

THE EFFECTS OF A PROFESSIONAL DEVELOPMENT PROGRAM ON
SCIENTIFIC INQUIRY ON ENVIRONMENTAL EDUCATORS'
BELIEFS, SELF-EFFICACY, AND INSTRUCTION

by

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ABSTRACT

As educators are faced with the challenge of trying to reform their science teaching and incorporate the Next Generation Science Standards, training to support this change is needed. A professional development program, Understanding Newly Learned Environmental Science Skills (UNLESS), occurred over the course of the 2015-16 school year with a self-selected cohort of environmental educators. This action-research based study examined the question, *What are the effects of a professional development program on scientific inquiry on educators' beliefs, self-efficacy, and instruction related to inquiry?* These educators learned from science experts and through collaborative inquiry-based lessons shared by the cohort. The course of the program was directed by the interests of the educators. Methods to collect data included surveys, observations, concept maps, interviews, and the facilitator's journal notes. At the conclusion of the UNLESS program, the data showed an increase in participants' confidence, attitude, and instruction related to inquiry. Participants went from less than 20% of their programs including a student-driven investigation to 52%. Indicators of inquiry-orientation seen in observations also increased. While educators still described some ongoing challenges to doing inquiry with students at the conclusion of the program, other challenges were no longer reported. Suggestions for the future of this program are shared along with implications for how to support environmental educators in their pursuit to become more inquiry-based teachers.

INTRODUCTION AND BACKGROUND

My teaching is built on a belief that educational experiences in nature have the capacity to inspire students to learn about and take care of our natural world. My beliefs have been cultivated by my work with NatureBridge, a residential environmental education program that operates in Yosemite National Park. NatureBridge's mission is to "foster environmental literacy to sustain our planet" (NatureBridge, 2012, Mission section, para. 1). The core educational framework for NatureBridge environmental science programs has themes of sense of place, interconnections, and stewardship. These themes help us strive for desired student outcomes of personal growth, improved interpersonal skills, academic impact, and responsible environmental behavior (Appendix A). We push students to expand their comfort zones, work together as a team, and learn about the natural world by engaging in science. We hope that students leave our program equipped with ideas and inspiration to make a positive impact on our world.

NatureBridge in Yosemite National Park usually serves over 10,000 students each school year. From July 1, 2013 to June 30, 2014, NatureBridge had over 13,000 youth participants for environmental science programs (R. Dunn, personal communication, June 5, 2014). Students are typically from California. They come to Yosemite for a one to six-day program. The trip coordinator, which may be a school teacher or principal, can prioritize the outcomes that they want for their students. NatureBridge currently employs 40 educators in Yosemite National Park. Some of these educators come to NatureBridge with teaching credentials and/or a background in science. As a Mentor Teacher for NatureBridge in Yosemite National Park, I work with NatureBridge educators to help them consider how they can improve their teaching.

NatureBridge is committed to teaching high quality science and has adopted the Next Generation Science Standards (NGSS Lead States, 2013). During the 2014-2015 school year, NatureBridge strived for each student to take part in an investigation that involved multiple practices of science. As NatureBridge educators moved toward strengthening their inquiry-based instruction and each student participating in an investigation, it became clear that they needed more training about how to teach in this manner. During that same school year, the Understanding Newly Learned Environmental Science Skills workshop (UNLESS) was started as an optional professional development program. For its first year, the program targeted NatureBridge educators who had been with the organization for at least two years. Modeled after professional development offered by the Exploratorium in San Francisco, the UNLESS program strived to develop a learning community for our educators and learn from other organizations. Educators met for one and a half hours each month for one school year. During the fall semester, participating educators learned how inquiry was being implemented in other organizations and got to know about real science research that is being conducted in Yosemite. In the spring semester, small groups of two to three educators presented a lesson, activity, or artifact related to scientific inquiry to the other members of UNLESS.

This action research-based study was an effort to improve this professional development program as it entered its second year. My hope was to better understand the impact that the program has on NatureBridge educators. Furthermore, this study could have implications for how to support educators in environmental education organizations to teach science as inquiry with confidence and skill.

This study's primary focus question was, *What are the effects of a professional development program on scientific inquiry on educators' beliefs, self-efficacy, and instruction related to inquiry?* The following sub-questions were addressed.

1. What are educators' beliefs, perceived competency, and implementation of inquiry instruction before, during, and after the UNLESS professional development program?
2. What challenges are educators facing in reforming their teaching after being in this program?

CONCEPTUAL FRAMEWORK

The process of doing science can engage students' curiosities and motivate them to learn (National Research Council [NRC], 2012). Inquiry has been shown to have positive results in building students' conceptual understanding of science principles and their ability to apply science knowledge in real-life issues (Anderson, 2002). The American Association for the Advancement of Science, National Science Teachers Association, and the NRC recommend inquiry-based instruction as a way to understand and teach science (Llewellyn, 2013).

Students' understanding and interest in science is a way for citizens to be able to make well-informed decisions regarding the future (NRC, 2012). Rudolph (2014) states that the focus of science education "should be on helping students see how science generates knowledge in all its diversity" (p. 1074). This is a reflection of what Dewey recommended in the early 1900s. Dewey believed that students should do science and learn from their own experiences. When students are involved in the practices of science, scientific knowledge can carry more meaning and will be integrated into the way students think about the world (Crawford, 1999).

Understanding Inquiry

When pursuing inquiry-based instruction, the problem arises of trying to understand precisely what inquiry means. A variety of definitions and interpretations have surfaced in the science education community regarding inquiry (Anderson, 2002; NRC, 2012). The NRC (2000) identified five essential characteristics of inquiry teaching and learning. These included learners (1) being engaged by scientifically oriented questions; (2) giving priority to evidence; (3) formulating explanations from evidence; (4) evaluating explanations in light of alternative explanations; and (5) communicating and justifying proposed explanations.

Research has suggested that teachers may have an inaccurate understanding of inquiry and lack the knowledge of how to do it. Capps and Crawford (2013) found that while beginning teachers' understandings of inquiry were not aligned with what was expressed in the National Science Education Standards, the teachers were confident in their ability to teach science as inquiry. This supported other research that showed a misunderstanding between what teachers may think of inquiry and how it is defined in standards documents. This confusion can prevent actual changes toward inquiry-based teaching (Davis, Petish, & Smithey, 2006; Windschitl, 2003). Additionally, teachers who lack experience as students in an inquiry-oriented learning environment may find implementing inquiry to be an abstract strategy (Lotter, Harwood, & Bonner, 2006). In order for teachers to shift toward inquiry-based instruction, they need to develop an understanding of what it means to teach and learn science as inquiry (Bigger & Forbes, 2012; Davis et al., 2006; Llewellyn, 2013).

The lack of understanding surrounding the definition of inquiry “provides an opportunity for these groups [education researchers and teachers] to collaborate and refine their thinking about what inquiry is and how to best support inquiry-based instruction” (Levy, Thomas, Drago, & Rex, 2013, p. 390). The Next Generation Science Standards use science practices as a way to represent inquiry (Llewellyn, 2013; NRC, 2012). These practices intend “to better specify what is meant by inquiry in science and the range of cognitive, social, and physical practices that it requires” (NRC, 2012, p. 30). The science practices include (1) asking questions; (2) developing and using models; (3) planning and carrying out investigations; (4) analyzing and interpreting data; (5) using mathematics and computational thinking; (6) constructing explanations; (7) engaging in argument from evidence, and (8) obtaining, evaluating, and communicating information.

Addressing Teachers’ Beliefs

Teachers’ beliefs of scientific inquiry have been shown to play a critical role in the teachers’ implementation of inquiry-based instruction (Brand & Moore, 2011; Crawford, 2007; Windschitl, 2003). Teachers need to examine their current beliefs and gain evidence that inquiry-based instruction is effective in their setting. Forbes and Zint (2011) learned that teachers who valued scientific inquiry also believed that they were capable of and did scientific inquiry with their students. In a different study by Biggers and Forbes (2012), preservice teachers believed student-directed forms of inquiry provided more authentic science experiences and created opportunities for students to develop higher levels of ownership and engagement. These values for inquiry-learning were important in the decisions the teachers made about science lessons.

Making teachers aware of their beliefs may be necessary for teachers to accept a more realistic view of scientific inquiry (Windschitl, 2003). If teachers' beliefs are not addressed, this can hinder the effectiveness of the implementation of inquiry-based teaching (Crawford, 2007). Teachers need to examine their practices alongside their values and beliefs in order for the change to inquiry-based instruction to be lasting (Blanchard, Southerland, & Granger, 2009).

Beginning teachers who are able to expand their beliefs of inquiry to include teacher-directed guided inquiry may be more successful in initially implementing inquiry-based instruction (Biggers & Forbes, 2012; Davis et al., 2006). Teachers with a limited understanding of the inquiry continuum restricted their view of inquiry to only open, student-directed inquiry. They felt overwhelmed and as though they were losing control of their students (Biggers & Forbes, 2012). The inquiry continuum can also be part of a teacher's strategy to support students as they engage in inquiry. Teachers should be prepared with methods to help students understand and use science practices (Windschitl, 2003). In these ways, scaffolding science endeavors can be helpful for teachers and students who are new to inquiry.

Supporting the Transformation to Inquiry-Based Instruction

Long-term professional development, in which teachers work collaboratively and help determine the goals of the training, can be effective in helping teachers reform their teaching (Lotter et al., 2006; Brand & Moore, 2011). The professional development should include content and pedagogy. Teachers should be engaged in inquiry as a learner and be able to make connections to their teaching setting (Davis et al., 2006). Brand and Moore (2011) studied a professional development program that created an environment

where concerns were addressed, new knowledge was constructed, and ideas were shared and supported. This helped to move these teachers toward reforming their science teaching strategies.

Reflection can be a key part of growth and adopting inquiry into one's teaching. According to Llewellyn (2013), the path to becoming an inquiry-based teacher involves assessing your present self. In order to address naive perceptions of inquiry, teachers' beliefs should be clear to themselves (Windschitl, 2003). Capps and Crawford (2013) discovered that teachers were more successful changing their practice if they were engaged in reflection. Specifically, the reflection should connect knowledge to practices and encourage teachers to alter their beliefs. Reflection can also motivate and encourage teachers to learn from their experiences (Crawford, 1999). For reflection to be effective there should be focus on what action the teacher plans to take (Loughran, 2002). Blanchard et al. (2009) reported that teachers' open reflection was a driver for them to consider future changes. Reflection helped these teachers change their practices as well as how they thought about teaching.

Crawford and Capps (2013) found that professional development was effective when teachers were engaged in scientific investigations and encouraged to reflect on their teaching practices. Windschitl (2003) uncovered that commonality among the teachers in his study that incorporated inquiry into their own teaching was their long term research experiences. Teacher professional development with science experiences should grant time for the teachers to reflect on bridging the gap between the science and student inquiry experiences (Lotter, Harwood, & Bonner, 2007). Structured, strategic questions

could help teachers make the connections between their beliefs and conception of inquiry and their design of future learning experiences for students (Windschitl, 2003).

Teachers can be challenged to start teaching inquiry even when it aligns with their beliefs (Davis et al., 2006). To teach inquiry, Crawford (2000) found that the teacher takes on many roles and potentially greater levels of involvement than the traditional teacher. Focus toward how to help teachers succeed in the everyday events of inquiry-based instruction is needed. Ongoing mentoring alongside professional development has been recommended by the NRC (2012). Beginning teachers were able to improve their inquiry-based practices with the assistance of collaborative mentors (Crawford, 1999; Nam, Seung, & Go, 2013). Mentors supported trying new things and stimulated reflection.

Llewellyn (2013) says that support is needed during the self-discovery process to become an inquiry-based teacher. Shifting to inquiry-based teaching is a change from the status quo (Crawford, 2007). Blanchard et al. (2009) “suggest the need for further research to identify the most effective and appropriate way of weaving together theory, reflection, and the research experience to engender teacher change” (p. 356). Research needs to be done to explore the challenges faced by new and experienced science teachers as they shift to more inquiry-based instruction (Davis et al., 2006).

METHODOLOGY

NatureBridge employs 40 educators to teach environmental science programs in Yosemite National Park. Eleven of these educators participated in the Understanding Newly Learned Environmental Science Skills (UNLESS) professional development program during the 2015-2016 school year. These educators opted to participate for a

variety of reasons, ranging from wanting to be part of a learning cohort to wanting to feel more confident in facilitating investigations with students. Educators' experience stretched from one semester to six years with our program. Some educators had formal training as teachers while others had graduate degrees in science. The one requirement for participation in the UNLESS program this year was the NatureBridge educator must have taught at least one semester for the organization. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

This was the second year NatureBridge used UNLESS as a professional development program to help equip our educators as they endeavor to become more inquiry-based in their instruction. I participated during the 2014-2015 school year and became the facilitator of the 2015-2016 program. The beginning of UNLESS happened in conjunction with NatureBridge's commitment to having students engaged in investigations as part of our environmental science programs. Changes were made in this year's UNLESS program as a result of feedback from last year's participants.

UNLESS started in October with a full-day of training. For half of the day, we went out with National Park Service scientists, specifically the park's hydrology team. Educators were able to see and try different techniques that are used in resource monitoring. The latter half of the day included a workshop from the Exploratorium's Institute for Inquiry to have educators consider different approaches they use to teach science (Exploratorium, 2006). This involved educators going to three stations that had different approaches to explore a similar idea. One station had instructions for participants to follow, another had challenges to try, while the last was discovery

exploration. After educators tried each approach, we discussed the characteristics of each and when they might choose to use those in their teaching. Each month following through March, educators met for an hour to an hour and a half. The November and December meetings involved learning about a park topic, the intertwining effects of drought, fire, and pine bark beetles, and then educators brainstormed how we might teach that information to students in the form of an investigation. A guided inquiry, in which the educators participated as students, was demonstrated in the December meeting. For the January through March meetings, educators worked in small cooperative groups to lead the rest of the cohort through an inquiry-based lesson.

Data collection included several approaches: surveys, observations, concept maps, interviews, and notes in my journal. The Pre- and Post-UNLESS Survey was based on a similar survey by Forbes and Zint (2011). The survey measured participants' beliefs, perceived competency, and reported instruction for elements of inquiry (Appendix B). It was given during the first and last UNLESS meetings. The survey was scored using a Likert Scale of *strongly disagree* (1), *disagree* (2), *somewhat disagree* (3), *undecided* (4), *somewhat agree* (5), *agree* (6), and *strongly agree* (7). The data were analyzed with the Wilcoxon Signed Rank Test and examined for frequency changes. Cross tabulation tables were used to examine relationships between items or additional variables, such as tenure with our organization and formal teacher or science training.

The Reformed Teaching Observation Protocol (RTOP) was used during observations to assess the educator's inquiry orientation during a half or full teaching day (Appendix C). Field observations were conducted during and after the professional development program for three participants. The RTOP was scored using a scale of *never*

occurred (0) to *very descriptive* (4). Items specifically related to inquiry orientation were focused upon during data analysis. The data were analyzed with the Wilcoxon Signed Rank Test, and frequency changes were also examined.

Semi-structured questions were asked in one-on-one interviews during and after the treatment with three of the participants (Appendix D). Questions were also asked after observations and as a part of reflection during the professional development program. These questions encouraged reflection on beliefs related to inquiry instruction and its implementation. The data were analyzed for themes, and quotes were also used as evidence for other findings.

Concept maps around the topic of science teaching were created by participants as a cooperative group at the start and end of the program. As suggested by Miller et al. (2009), the difference in number of nodes and quality of the concept maps before and after treatment were examined. An example of the way the concept maps were analyzed was to see if concepts or terms were included that connected to elements learned in the professional development workshops. Nodes were categorized according to the level of knowledge, confidence and skills, professional language and terminology, and attitude or disposition in both the pre- and post-maps. Changes in the pre- and post-concept maps were related to the Post-UNLESS Survey questions.

The NatureBridge Science Investigation Tracking Form (Appendix E) was completed by educators upon the conclusion of each school group program they taught. This was a form created by NatureBridge to inform whether educators were conducting inquiry investigations with students. This data was examined to determine if there were any

trends or frequency changes in whether UNLESS participants engaged in this type of inquiry over the course of the program.

In addition to these data collection strategies, I wrote in a journal to record my reactions and some of my interactions with participants during the program. The information in my journal was another way to look at the effectiveness of the program and how it may have affected my own teaching practice or the participants. Journal entries were used as evidence for other findings.

The triangulation matrix shows how these instruments provided multiple sources of data to answer my primary and secondary questions (Table 1).

Table 1
Data Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5
<i>Primary Question:</i> What are educators' beliefs, perceived competency, and implementation of inquiry instruction before, during, and after the UNLESS professional development program?	Pre- and Post-UNLESS Survey	Interviews during and after the program; Interviews after observations	Reformed Teaching Observation Protocol	NatureBridge Science Investigation Tracking Form	Pre- and Post-UNLESS Concept Maps
<i>Secondary Question:</i> What challenges are educators facing in reforming their teaching after being in this program?	Pre- and Post-UNLESS Survey	Post-treatment and observation interviews	Pre- and Post-UNLESS Concept Maps		

DATA AND ANALYSIS

The data revealed an increase in confidence, positive attitudes, and instruction in relation to inquiry after UNLESS was completed. The Pre- and Post-UNLESS Concept Maps showed a greater number of nodes before the program (nodes= 43) versus after the program (nodes= 26; Figures 1 & 2). Some of the Pre-UNLESS Concept Map nodes were repeated within the map, although there was not enough repetition to cause the total to be

less than the Post-UNLESS Concept Map. The number of nodes categorized as related to level of knowledge and professional language and terminology were greater before the program while the number of nodes related to confidence and skills were greater after the program. Nodes categorized as related to attitude and dispositions were greater before the program although these nodes were less positive and related more toward the challenges of science teaching. The concept map before the program had multiple nodes that focused on buy-in, shifting expectations, and defining science. After the program, while there were nodes related to challenges, there were also nodes for fun, doesn't have to be complicated, support from peers and management, and science as a way to help students understand the world. An educator said that her concept of science teaching changed through participating in UNLESS because she learned "that science on trail does not have to be difficult or boring; it can be quick, fun, and simple...by discussing ideas with educators and hearing what they do on trail to encourage student-driven inquiry." Another educator said that, "group reassurance (a.k.a. science therapy) is always motivating for me!"

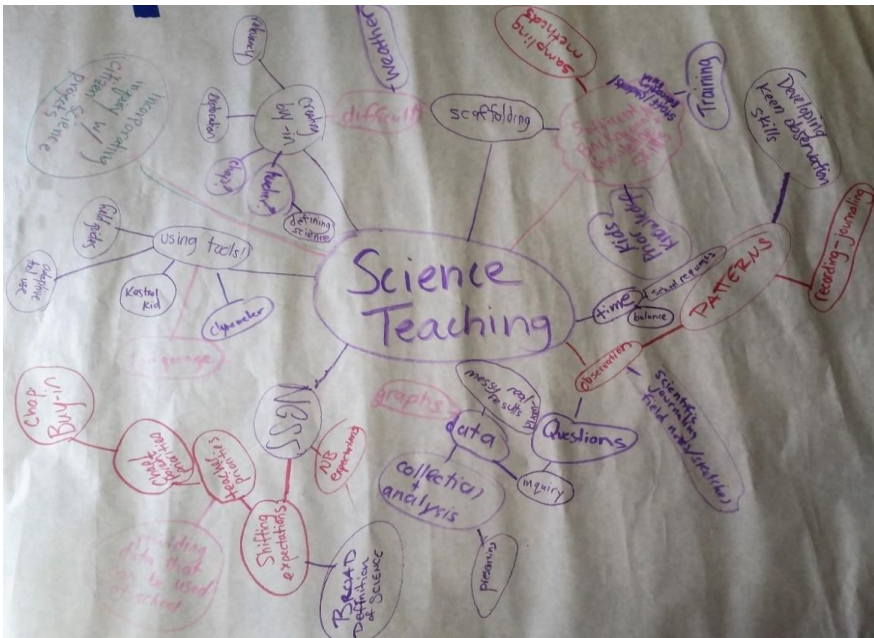


Figure 1. Pre-UNLESS concept map.

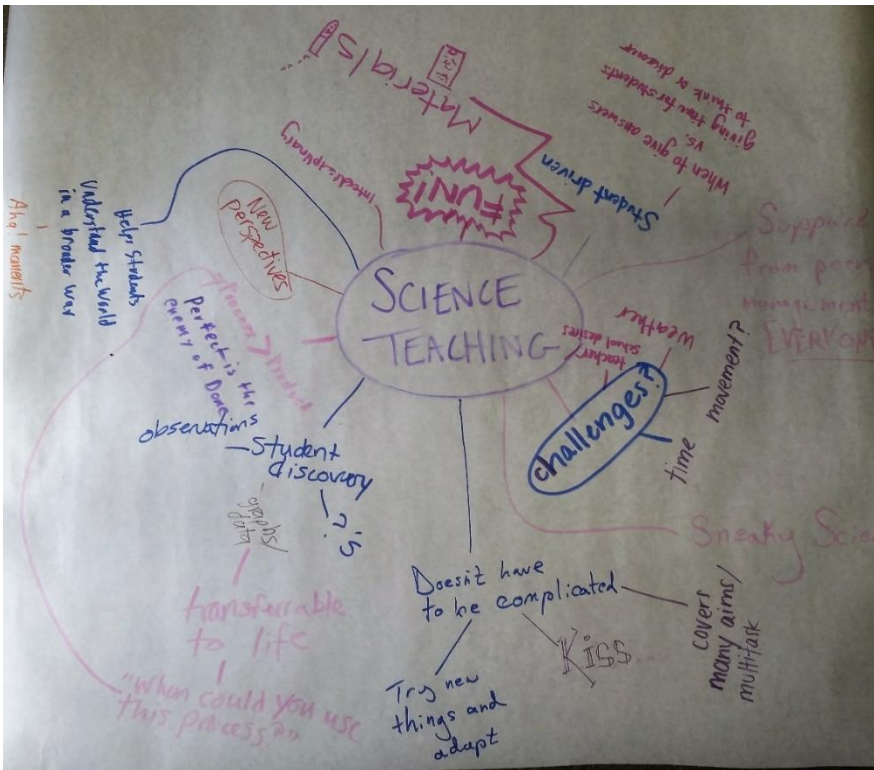


Figure 2. Post-UNLESS concept map

The Pre- and Post-UNLESS Surveys showed an increase in the median response of each Likert item related to what educators currently do to support their students in different elements of inquiry ($N=7$; Figure 3). There was a significant increase between the Pre- and Post-UNLESS Survey responses for whether educators currently teach students to defend an explanation based on evidence (Wilcoxon Signed Rank Test, $p= 0.036$) and communicate and justify proposed explanations ($p= 0.036$). The only other significant difference between the Pre- and Post-UNLESS Surveys was the increase in educators reporting that they have the necessary knowledge, skills, and resources to support their students to communicate and justify proposed explanations ($p= 0.022$). The least amount of change occurred in responses related to what educators believe that they should do as part of their science teaching. In these items related to educators' beliefs, the median responses only changed up to one rating on the Likert scale and were almost all *agree* or *strongly agree* in the Pre- and Post-UNLESS Surveys. One participant said after the program, "Since joining UNLESS, I have taken a shot at incorporating completely student-driven projects into my day, and have seen students be generally engaged." This was coming from a participant who before the program said, "I want to feel confident and competent guiding students in inquiry-based science investigations. I want to feel bought in!!"

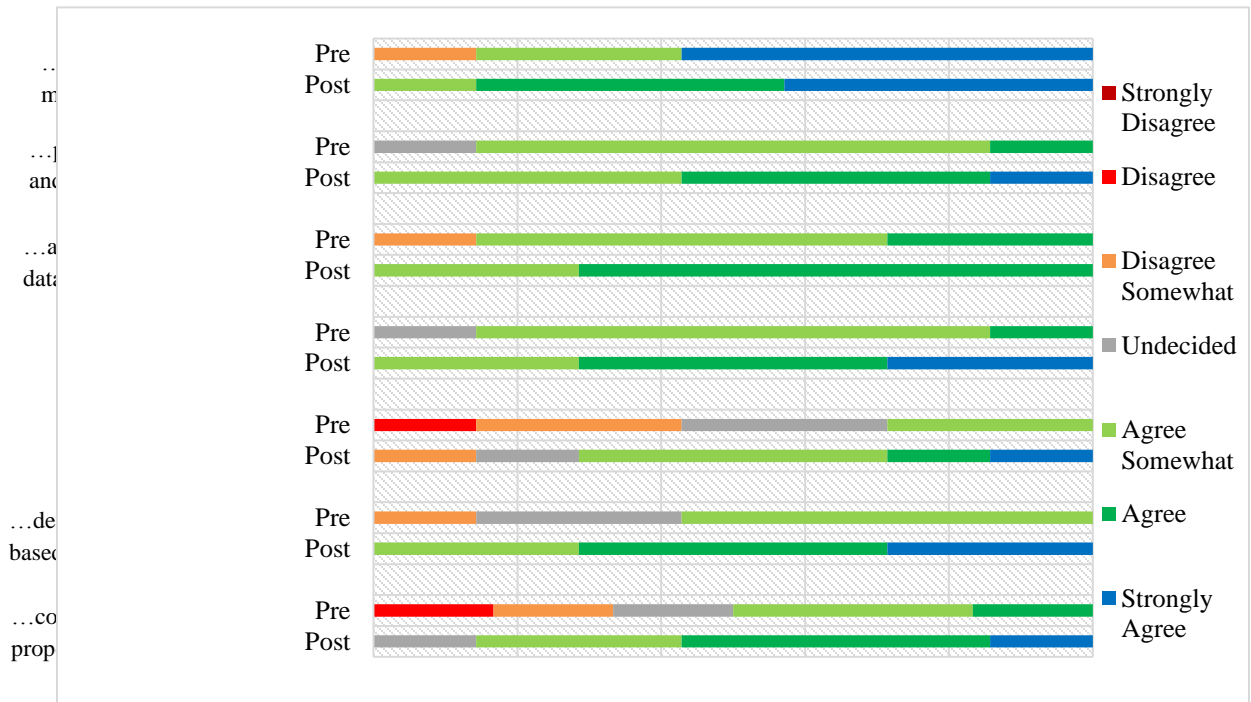


Figure 3. Likert

items from the Pre- and Post-UNLESS Surveys related to educators' instruction in elements of inquiry, specifically what they currently support their students to do as part of their science teaching, ($N=7$).

Cross tabulation tables from the Pre- and Post-UNLESS Surveys showed that educators who had a graduate degree in science had median responses before the program of *somewhat agree* while the responses of educators without this level of science education were *undecided*, *somewhat disagree*, or *disagree* in regards to whether they currently support their students doing elements of inquiry ($N=7$). All educators' median responses for whether they currently support their students to do elements of inquiry increased to *somewhat agree*, *agree*, or *strongly agree* in the Post-UNLESS Survey with the greatest change occurring for those educators without graduate degrees in science. Cross tabulation tables otherwise showed overlap and no clear trends between median responses when examining tenure at NatureBridge and formal training as a teacher.

The Reformed Teaching Observation Protocol showed a trend toward more of an inquiry orientation in instruction after the program ($N=3$; Figure 4). The biggest shift occurred in students making predictions or hypotheses and developing means to test them although this was not a significant difference (Wilcoxon Signed Rank Test, $p=0.371$). The frequency of students making predictions and devising ways to test them was lower compared to the other indicators of orientation toward inquiry during and after the program. This result was supported by a note in my journal that said, “We don't know our students really well, but I know that some educators are better able to jump in and let them try to answer something while others still hold onto more control. Students are doing science, but they aren't necessarily in control of the whole process.”

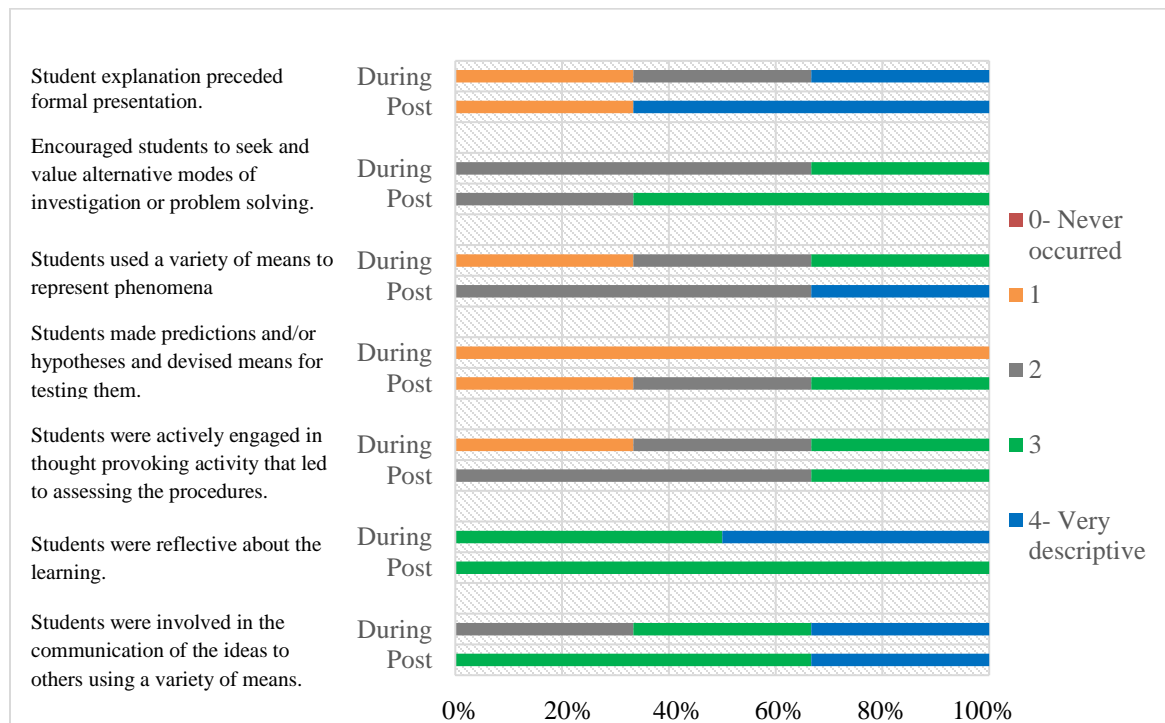


Figure 4. Percentages showing how much an indicator of inquiry orientation was seen in an observation using the Reformed Teaching Observation Protocol, ($N=3$).

The Science Investigation Tracking Forms indicated an increase in student-driven investigations from 17% in September to 52% in March ($N=86$; Figure 5). Six reports of investigations had similarities to what was presented during UNLESS. These often occurred in the week directly after the meeting or after the video of UNLESS was shared online with the whole education staff. Notes from my journal also indicated that participants were trying new things based on what they were experiencing in UNLESS. During January, I wrote, “The educator referred to one of our fall sessions, which seemed to have given her more confidence to have her students explore and learn about bark beetles in this way. This was from an educator that loves teaching science yet has been hesitant to dive into students doing investigations.” I also wrote about another educator who had told me at the start of UNLESS that she had never had her students actually engaged in an investigation, rather they asked questions and discussed how they could try to answer that without actually doing it. That participant tried what her group collaboratively presented in UNLESS during her next week in the field with students. She also reached out to have an education support staff person help her lead a more open investigation with students. Later in the semester, she reported facilitating an open inquiry with students without the help of additional support staff.

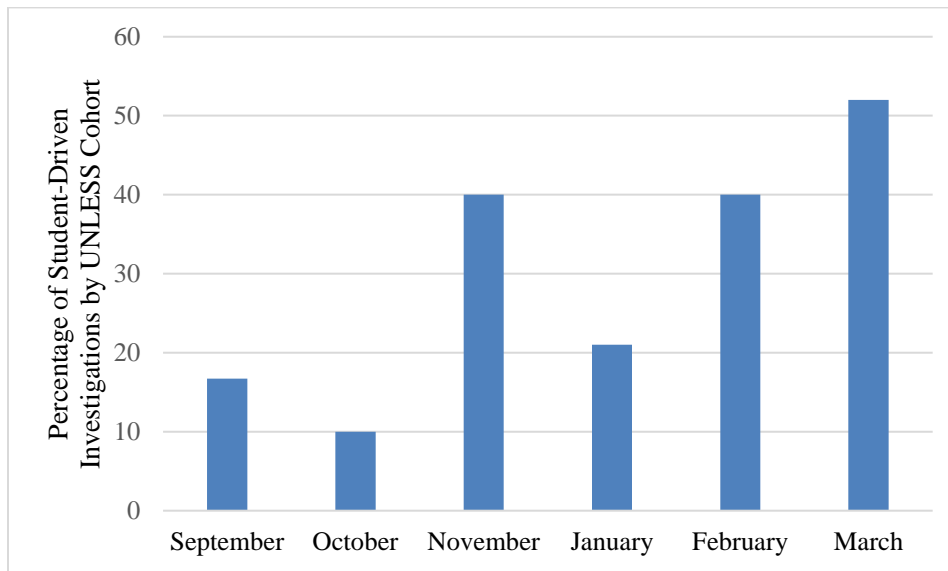


Figure 5. Percentage of student-driven investigations per month as reported by NatureBridge program with the Science Investigation Tracking Form, ($N= 86$).

Some challenges reported by participants still remained at the end of the program while other challenges were only reported at the start (Table 2). Challenges that were reported in the Science Investigation Tracking Form that prevented investigations from occurring included not enough time (with either too many other school requests or the program was too short), school wanted a break from academics while on our program, students were not prepared, inclement weather, or that the educator chose to teach science in a different way. Sometimes the different approach to teaching science was still inquiry-based such as making observations, asking questions, and/or constructing explanations from evidence without planning or doing an investigation. Challenges listed on the Post-UNLESS Concept Map were time, movement, teacher and student desires, and weather. After UNLESS was finished, an educator described the challenges she still has as “balancing the desires of what NatureBridge says we should provide and what the schools that actually come are looking for.” In asking about whether it is the Next

Generation Science Standards (NGSS) Science Practices or other expectations that NatureBridge has about how to teach science that presents a challenge, she added, “The hard part is getting through the Practices because some students come with so little base knowledge that all you can get through is observation and questioning, not any farther than that.”

Table 2
Summary of Pre- and Post-UNLESS Challenges to Doing Inquiry as Reported by Participants

	Challenges		
	Pre-UNLESS	During UNLESS	Post-UNLESS
Time (short program, too many other program requests)	X	X	X
Teacher and school requests	X (Buy-in from teacher and chaperones; Creating buy-in)	X (School wanted a break from academics)	X (Teacher and student desires)
Weather	X	X	X
Students' prior knowledge	X	X	X
Movement			X (written with a question mark)
Difficult	X (Sufficient knowledge and background skills; training)		
Shifting expectations	X		
Broad definition of science	X (Defining science)		

INTERPRETATION AND CONCLUSION

The Pre- and Post-UNLESS Surveys showed that most educators believed that they should support their students in learning through inquiry before and after the

professional development program. Participants' perceived competence for doing inquiry was also high before the program started although the concept maps showed more breadth and growth in educators' confidence and skills at the conclusion of the program. Positive attitudes toward inquiry also increased with less of a focus on what challenges existed. There was a commonly expressed result that teaching science through inquiry wasn't as difficult as they had thought. The collaborative spirit in learning from and with peers seemed to fuel this inspiration and motivation to try new ways to teach science.

The results of the cross tabulation tables showed educators who had a strong background in science could be a predictor of whether that educator is more likely to engage in elements of inquiry with their students. Both educators that did and didn't have a significant science background reported that they teach more elements of inquiry with students after the UNLESS program, but this growth was stronger for educators who did not have as strong of a science background. This shows what type of participants may benefit the most from a program like UNLESS in terms of reforming their science teaching. A participant with a master's degree in science wrote, "I've realized it's easier than I thought, doesn't have to be super complex." So while even though educators with a strong science background may be more likely to include inquiry in their instruction, professional development may also help these educators realize doing simple science investigations can be valuable for students. The perception that science is too difficult to do could be part of the reason that those with strong science training may be more likely to try it over an educator has limited personal experience doing inquiry. This action research supports Windschitl's research (2003) that an educator's previous work with

long-term research experiences may predict whether teachers are more inclined to teach through inquiry.

As shown by the Science Investigation Tracking Form and Reformed Teaching Observation Protocol (RTOP), there was an increase in teaching through science investigations and inquiry-oriented instruction after the program. Participants mentioned being more confident, comfortable, and having more skills and ideas at the end of the program. The space to share professionally and see how other educators approached inquiry seemed to be a strong element in the success of the program. Even though most participants reported having the positive beliefs and the skills before the program that would move them toward inquiry, the learning experiences in UNLESS may have potentially played a role in these educators actually doing more inquiry with their students.

Challenges in teaching science through inquiry did not go away as a result of participating in UNLESS; however, these challenges were much less of a focus in the Post-UNLESS Concept Map compared to the Pre-UNLESS Concept Map. The challenges around buy-in and shifting expectations were no longer present. The feelings of dragging students through investigations and wanting to know how to get students engaged in investigations also seemed to be less expressed after the program. The experiences educators had with a group being engaged and excited with inquiry seemed to help educators overcome this concern. Challenges around time, weather, and teacher and school desires still existed after the program. The Post-UNLESS Survey and Science Investigation Tracking Form also showed that there were still concerns about having a

trail group that wants science and students who are interested and prepared for an investigation.

VALUE

This study concluded with many ideas and recommendations for next year's program. Through examining and measuring the impact of UNLESS, there has been validation for the benefits of the program. I hope that the success of this program may help UNLESS to spread to other NatureBridge campuses and provide a potential example for other environmental education schools who are considering how to support their educators in reforming science teaching. Because the transition to becoming an inquiry-based teacher can be slow, UNLESS has shown to play a role in encouraging educators to share ideas and try new lessons (Llewellyn, 2013). This collaboration can keep enthusiasm and interest from educators high as they try to change their way of teaching.

While UNLESS is a good starting point and participants seemed to make great strides toward becoming inquiry-based teachers, the longevity of the program does not seem like enough to allow each participant to feel fully ready, confident, or prepared to keep that momentum. Several educators mentioned wanting to participate in UNLESS again next year, which may be a way to help these educators continue to grow. With the program's plan being directed by participants' goals and requests and unique collaborative presentations in the spring, each year may be different enough that educators could repeat the program without feeling like they were doing the exact same thing twice. If it was possible to include more scheduled time and funds to support educators' time, I would suggest longer meetings (at least 30 more minutes) and one additional final meeting to provide time for more open inquiry and deeper reflection.

The educator who went from only having students talk about how they would answer a question to letting students engage in open inquiry showed that utilizing mentors and peer support was helpful along the path to reforming her science teaching. Another aspect of her situation that seemed effective was successful inquiry experiences with actual students. This was an aspect that was missing as part of the UNLESS program. We often ended UNLESS with the question of what you want to try with students, but never opened the next meeting with what was tried and how it went. While UNLESS seemed to build confidence through seeing that you and your peers were trying what they were learning throughout the course of the program with students, there could be negative teaching experiences with students that would reinforce the idea that inquiry isn't valuable. Similar to the challenges being expressed, an educator might not pursue inquiry because a difficult experience may support the thought that inquiry is not for all students or that not all students are interested or will benefit from this type of learning. An educators' belief that students are generally unprepared for inquiry could also be reinforced. One participant shared that "UNLESS has provided more ideas for incorporating science investigations into my days." The same educator said, "I haven't had a group that wanted a science investigation or was willing to sacrifice any destinations." This participant did not respond to the Pre-UNLESS Survey Likert items related to her beliefs, and instead wrote that whether she engages in inquiry with students was dependent on "students' prior knowledge and readiness." While her beliefs seemed to be changing about the value of inquiry, it was taking more time and would likely take further support for her to implement changes in her instruction. She was an example of a participant who was still not over the hump of trying to reform her teaching. She said at

the conclusion of the program “my confidence in doing fun investigations has increased. It doesn’t have to be all numbers and slow.” This participant would likely benefit from a professional development program with more follow-up training sessions. From this, she may be better able to strike the balance of science as a valuable way to spend part of students’ program time when competing options exist.

When educators shared what they wanted from UNLESS, there was a request for seeing successful investigations and inquiry in action. While initially planning the program I thought educators would benefit from more pedagogical knowledge related to inquiry, this turned out to not be what educators wanted from the program. Perhaps educators who already have a belief that they should do inquiry with students are less in need of instruction about why teaching science in this way is beneficial for students. Instead, as a group, we focused on how to set up an inquiry experience and what a student-driven investigation could look like. By seeing inquiry in action and collaborating with peers to facilitate an investigation themselves, the issue of wanting to be personally bought into inquiry seemed to fade. The educators’ request of wanting to see more inquiry in action may have helped them in their movement to realizing that it doesn’t have to be super complex. This may have increased the amount of reported inquiry instruction. These findings support the research that it is important for participating teachers to help develop the goals for the professional development program (Lotter et al., 2006). The set-up of the program to include any educator that was interested could be something to consider. A participant in UNLESS this year said that part of the reason that it was fun was because everyone wanted to be there. If this was a program that wasn’t

optional, there may have been a greater need for pedagogical knowledge because perhaps those that opt to not be in the program do not have beliefs in inquiry from the beginning.

Another consideration for the future of UNLESS is to think about how to share examples along the spectrum of inquiry. Due to the length of our meetings, most collaborative groups chose to share a guided inquiry. One group focused on tips for how to prepare students or set up different parts of an investigation. The initial UNLESS day-long training could be a time to allow educators to participate in a more open inquiry. This might help them be more comfortable teaching in a way where they may feel less control. It would also provide a model for how to relinquish some of that control and engage students in active, inquiry-based learning. An experience with open inquiry could also help educators consider how to help students navigate common inquiry challenges. Windschitl (2003) found that actually experiencing inquiry difficulties was helpful and supportive for pre-service teachers.

The Pre-UNLESS Survey was an opportunity for educators to consider what their beliefs and conceptions were toward inquiry. This is thought to be a first step toward understanding inquiry and reforming instruction. While participants regularly considered what they valued, what they would modify, and what would I like to try throughout the UNLESS program, I didn't really challenge what they thought inquiry means. Challenging an educator's concept of inquiry may help them further understand their own views. Including reflection questions of this nature may be something to consider for future UNLESS programs. As a facilitator of the program, I wonder if I could have pushed educators to think more critically about their lessons and how they could be more student-driven without negating the progress they were making. The questions that had

educators think about what they would modify or try seemed to correspond with how they might scaffold a lesson for their students. Windschitl (2003) found that strategies that help students understand elements of inquiry were a need of pre-service teachers. I think the collaborative nature of UNLESS with open sharing by educators helped us discuss and work together to consider what these strategies might look like in our setting.

Participants shared in the Post-UNLESS Concept Map that science teaching can cover many aims. This ability to consider how inquiry can help hit many goals was connected to keeping science simple. Not all of the observations that were part of the RTOP were science-based teaching days. Some were more focused on teambuilding or cultural history; however, the shift that was seen in the RTOP may show that the orientation toward inquiry may cross into these other subject areas. As a way to improve UNLESS, one educator said, “the thing that I feel like I’m still missing is how it connects with other parts of my day, or into the flow, as opposed to suddenly switching gears and saying okay now it’s science time.” Considering how to help educators weave inquiry into other aspects of their teaching may further prepare them to reform their teaching and be more inquiry-based across subject lines. In a future program, there could be a greater emphasis on including interdisciplinary inquiry examples. This may be especially relevant in a non-traditional learning environment, such as environmental education, in which subjects in addition to science are taught by the same educator.

While positive energy and enthusiasm for science teaching seemed to occur over the course of the program, Windschitl (2003) found that this association with pre-service teachers was not enough to predict who would use inquiry. Only half of the teachers in Windschitl’s study regularly used inquiry in their classrooms. After more time passes, the

lasting effectiveness of UNLESS could be examined by whether participants are still trying inquiry with students. Seeing what continues to encourage these educators after the conclusion of UNLESS could help determine what next steps are effective and how to continue to offer support educators on their journey to more inquiry-based instruction.

Since time was presented as a challenge from educators, it would be interesting to examine how the program length correlates to whether educators did an investigation with their students. Because trying to cover multiple NGSS Science Practices was also a challenge and some educators were engaged in inquiry-based learning, just not specifically an investigation, it may be supportive to more broadly train educators in inquiry and the Science Practices. This may help educators meet multiple goals with their students while also reforming their science teaching. This professional development program started with a broad approach to teaching inquiry, but since NatureBridge is currently focused on students doing investigations, the professional development program's focus also narrowed. This has caused some educators to consider an investigation as the only time for science rather than gaining a fuller understanding of how to integrate an inquiry-based approach into their teaching. The benefits and restrictions of a narrow focus on one of the NGSS dimensions could be something to consider for organizations as they shift to NGSS. A broader focus may help when time is more restricted, and allow inquiry-based instruction to still be part of a shorter program or a program with lots of requests. A program like UNLESS could also have a broader focus and may be better able to include more diverse examples of inquiry-based learning that hit different program goals.

As the facilitator of this program, I felt that I grew a lot in my understanding of how to support educators. After our initial training day, one educator commented how she found it interesting that the part of the day where we were the most involved in inquiry was the most boring. She was referring to when we used hydrology tools to learn how to measure a cross-section of the river. This comment left me a somewhat despondent about the potential for the success of the program; however, as time progressed, I found that the attitudes of educators changed with the more that they experienced and tried. Even though we started with moments to openly express what was not working about trying inquiry and this sometimes made me feel down as the facilitator, giving educators time to validate their feelings and be heard was important. Allowing them to express how it was going for them did not cause the program to spiral into negativity, but instead created a cohort that honestly shared and from there, helped support each other to grow. Letting the challenges be said out loud helped us move forward. I tried to not push inquiry as the best option, but share it as a way to grow, help our students, and try something new. This focus was supportive and encouraged reflection. I know that the strength found in listening, encouraging, and learning from each other is one of my greatest lessons from this program and perhaps one that others trying to support and train educators can learn from.

In observing educators change their practices as a result of UNLESS, I realize how much I have been growing myself as an inquiry-based teacher. I have become much more comfortable with spurring questions and curiosity without knowing all the answers. I enjoy the invigoration that comes in not knowing what results will occur and the challenge of teaching content in this way. I am becoming more familiar with how to help

students analyze whatever data they might collect. Knowing that becoming an inquiry-based teacher is a process, it was easy to model being a learner in UNLESS. Just like the educators, I was motivated and inspired by what other educators shared. UNLESS has allowed me to have many open discussions with educators about what is working and what isn't, which constantly pushes me to reflect on effective science teaching. From strategies that cause students to think critically to active learning through doing science, I feel that UNLESS has caused me to further evaluate my own teaching and how to share my own growth with others.

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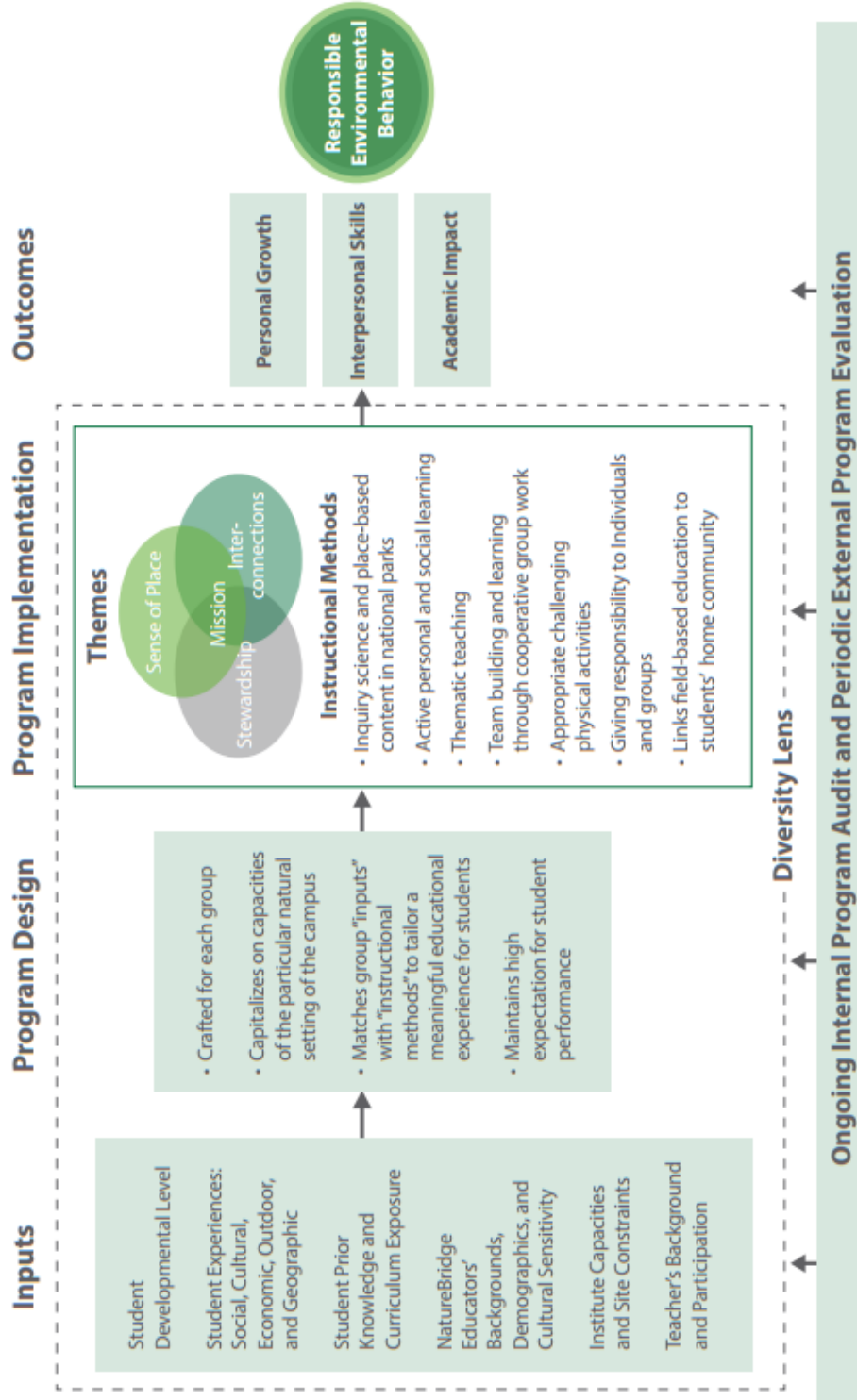
APPENDICES

APPENDIX A

SKETCH OF NATUREBRIDGE CORE EDUCATIONAL FRAMEWORK



Sketch of Core Educational Framework



APPENDIX B
MSU PROJECT EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Laura Ouborg and John Graves
FROM: Mark Quinn, Chair *Mark Quinn exj*
DATE: November 19, 2015
RE: "The Effects of a Professional Development Program on Scientific Inquiry on Environmental Educators' Beliefs, Perceived Competency, and Instruction" [LO111915-EX]

The above research, described in your submission of November 19, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- _____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- _____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- _____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- _____ (b) (6) Taste and food quality evaluation and consumer acceptance studies. (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C

PRE- AND POST-UNLESS SURVEYS

Name _____

UNLESS Pre- and Post- Survey and Questions

Participation in this research is voluntary and participation or non-participation will not affect your professional standing in any way. You can choose to not answer any questions you do not want to answer and/or you can stop at any time.

As part of my science teaching, I should support my students to . . .

	Strongly disagree	Disagree	Disagree somewhat	Undecided	Agree somewhat	Agree	Strongly Agree
. . . ask questions and make predictions							
. . . perform investigations and gather data							
...analyze and interpret data							
. . . construct explanations from evidence							
. . . evaluate an explanation in light of differing viewpoints							
...defend an explanation based on evidence							
...communicate and justify proposed explanations							

I have the necessary knowledge, skills, and resources to support my students to . . .

	Strongly disagree	Disagree	Disagree somewhat	Undecided	Agree somewhat	Agree	Strongly Agree
. . . ask questions and make predictions							
. . . perform investigations and gather data							
...analyze and interpret data							
. . . construct explanations from evidence							
. . . evaluate an explanation in light of differing viewpoints							
...defend an explanation based on evidence							
...communicate and justify proposed explanations							

As part of my science teaching, I currently support my students to . . .

	Strongly disagree	Disagree	Disagree somewhat	Undecided	Agree somewhat	Agree	Strongly Agree
. . . ask questions and make predictions							
. . . perform investigations and gather data							
...analyze and interpret data							
. . . construct explanations from evidence							
. . . evaluate an explanation in light of differing viewpoints							
...defend an explanation based on evidence							
...communicate and justify proposed explanations							

Pre-UNLESS Questions:

What do I want to gain through participating in UNLESS this year?

What specific topics related to science teaching do I want to learn more about?

Post-UNLESS Questions:

What have you gained through participating in UNLESS this year?

Has your concept of science teaching changed since participating in UNLESS?

- If so, how and what contributed to that change?

Have you changed your science teaching since participating in UNLESS?

- If yes, how has it changed?
- If no, why not?

What would make UNLESS better next year?

APPENDIX D
REFORMED TEACHING OBSERVATION PROTOCOL

Appendix II
Reformed Teaching Observation Protocol (RTOP)

Daigo Sawada External Evaluator
Michael Pibum Internal Evaluator

and

Kathleen Falconer, Jeff Turley, Russell Benford and Irene Bloom
Evaluation Facilitation Group (EFG)

Technical Report No. IN00-1
Arizona Collaborative for Excellence in the Preparation of Teachers
Arizona State University

I. BACKGROUND INFORMATION

Name of teacher _____ Announced Observation? _____
(yes, no, or explain)

Location of class _____
(district, school, room)

Years of Teaching _____ Teaching Certification _____
(K-8 or 7-12)

Subject observed _____ Grade level _____

Observer _____ Date of observation _____

Start time _____ End time _____

II. CONTEXTUAL BACKGROUND AND ACTIVITIES

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Record here events that may help in documenting the ratings.

Time	Description of Events

During observations for UNLESS participants, items 3, 4, 11, 12, 13, 14, and 16 will be focused upon due to their inquiry orientation.

During observations for UNLESS participants, items 3, 4, 11, 12, 13, 14, and 16 will be focused upon due to their inquiry orientation.

III. LESSON DESIGN AND IMPLEMENTATION

		Never Occurred	Very Descriptive
1)	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1 2 3 4
2)	The lesson was designed to engage students as members of a learning community. In this lesson, student exploration preceded formal presentation.	0	1 2 3 4
3)	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0	1 2 3 4
4)	The focus and direction of the lesson was often determined by ideas originating with students.	0	1 2 3 4

IV. CONTENT

Propositional Knowledge			
6)	The lesson involved fundamental concepts of the subject.	0	1 2 3 4
7)	The lesson promoted strongly coherent conceptual understanding.	0	1 2 3 4
8)	The teacher had a solid grasp of the subject matter content inherent in the lesson. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0	1 2 3 4
9)	Connections with other content disciplines and/or real world phenomena were explored and valued.	0	1 2 3 4
Procedural Knowledge			
11)	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1 2 3 4
12)	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1 2 3 4
13)	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1 2 3 4
14)	Students were reflective about their learning.	0	1 2 3 4
15)	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1 2 3 4

During observations for UNLESS participants, items 3, 4, 11, 12, 13, 14, and 16 will be focused upon due to their inquiry orientation.

V. CLASSROOM CULTURE

Communicative Interactions		Never Occurred	Very Descriptive
16)	Students were involved in the communication of their ideas to others using a variety of means and media.	0	1 2 3 4
17)	The teacher's questions triggered divergent modes of thinking.	0	1 2 3 4
18)	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1 2 3 4
19)	Student questions and comments often determined the focus and direction of classroom discourse.	0	1 2 3 4
20)	There was a climate of respect for what others had to say.	0	1 2 3 4

Student/Teacher Relationships

21)	Active participation of students was encouraged and valued.	0	1 2 3 4
22)	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0	1 2 3 4
23)	In general the teacher was patient with students.	0	1 2 3 4
24)	The teacher acted as a resource person, working to support and enhance student investigations.	0	1 2 3 4
25)	The metaphor "teacher as listener" was very characteristic of this classroom.	0	1 2 3 4

Additional comments you may wish to make about this lesson.

During observations for UNLESS participants, items 3, 4, 11, 12, 13, 14, and 16 will be focused upon due to their inquiry orientation.

APPENDIX E
SEMI-STRUCTURED INTERVIEW QUESTIONS

INTERVIEW QUESTIONS FOR PARTICIPANTS

These questions will be asked in a one-on-one setting. The following statement will be shared with participants: Participation in this research is voluntary and participation or non-participation will not affect your professional standing in any way. You can choose to not answer any questions you do not want to answer and/or you can stop at any time.

Questions asked in an interview mid-way through and at the end of the professional development program:

- What do you consider when you plan a science lesson?
- Do you think it is important to involve elements of inquiry? Why or why not?
- Is UNLESS helping you to feel more confident in your science teaching? Please explain. Why or why not?
- Do you feel more competent in teaching science as a result of participating in UNLESS? Please explain. Why or why not?
- Have you changed how you teach science as a result of UNLESS? Why or why not?
- What challenges are you continuing to face in your science teaching?

As a part of observation debrief:

- What goals did you have for this science lesson?
- What elements of inquiry did you involve in this lesson?
- Did you try anything different from what you've done before? Why or why not?
- Did you feel confident in what or how you were teaching? Why or why not?
- What did you think was particularly successful or effective?
- What would you want to do differently next time?

Journal entry questions related to different professional development sessions:

- How did I find this valuable?
- How does this relate to how or what I teach?
- What do I want to try or apply to my science teaching?

Questions may be added in order to clarify or have participants expand on their responses.

APPENDIX F

NATUREBRIDGE SCIENCE INVESTIGATION TRACKING FORM

Science Investigation Tracking Form, Spring 2016

Educator: _____ Program Dates: _____ # Instruction Days: _____

School Name: _____ Grade: _____ # Students: _____ # Adults: _____

Which type of science investigation did your group participate in this week?

Student-Driven Investigation (SDI) _____ Citizen Science (CS) _____ Both SDI and CS _____ Neither _____

<p>Briefly describe the SDI and/or CS you did with your students. What did your investigations reveal?</p>		<p>Total time spent on investigation</p> <p>_____</p>
--	--	---

If you did not conduct an investigation this week, please explain (use back if needed):

<http://www.illustrativemathematics.org/HS-Science-Investigation-Tracking-Form-2016>