the kids. It’s one thing to teach info from a book, but it adds a whole new dimension when you can teach from experience.
- This professional development offers real world examples of how biology knowledge is used everyday; I use photos in my classes as examples; it’s why I’m a teacher.
- The time spent at the field station helps reconnect me with a lot of the ecological concepts and gives me that real world connection. I wished that more time could be spent there to perhaps fine tune or develop lesson(s) where data or perhaps visiting the station would be useful.
- Most real-life research examples I use stem from my experience at the field station both as a student in college and now as a teacher. I can use it as a place right in their backyard that does ‘science.’ I’d love to in the the future, use the data to design lesson plans.
- One great advantage to the field station experience is witnessing as a peer, that college-level teaching. It allows/lends itself to great collaboration. Overall, I leave the workshops re-energized and passionate about teaching science.
- It makes my teaching more real-world for the students. Being able to reference current research being done locally helps them apply concepts in class to their lives. Seeing the options of activities at the field station that I can customize to my field trip helps me to tailor certain lessons to what the students will see on their field trip to the station.

Evidence of planning and logistical strategies

Administrator Questionnaire:
- Multi-day Summer/June weekday workshops work best
- We pay the teachers a stipend as an incentive to participate in our programming.
- Our funding comes from Foundations, both local and national.

Administrator Interview:
- Summer is best time for workshops.
- Teachers get paid to go to summer workshops; we then go out and visit schools throughout the school year. University faculty get stipend for visiting schools and teaching workshops.

Teacher Questionnaires:
- Single weekdays during the summer are best.
- Some prefer graduate credits and some prefer graduate credits

Other Pertinent Data

From Administrator:
- We have both quantitative data and qualitative data. Here are a couple of quotes:
  “I feel that cooperative nature between college faculty and STEM teachers within the program is the most useful aspect of the project. The far-reaching opportunities to both faculty and students will certainly last throughout the remainder of the program and produce relationships that will reach into the future.”
- “The shared ideas and best practices between participants and instructors. This has been a wonderful experience; I know have a network of teachers in my field that can help me in my classroom. The technology ideas were really helpful to me. I love technology, and found some new tools to aid my instruction.”
- From their feedback, the collaboration with faculty and teachers, the facilities and the on-going, year-round support is most unique and valuable to them.
- Taking teachers out to the field station creates a familiarity with the place so that they will more likely bring their students out for field trips. They become ambassadors for the field station.
- College faculty and teachers went a ‘roadtrip’ to visit each of the teachers’ classrooms in order to better understand what their available resources and space includes. This built credibility between the teacher group and the teachers and faculty; a very strong community. This made the college faculty more sensitive to proposing things to teachers that are actually within the realm of possibility and implementation in their classrooms. The college faculty gained a much stronger understanding of the teachers’ constraints and have since helped the teachers develop activities that work within their current situations.
- During the month of May after the college semester if completed, students from the education department (pre-service teachers) pair up with field station undergraduate interns to facilitate K-12 field trips.

From Teachers
- It allowed me to connect with other science teachers, where we can share ideas and learn for each other. Which is way more helpful and important than any other PD that I have been a part of in the last 10 years.
Evidence of bringing teachers and scientists or researchers together

Administrator Questionnaire:

- We have a few scientists/researchers on site and also our hydrology and climate technicians. The bulk of our scientists are based on the main university campus two hours away.

1) Teachers work alongside scientists for research studies as part of Research Experience for Teachers Fellowships (or similar programs) or during two-day workshops, and
2) Teachers practice field investigations during workshops that are similar to or based on our research and then they engage their students in these same field investigations with help and support from the scientists (e.g., a network of teachers/students doing leaf litter decomposition studies based on our LTER long-term decomposition studies).

- 1). Make the experience as easy as possible for the researcher. They really don't get much credit for doing this kind of work so it's important to make it super easy for them! Be organized, purchase field supplies for them, get them a motor pool car, help them think through how they want to engage the teachers, and give them a thank you mug or coffee gift card at the end. They really do appreciate being appreciated. If you have access to funds, acknowledge their contribution by providing salary for them or for one of their staff to help out. 2). Pick the right researcher! Some are very eager to do this and clearly have good communication skills. Some are eager to do the work, but need a bit more hand holding to communicate with the teachers at an appropriate level, but if you work with them, then they can help out in future interactions with teachers. Also, keep track of who you have asked and don't ask them too many times! It IS important to work with the researchers to help them design a good experience for the teachers so the teachers will get what they need out of it.

Administrator Interview:

- At our field station, people are more inclined to working with people; it’s a collaborative environment. Personal relationships make all the difference.
- I the program coordinator for our teacher workshops make it as easy as possible for the scientists to participate by offering generous appreciation for their time and commitment to the program.
- Teachers are interested in working with any professional science folks (grad students, researchers, scientists, etc.).
- When possible scientists are given a salary for working with teachers.
- Clear articulation that the teachers are doing something that is valuable and are creating a product. It is the product that the scientists identify with most of the time.
- It is the teacher/scientist relationships that motivate teachers to participate in the program; not so much the LTER. However it is a package deal; teachers do appreciate contributing to long term data and drawn to contributing the the program.
Field Observation:

- During the data literacy planning retreat, K-12 math and science master teacher teams from local schools joined university scientists to develop and plan the upcoming summer teacher institute. These teacher-scientist relationship formed during the planning retreat were authentic and productive.
- Scientists committed to helping teachers teach data literacy by providing relevant data sets to the teachers and serving as a resource.
- Scientists were completely engaged in learning the language of K-12 math and science teachers while also, the teachers were engaged in finding common language with the scientists to collaborate on data literacy.
- Scientists are excited to work with teachers; one stated that “working with teachers give me something ‘real’ to do. It makes her work feel important and allows scientists feel that someone else cares about her work. Another scientists noted that “science needs to come out of the journals” and needs a voice; we need to translate the science to the non-scientist community.
- Emphasis was put on the fact that all involved with the planning retreat were experts, teacher and scientists alike.

Evidence of outdoor field-based programming
Administrator Questionnaire:

- I work in a program that is the Schoolyard LTER partner for our LTER site, and our entire focus is on getting teachers (and ultimately their students) outdoors. We design our professional development to get teachers outdoors as much as possible! We try to sprinkle the outdoor time in between some indoor seat time to keep everyone interested and awake and engaged, and this strategy is helpful if the weather isn't so great. We use our LTER field station headquarters because it is affordable and easy to house teachers there, and because there is easy access to the outdoors.
- Yes, our teacher professional development programming requires outdoor field sites to facilitate the program.
- I cannot as easily facilitate our teacher professional development indoors. I certainly CAN facilitate it indoors, but it would not be as effective because the goal is to increase teachers capacity in engaging their student in field investigations. They cannot increase their confidence in doing this without experiencing outdoor field investigations themselves! That being said, we can certainly demo and practice with some equipment or setup stream tables or bring in soil or potted plants to practice some elements of field investigations. In fact, preparing teachers to think about doing indoor prep AHEAD of taking students outside is a good thing to include in professional development.
- It is very important to visit your field site before you take teachers there, and make sure you have everything set up ahead of time. Teachers need to be briefed on appropriate clothing to wear. it's good to have a plan "B" if weather might be an issue - for example, when we put out pitfall traps for insects, and it rains, you
often don't get many insects for them to work with. We have had a cache of insects from other related studies that we could look at in this situation and/or we have had an already collected dataset of insect biodiversity that we have used in that situation too. The teachers went and collected the traps, but used the already collected dataset.

Administrator Interview:
- We get teachers outside almost immediately upon their arrival at workshops.

Field Observation:
- A field trip to the actual research sites across the forest was facilitated during the planning retreat. Teachers appreciated seeing the science in action as a means to brainstorm field possibilities for the larger summer teacher institute.
- The primary focus was to consider teaching with context in context; meaning to teach relevant content in the place where the content may be generated (science in the field).

Evidence of inquiry-based learning and instruction

Administrator Questionnaire:
- We like to start teacher workshops with an opportunity to do a mini very open ended outdoor investigation (for example, hand out pictures of local species and have the teachers go into the forest in small groups to find them and come up with questions they are curious about). We practice and discuss researchable questions, and if the time allows, we guide our field investigations for the workshop with the questions that the teachers come up with. We break the teachers into small groups to look at insects and/or make visualizations of the data they collected and have them present their work to the rest of the group.
- We have the same struggle that teachers have in the classroom in structuring our field investigations and workshops based on participant-centered investigations vs. instructor-centered questions. In a typical two-day workshop, we will provide some mini participant-guided investigations (as described above) that allow participants to explore, but then we'll have an instructor-guided field investigation (such as about insect biodiversity in different types of forests) that we will do to give them practice in all steps of the science inquiry process.

Administrator Interview:
- We do hook activity almost immediately to get teachers engaged in curiosity and wonder. This models what they can do with their students back home. We spend a lot of time formulating scientific questions with teachers. We practice many protocols and then give teachers opportunity to choose which protocols they want to use with their students to answer their questions.
- We are limited by time just like teachers are in their classrooms to fully explore some scientific questions. And the teachers have varying capacity and comfortable to incorporate inquiry. We wrestle with the issue of teachers developing experiments that may or may not work as we want them to be successful.

Field Observation:
The purpose of the teacher-scientist planning retreat was to explore opportunities for teachers to incorporate inquiry into mathematics education as well as science curriculum. Opportunities for inquiry were identified within the Next Generation Science Standards and Common Core State Standards in Mathematics Math Practices often throughout the planning retreat.

The Scottish Storyline Method incorporates inquiry while it also motivates students to learn as they become their own ‘meaning makers.’

The focus of this particular teacher-scientist partnership program is data literacy (using, understanding, and analyzing data) and less on data investigations.

During the planning retreat, inquiry and adaptation was modeled by the retreat facilitators as they welcomed the need for program evolution, adaptation, and reiteration.

Evidence of increasing environmental literacy for both the teachers and their respective students

Administrator Questionnaire:

- environmental literacy and science topics have you recognized that teachers could use more training in: climate change, data literacy - e.g., designing how to collect and manage environmental data, analyzing environmental data
- We spend a lot of time on creating researchable questions in our teacher workshops and make sure that teachers get to practice all parts of the scientific process (including working with data). We have gotten funding to do specific institutes focused on climate change topics, and those programs have been very popular.
- At our field station LTER, we incorporate the knowledge generated at that place (as described above in how we involve scientists). We also incorporate the writings of the Long-Term Ecological writers in residence program which is very place-based. Then we help the teachers think about how THEY can incorporate local place-based content back in their communities and schoolyards.

Administrator Interview:

- Teachers are self-selected and have a high level of prior knowledge. Teachers are not coming to a 1-day workshop, rather it’s a deep extensive long-term professional development experience.
- We focus most on the process of science and less on content.

Field Observation:

- One scientist noted that “veteran teachers were not trained in climate science as it was not taught when they were in school; so in-service programs are essential.”
- It was noted during the training retreat the importance of learning the stories of this place, of this field station through reflective activities outdoors, interactions with the current research on the ground, etc.
- Teachers admittedly need help learning to use data tools such as Excel and google spreadsheets.
- Teachers need practical experience and practice with online data tools and accessing databases such as SNOTEL, USGS stream flow, etc.
- An intended outcome for the Numbers in Nature program is for teachers and scientists to develop a better understanding of contextualized curriculum implementation.
- During the planning retreat, scientists shared their research and more specifically their process of science and investigations.

Evidence of STEM education

Administrator Questionnaire:
- We do address interdisciplinary topics such as climate change whenever possible. We also make connections between math and science through working with ecological data. We try to recruit science-math teacher teams, but we have not been super successful with that effort. We do have a science teacher and a math teacher team who will be our RETs for the summer of 2016, and I think they will really be able to help us with our efforts to better integrate math and science. Some of the RET experiences have been very STEM-focused (e.g., physics teacher investigating watersheds as airsheds with one our atmospheric scientists and looking at change in forest cover using satellite data with a landscape ecologist).

Administrator Interview:
- The university’s STEM research center is a key player in the facilitation of this program.

Field Observation:
- The data literacy program is clearly including science concepts and understanding, mathematics practices, and the use of technology to access and manipulate data.
- The Next Generation Science Standards (NGSS) and Common Core Content Standards (CCCS) for Mathematics were critical in the programming and include STEM principles and content.
- The NGSS and CCCS were thoroughly explored during the planning retreat to ensure that the scientists and teachers were appropriately introduced and on the same page with the language of academic standards.
- It is a goal of the data literacy program to create math and science literate citizens.

Evidence of a strategy for increasing diversity/inclusion as a means to attracting minorities to the science and natural resources field

Administrator Questionnaire:
- Our field station is in a rural area with mostly rural, white, low socioeconomic status. We recruit teachers from throughout our state, and that includes just about everything! Urban, rural, many languages spoken, etc.
- We specifically recruit for teachers working in title one schools/school districts by giving them priority in our application process. We make no effort to recruit diverse populations of teachers except if we consider their content areas (e.g., science or math), the types of school in which they work (charter vs. public vs. private), and how many years they have been teaching.
Administrator Interview:
- We encourage teachers to build a team to attend professional development with them.
- Our priority has been reaching teachers at Title-1 schools.

Field Observation:
- Program focus is on ‘high-need school districts’ which is determined by the percentage of teachers who are not considered ‘highly qualified’, students who receive free and reduced lunches, as well as other socio-economic factors.
- Master teachers who participated in the planning retreat were from rural public charter and public schools with ‘high-need’ status.
- Math and science teachers from elementary, middle, and high school were included.

Evidence of data-driven assessment and evaluation of efficacy of teacher/scientist partner programs

Administrator Questionnaire:
- We are very often interested in what happens well after the teachers are finished with the PD. It is hard to find the time for us to follow up with them much later and to get the teachers to respond when they are not sitting in front of you anymore. When they are taking a course for credit, then you can get them to respond to surveys or write reflections, etc.

Administrator Interview:
- Funders are looking for effective documentation outcomes.
- We have conducted external reviews.
- We conduct surveys for our workshops
- We complete logic models identifying clear outcomes and have other strong evaluation plans.

Field Observation:
- It was clear that evaluation and assessment are a critical piece to the programming with the robust sample curriculum pieces and discussions around developing new curriculum.
- During a one-on-one teacher-scientist dialogue activity they were asked to discuss potential date literacy assessment tools.
- Planning retreat participants were asked to complete a retreat evaluation.

Artifacts and Documents
- Sample curriculum documents included assessment and evaluation pieces.
- A stated project outcome for the planning retreat was to determine the evaluation goals of the data literacy program.

Evidence of programmatic structure for implementation and transference back into the 12 classroom or field experience:

Administrator Questionnaire:
We ALWAYS include time at the end of a workshop for planning. We usually give them the option of individual planning or working with another teacher. We provide a guide for planning, but don't require them to use it. We want them to do something that is useful for them. If it is a long-term PD experience that includes multiple workshops, then we include time for planning at each workshop and emphasize refinement of their new teaching techniques, content, etc. that they practiced in the classroom. Especially for the more intensive experiences like RET fellowships we recruit teachers in pairs from the same school if at all possible so they get to plan and implement together.

It is really challenging to have any accountability mechanisms in place to ensure teachers are implementing their new knowledge and learnings into their teaching environments if we have only a two-day workshop. We definitely have accountability when we credit the workshops, and whether we credit them or not depends on how many teachers are interested. Their assignments for course credit are to implement their new knowledge and to tell us how it went and how they might improve and refine. For RETs, we structure the pay in such a way that they are required to implement their new knowledge and write a report to us before receiving the second half of their stipend.

Field Observation:
- It was clear that the program understands that handing teachers a curriculum will not result in implementation; instead teachers need to experience the data to have more success with implementation. It’s important to make it real, authentic, and relevant to their lives.
- Much time was spent by teacher and scientists sharing ideas about how to implement data literacy work into their classrooms as well as into the other teachers’ classrooms who will be participating in the summer teacher institute.
- The intent was to create a curriculum that serves as a lens or framework for teachers to teach through to increase data literacy for their students. The intent was not to create a new curriculum to hand to teachers to strictly implement.

Artifacts and Documents
- Samples of potential curriculum were shared that include multiple ideas on how to implement data literacy and the science from the field station into the classroom.

Evidence of planning and logistical strategies
Administrator Questionnaire:
- mid-fall (October) is a good time. Early spring (early April) isn't bad either. Summer sometimes works well.
- It is always multi-day - from two days to four weeks (if you count RETs and similar research experiences); weekdays are best.
- I write many many grants. We get some support through the NSF LTER program, and we get some small pieces of support (substitute reimbursement usually) through our state natural resources program, the program in which I work.
- No, we do not charge a fee; our programs are FREE
In regards to offering graduate credit or continuing education credits for participants: “sometimes. It depends on the interest level of the group. We generally give continuing education credits (graduate level), but we struggle to find ways to make it affordable for teachers.”

Field Observation:
- The program is made possible by a $135,000 grant from the US Department of Education.
- Group norms were stated and shared during the introduction of the retreat to encourage strong participation and establish an equal playing field for the teachers and scientists.
- The program is striving to create groups of practice or networks of teachers who can work together.
- The teachers and scientists were asked to provide a 5 minute introduction presentation as a means to build a common understanding of the perspectives and experiences each brought to the retreat.
- Master teachers participated in planning retreat and then will assist in facilitating the summer teacher institute for 30 local teachers.
- Program involves a year long commitment from all teachers involved.
- Master teachers along with the 30 local teachers will receive 6 graduate credits throughout the year long program.
- Teachers receive support for student experiences as well as ongoing support from the university field station and scientists throughout the year.
- Catered meals were provided for free to all retreat planning participants.
- Some level of compensation/stipend will be offered to the master teachers and scientists for participating in the planning and facilitating the summer teacher institute.
- Teachers prefer graduate credits to continuing education credits as the graduate credits allow them to move up the pay scale AND keep their teaching license current while continuing education credits only apply to license renewal.
- The intention was made during the planning retreat to avoid too much ’sit and get’ style of workshop facilitation and instead much time was spent in partner dialogue, small group discussion/sharing, and large group discussion as well.

Artifacts and Documents
- A clear agenda with clearly articulated project outcomes was emailed to planning retreat participants in advance as well as a contact sheet.

Other pertinent data:

How administrator’s position is funded:
- The state Natural Resources Education Program, a partnership program funds her position; partnership between the university Forestry and Natural Resources Extension and now the university STEM research center.

From Administrator:
Most teachers find it very valuable. They find things they can put to use in the classroom right away. Many choose to come back for more and have long-term relationships with me, the Andrews LTER, and the scientists they have worked with.

- It is deep/long-term and focuses on "science in action" and how to get their students involved in science in action.
- We ask teachers to help draft the structure of the workshops and ask teachers to facilitate pieces of the workshop. We identify teachers who bring perspective and expertise that folks at the field station don’t necessarily have.

From Field Observation:
- During the planning retreat a fair amount of time was spent considering where teachers are at on the contextualization continuum spectrum. Acknowledging where they are at and where they feel comfortable teaching in context with context is helpful in understanding how they may implement their experiences during in-service teacher professional development back to their students.