1-1-2015


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Plan B Project

Submitted in partial fulfillment of the requirements for the degree of Masters in Science in Natural Science/Mathematics in the Science and Mathematics Teaching Center at the University of Wyoming, 2015

Laramie, Wyoming

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Abstract

Some organizations that conduct ecological restoration offer classrooms the opportunity to learn science concepts while working on ecological restoration projects through restoration service-learning (RSL) experiences. RSL involves three stakeholders: restoration organizations who are concerned with community outreach and successful restoration, the students who are engaged when educators lead quality service-learning experiences, and the teachers and schools who are required to have their students meet mandated science standards. This project aims to seek the intersection where restoration practice, quality service-learning practice, and the Next Generation Science Standards (NGSS) align. The literature suggests that all three stakeholders share an authenticity of experience, a focus on depth of knowledge verses breadth, an incorporation of practice with content knowledge, and a disciplinary focus on human impacts on natural systems. A thematic analysis of three RSL organizations identified how organizations are approaching integrating NGSS into their curricula and the challenges they have experienced with its integration. Results indicate that RSL and NGSS alignment is possible in practice, however there are limiting factors preventing an ideal integration of quality service-learning pedagogy, restoration practice, and NGSS. These include RSL organizations’ primary focus on accomplishing successful restoration, the complexity of NGSS, and a lack of time for RSL organizations and classroom teachers to engage in and understand NGSS. Given these limiting factors, recommendations are presented for RSL organizations that are seeking to incorporate NGSS into their curricula.
Acknowledgments

I am grateful for those working hard at SOLVE for inspiring me to pursue this project, and to the Jesuit Volunteer Corps for their support working there. Thanks to my Teton Science Schools families for emotional support during my entire graduate education and the completion of this project, especially to Sarah Hackworth for several helpful discussions on NGSS and the thesis writing process and to Gina Graziano for our many conversations that helped shape this project. Thank you to my thesis committee for their guidance throughout this whole experience and for their patience as this project evolved from its initial permutation. Thank you to the Nunn family, the Plummer family, and Sigrid See for their generous financial support of my education. I appreciate Bill Hoskyn for encouraging me to pursue this degree and the support he has given throughout the process. Finally, I appreciate the support of my family throughout my educational career as they continue to struggle telling others exactly what degree I am pursuing and what my project explores.
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Chapter 1: Introduction

Several organizations across the United States have the respectable aims of bringing communities together, improving local natural areas, and educating students in environmental literacy. They often engage classrooms of students in local ecological restoration processes and use that experience as a context to teach about native ecology, local history, and the scientific practices that can improve the natural systems in these degraded areas. Such experiences are labeled restoration service-learning (RSL) in this project. Since many RSL organizations are outreach branches of larger restoration organizations, they involve students in their restoration practice to seek community support for their local restoration work. RSL organizations attract the participation of schools by advertising that their programs can apply real-world experiences to concepts learned in the classroom and can help teachers meet science standards.

I worked for an RSL organization for a year as an AmeriCorps volunteer. While leading students in RSL projects, I noticed that the experience brought a level of environmental awareness to students, increased their interest in the relevant subject, and fostered connections within their community. The organization’s aims of teaching rigorous science within these experiences seemed to be unsuccessful even though the work students accomplished seemed to align with several scientific concepts they were expected to learn. If these organizations are not meeting education standards with their curricula, they might be challenged to find participating classrooms in the future. This experience was the genesis for this project: to see how a RSL experience could best teach science and fulfill the expectations of meeting mandated standards.
Sigmon (1996) notes there are three stakeholders involved in service-learning (Figure 1). While Sigmon’s notions about service-learning are in the context of higher education, his ideas also apply to other service-learning experiences. As demonstrated in Figure 2, the three stakeholders in a RSL experience include the students, the RSL organizations, and the institution. Figure 2 serves as this project’s framework.

*Figure 1.* The three forces that come together in service-learning in higher education. Service-learning sits at the center. Used with permission (Sigmon, 1996, p. 16).
Figure 2. The framework for this project: the three parties that are invested in an RSL experience and what they value/require. This project seeks to find the area where all three parties’ goals and values align. Adapted from Sigmon (1996, p. 16), used with permission.

In this framework (Figure 2), the students are invested in quality service-learning. Service-learning can have an effect on how students approach their learning through increasing interest in the subject, increasing engagement, and deepening cognitive thought (Billig 2009; Billig, Root, & Jesse, 2005a; Eyler & Giles, 1999; Steinke & Buresh, 2002). Students are ultimately responsible for their own learning and value understanding the importance of what they are learning. Since service-learning is inherently local, a student’s education is tangible, connecting them to their community and its values (Smith & Sobel, 2010).

RSL organizations are concerned with ecological restoration. They facilitate RSL experiences in order to engage the community in their efforts, as a lack of community support for
restoration projects is often a limiting factor for restoration success (Geist & Galatowitsch, 1999). Integrating the local community with restoration efforts through both education and participation is vital for restoration projects. Since RSL organizations are spending the time and resources to conduct restoration projects with students, they also value that their RSL efforts are environmentally successful.

The institution in Figure 2 refers to the teachers, administrators, and school districts that are held to specific learning outcomes or standards. There is institutional pressure for students to meet academic standards, especially with the passing of the No Child Left Behind Act (2001). Teachers and schools will often not support an innovative learning experience (like service-learning) unless it will help students to meet mandated academic benchmarks (Steinke & Buresh, 2002). One such set of benchmarks is the recently published Next Generation Science Standards (NGSS) (NGSS Lead States, 2013a). Based on the most current research on cognitive development and learning, twenty-six states were involved in developing the standards and are in the process of implementing them (NGSS Lead States, 2013f). With many more states and school districts likely to follow, NGSS are becoming the new national standards for science. As accountability and testing are already a significant pressure on the school system (Kohn, 2001), teachers and schools will likely not engage their classrooms with RSL unless the experience can be shown to align with current standards, in this case the NGSS.

NGSS pares down content knowledge and has a stronger emphasis on scientific practices than previous standards, so its expectations are more conducive to innovative teaching techniques (National Research Council [NRC], 2011). One could therefore argue that the introduction of NGSS has made it easier for educators to engage their classrooms in a RSL
experience. Since NGSS are so new, there have been few investigations as to how organizations offering RSL can best align their curriculum with this new set of standards.

**Purpose**

This project initially explores the topics of service-learning, ecological restoration, and NGSS individually to identify their values and needs for quality practice. Then it compares the three topics to ascertain where the three stakeholders in RSL align in the center space within Figure 2. Many people leading RSL experiences are novice educators and may not have the experience to adjust their curriculum to science standards, such as the NGSS. This research explores how an organization can incorporate NGSS into an RSL experience for secondary students and still meet the needs of the three identified stakeholders. Incorporating NGSS with RSL has the potential to increase the environmental literacy of students, foster community support and buy-in for restoration efforts, and meet institutionally mandated benchmarks.

**Research Question**

The research question that guided this project is:

How can third-party organizations facilitating RSL experiences for middle and high school students connect their curriculum to Next Generation Science Standards in places where they naturally align?

This question was addressed by exploring the following sub-questions:

1. Where do NGSS and RSL naturally align?
2. What is currently being done in the field?
3. What limits exist that prevent or might prevent RSL organizations from integrating NGSS into their curricula?
A conventional literature review answered the first sub-question through identifying places where RSL and NGSS naturally align. A small qualitative thematic analysis of data collected from RSL organizations investigated the second and third sub-questions.

**Definitions**

The following definitions clarify common terms used throughout this paper:

- **Authentic Instruction:** an approach to teaching and learning in which students apply classroom-learned skills and knowledge to real-world situations (Dennis & O’Hair, 2010).
- **Ecological Restoration:** “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed” (Society for Ecological Restoration International Science & Policy Working Group, 2004, p. 3).
- **Experiential Education:** an educational philosophy in which an educator incorporates direct experiences into curriculum and the learning environment in order for a learner to develop skills, knowledge, and/or values (Itin, 1999).
- **Next Generation Science Standards [NGSS]:** a set of research-based K-12 science standards developed by twenty-six states using A Framework for K-12 Science Education (NRC, 2012) and is becoming widely adopted by states and school districts throughout the US (NGSS Lead States, 2013a).
- **Place-based learning:** an approach to teaching and learning that connects curriculum to the local community (Smith & Sobel, 2010).
- **Restoration ecology:** The science on which the practice of ecological restoration is based (Society for Ecological Restoration International Science & Policy Working Group, 2004).
• **Restoration service learning (RSL):** a service-learning experience where students learn scientific principles and practice through engagement in ecological restoration efforts.

• **Restoration-based education:** using restoration as a context for teaching science and/or environmental concepts.

• **Service-learning:** “an approach to teaching and learning in which students use academic knowledge and skills to address genuine community needs” (National Youth Leadership Council [NYLC], 2015, para. 1).
Chapter 2: Literature Review

This conventional literature review, as described by Braun & Clarke (2013), investigated where RSL and NGSS theoretically align. This review individually summarized and compared literature on each of the three elements of RSL (as introduced in Figure 2): service-learning, ecological restoration, and NGSS. Empirical studies, practitioner papers, literature reviews, and books were collected using online databases including Google Scholar, ProQuest, Web of Science and other academic databases available at the University of Wyoming Library. Often the references of some sources provided guidance to further literature. This search focused on papers that defined each of the elements, provided insight on effective practice, and illuminated current efforts being made in those fields. A final synthesis of where the three topics fundamentally overlap provided a theoretical understanding of where RSL and NGSS align.

Service-learning

Defining service-learning. In the literature, “service-learning” can mean a number of different things to different academics and practitioners. This section explores how “service-learning” has and is being described in the academic literature and clarifies which definition this project uses.

Furco (2003) describes the challenge that educators and academics have had with defining service-learning. He notes that several people have identified it as any number of activities that are within the realm of experiential education. While some organizations define it broadly as any service experience with clear learning goals that students actively reflect on (National Society for Experiential Education, 1994), others define it more specifically as a service experience that meets community needs and enhances content learned in the classroom (Corporation for National and Community Service, 1990).
Furco (2003) presents a model in order to clarify where service-learning fits within the realm of all other service programs (Figure 3). He identifies five different service types (volunteering, community service, service-learning, field education, and internship) and places them on a continuum based on their focus (service or learning) and the beneficiary of the activity (the recipient or the provider of the service). The National Society for Experiential Education (1994) and the Corporation for National and Community Service (1990), two large service organizations in the US, both define service learning as a service activity where the providers of service are intentionally reflecting on their work. Most types of service might be lumped into service-learning according to this broad definition. Furco (2003) instead identifies that service-learning has equal emphasis on service and learning, providing equal benefits to the provider and recipient of the service.

The National Youth Leadership Council (NYLC) defines service-learning simply as, “an approach to teaching and learning in which students use academic knowledge and skills to address genuine community needs” (NYLC, 2015, p. 1). This project used NYLC’s definition of
service-learning. Like Furco’s (2003) model, the NYLC definition acknowledges that the
students and the community both benefit: the students through learning and the community
through the meeting of a genuine need.

**Service-learning and other pedagogical strategies.** This project approached service-
learning with the understanding that it is experiential, authentic, and place-based and that the
research and literature on these other pedagogical methods can apply to service-learning (Figure
4).

![Diagram of instructional strategies](attachment:image.png)

*Figure 4. Instructional strategies that influence and contribute to service-learning.*

Service-learning has its roots in experiential education and the ideas of John Dewey
(1938). Dewey (1938) believed in the educational power of direct experiences, especially when
reflective thinking is involved. He also claimed that learning is tied to students’ emotions and
that learning should focus on problems that capture their interest; students engaged in
experiences are passionate about their learning (Eyler & Giles, 1999). Reflection is integral to
learning in experiential education (Kolb, 1984). “Service-learning engages students in concrete experience followed by critical reflection on the service experiences and, in curricular service-learning, with academic content” (Jacoby, 2015, p. 6).

While Dewey (1938) advocated for experiential education, he did not believe that all experiences have educational value. The context of a learning experience is important. Authentic instruction, instruction that has higher expectations for students that allows them to apply skills and classroom-learned information to real-world situations (Dennis & O’Hair, 2010), is an effective pedagogy for students to develop rich understandings of content (Belland, Kim, & Hannafin, 2013; Braund & Reiss 2006; Dennis & O’Hair, 2010; Gulikers, Bastiaens, & Kirschner, 2004; Herczog 2000; Lee & Butler, 2003). Students develop deeper understandings because authentic experiences make coursework seem more relevant and students are more engaged in their learning (Braund & Reiss, 2006). Since service-learning focuses on students addressing genuine needs, they are working in an authentic context.

Service-learning can also be seen as an example of place-based education because it involves students engaging with their community. Smith and Sobel (2010) define place-based education as connecting curriculum to the local community. Because the learning is rooted in what is familiar, place-based learning enhances student engagement and achievement (Smith & Sobel, 2010).

Recall that the NLYC define service-learning as, “an approach to teaching and learning in which students use academic knowledge and skills to address genuine community needs” (2015, p. 1). “Community needs” reference the fact that service-learning is place-based, “genuine” references that it is authentic, and “students use academic knowledge and skills to address” recognizes that it involves Dewey’s reflective thinking based on direct experience. In this way,
the knowledge, strategies, benefits, and challenges concerning experiential learning, authentic instruction, and place-based learning apply to service-learning (Figure 4).

**Benefits of service-learning.** Most of the service-learning literature in both secondary and post-secondary education settings identifies benefits to both the agency served and to the students. This aligns with Furco’s (2003) definition of service-learning: both the provider and the receiver of the service receive benefits from the experience. Much of the service-learning research focuses on the benefits to the student participants rather than the benefits to the community.

This project categorizes student benefits into two categories: affective and academic. Affective outcomes refer to the changes in students’ attitudes and feelings towards the academic subject, their community, school in general, or their service work. Academic outcomes reference measurable records of student learning such as assignments, course grades, GPA, and standardized test scores. Affective benefits are those that might be valued by the students while academic benefits are those valued by the institution (Figure 2).

**Affective benefits.** Nearly every study researching student outcomes of service-learning experiences report significantly increased affective attitudes toward the community, their scholarship, or both (Billig, Root, & Jesse 2005a; Cramer, 2008; Dresner & Fischer, 2013; Eyler & Giles, 1999; Kennel, 2000; Reynolds & Ahern-Dodson, 2010; Schon, Eitel, Bingaman, Miller, & Rittenburg, 2014; Shapiro, 2009; Simmons, 2000; Willems & Gonzales-DeHass, 2012). Several studies report that engaging in a service-learning project increases a student’s sense of citizenship within their community (Billig et al., 2005a; Cramer, 2008; Eyler & Gyles, 1999; Kennel, 2000). Kennel (2000) reports that in his experience, students who had service-learning experiences were more likely to become emotionally attached to the places and organizations
where they accomplished their service-learning and were more likely to engage in conversations surrounding community issues in class. Eyler and Gyles (1999) note that along with students feeling more connected as citizens of their community, the institution itself becomes more accepted within the community, connecting community and schools. Studies that looked at service-learning in the context of political science report a greater sense of civic duty in their students (Billig et al., 2005a). Research on service-learning experiences in the field of environmental science suggests participating students develop lifelong connections to their local environment (Cramer, 2000) and they have significantly higher environmental stewardship attitudes and behaviors (Dresner & Fischer, 2013). This reflects research done on environmental place-based learning after which students tend to display more pro-environmental behavior (Kudryavstev, Dtedman, & Kransy, 2011).

Along with increased community attachments, many studies report that service-learning experiences increased student interest and engagement in their academics (Billig, et al., 2005a; Billig, 2011; Dymond, Renzaglia, & Chun, 2008; Eyler & Giles, 1999; Kennel, 2000; Reynolds & Ahern-Dodson, 2010; Simmons, 2000; Steinke & Buresh, 2002). Eyler and Giles (1999) found that service-learning projects increase student enthusiasm and motivation for their academics through providing relevancy and practical applications to academic knowledge. Also, students who participate in service-learning experiences report having elevated enjoyment in their class (Billig et al., 2005a). Because of their increased enjoyment and motivation for coursework, students participating in a high-quality service-learning program tended to have higher attendance, fewer tardy days, and fewer suspensions (Billig, 2009). One study reported that service-learning experiences even influenced students affectively enough to direct career pursuits (Austin, Vogelgesang, Ikeda, & Yee, 2000). Even brief, one time (8-10 hour long), service-
learning experiences can lead to students reporting an increased sense of social responsibility, an increased sense of the meaningfulness of their education, and an increased likelihood to pursue an occupation related to their service experience (Reed, Jernstedt, Hawley, Reber, and DuBois, 2005).

**Academic benefits.** Since so many studies report the increased affect students have toward their academics after participating in a service-learning experience, it might seem logical to find increased academic success from these students as well. While this is true in some cases, many studies have found no measurable academic benefit to students who participated in a service-learning project. Markus, Howard, and King (1993) published one of the most cited studies suggesting service-learning results in higher traditionally measured academic outcomes for students. They concluded that a service-learning experience increased students’ grades and comprehension. Austin et al. (2000) in a quantitative nationwide study, found higher GPAs and better critical thinking skills from students who participated in service-learning projects than students who did not.

Conversely, a nationwide study of similar scope on high school students that participated in different civic service-learning projects found that while students who participated in service-learning projects tended to have higher grades, their findings were not significant (Billig et al., 2005a). Steinke and Buresh (2002) and Eyler and Giles (1999), despite finding significant positive affective influences of service-learning on students, failed to show that service-learning had any significant influence on traditional academic measures. Several of these studies do note that they found that students seemed to have a higher quality of thinking after their service-learning experience and their knowledge of the subject material appeared to be much deeper (Austin et al., 2000; Eyler & Giles, 1999; Steinke & Buresh, 2002). Eyler and Giles (1999)
question whether the current method of measuring academic success and knowledge acquisition through grades and test scores is a fair representation of a student’s learning. They believe that current measures of achievement are flawed, especially in the context of service-learning. Many studies suggest that the increased connectedness to the community and practical application of content in service-learning lead to students making deeper connections and furthering their learning and academic interest (Eyler & Giles, 1999).

This authentic acquisition of knowledge is opposed to the superficial knowledge not connected to any experience or application that experiential education theorists Whitehead (1929) and Dewey (1938) describe as “inert knowledge” and “static knowledge” respectively. Eyler and Giles (1999) suggest that current measures of academic success tend to measure only this inert/static knowledge and call for a change in the way academic success is measured. Steinke and Buresh (2002), conclude that engaging in service-learning may not improve content knowledge (Dewey and Whitehead’s inert/static knowledge) but it improves the quality of thought. A problem-solving protocol may better measure cognitive growth and may show increased growth in a service-learning participant over a non-participant (Steinke & Buresh, 2002). While current measures of academic success may not show an academic advantage to participating in a service-learning experience, other measures of cognitive outcomes likely could.

The positive affective outcomes of a service-learning experience on students might seem enough to inspire the integration of service-learning into curricula, however, they are not the only stakeholders in a service-learning experience. Furco (2003) establishes that service-learning should fall in a balance between the learning (students) and the service itself (community/partner organizations) (Figure 3), but the education institution is also invested in a service-learning experience (Figure 1, Figure 2). Sigmon (1996) recognizes academic institutions are concerned
with finding the best ways to educate their students. Institutions need to identify concrete academic benefits a service-learning experience provides students in order to support it.

Since the No Child Left Behind Act (2001) was passed, students within federally funded public schools have been required to meet certain standards in order for the school to receive federal funding. The monetary pressure this places on public institutions makes them extremely invested in making sure that students are measurably meeting the standards. Even if a service-learning experience provides students with affective benefits that are not identified by testing or state mandated benchmarks, it is challenging for institutions to support a service-learning experience (Eyler & Giles, 1999; Herczog 2000; Smith and Sobel 2010; Steinke & Buresh 2002). Educators themselves may also view service-learning as an illegitimate pedagogical technique unless it is clear that there are cognitive benefits to incorporating it into a traditional classroom (Eyler & Giles, 1999; Steinke & Buresh, 2000).

**Service-learning standards.** When done well, service-learning provides students with many affective and academic benefits, but when poorly executed, it can have no impact and be a waste of time (Billig, 2009; Billig, 2011). In a review of empirical studies on service-learning experiences for students, Meinhard and Brown (2010) found that higher quality service-learning programs tend to be well-structured. Aspects of service-learning experiences that are of high quality include (a) clear educational goals; (b) opportunities for student reflection; and (c) the opportunity for students to make decisions (Meinhard & Brown, 2010). While these aspects, among others, can indicate a higher quality service-learning experience, Meinhard and Brown (2010) make no conclusions on which aspects or combination of aspects a program should have to be most effective. In 2008, the National Youth Leadership Council (NLYC), a national organization that advances the field of service-learning, developed a set of eight standards that
identify the elements that make a quality service-learning experience, they call these “K-12 Service-Learning Standards for Quality Practice.” The standards are based on a wide variety of academic literature on service-learning and education (Billig, 2011). While these are listed in detail in Appendix A, the following section provides a brief review of them.

One criticism of service-learning is that it can turn into volunteerism, with students spending valuable class time engaging in menial labor with no academic benefit, such as simply planting trees (Stemen, 2003). The standard, “Link to Curriculum: Service-learning is intentionally used as an instructional strategy to meet learning goals and/or content standards,” (NYLC, 2008, p. 1) takes into account the importance of having clearly defined learning goals. It is also important that teachers and community partners are both equally aware of these goals and be explicit about them to students during the experience so students can scaffold knowledge (Billig, 2011).

In addition to knowing what the learning outcomes of the experience are, a service-learning project should also provide opportunities for reflection, as described in the standard, “Reflection: Service-learning incorporates multiple challenging reflection activities that are ongoing and that prompt deep thinking and analysis about oneself and one’s relationship to society” (NYLC, 2008 p. 2). The greatest consensus in the service-learning literature is the importance of student reflection on the experience (Austin et al., 2000; Billig 2009; Billig, 2011; Dymond et al., 2008; Eyler & Giles, 1999; Meinhard & Brown, 2010). Reflection promotes both academic and affective benefits of student learning.

Reflection may also tie into the standard, “Meaningful Service: Service-learning actively engages participants in meaningful and personally relevant service activities,” (NYLC, 2008, p. 1) where students identify the service’s relevancy through their reflection. This helps to avoid
Gulikers et al.’s (2004) finding that students lose motivation in authentic instruction if they cannot identify that it is truly authentic.

Part of making service meaningful is having solid relationships with partner organizations as indicated in the standard, "Partnerships: Service-learning partnerships are collaborative, mutually beneficial, and address community needs" (NYLC, 2008, p. 3). It is important to make sure all parties involved share common goals and truly make service-learning experiences place-based.

The standard, “Youth Voice: Service-learning provides youth with a strong voice in planning, implementing, and evaluating service-learning experience with guidance from adults,” (NYLC, 2008, p. 3) parallels Meinhard and Brown’s (2010) assertion that it is important to give students decision-making power in a service-learning experience. While giving students a voice is important, students can be overwhelmed when given too much freedom (Billig, 2011).

Students should be involved in progress monitoring as identified in the standard, “Progress Monitoring: Service-learning engages participants in an ongoing process to assess the quality of implementation and progress toward meeting specified goals, and uses results for improvement and sustainability” (NYLC, 2008, p. 4). This refers to progress monitoring of reaching specified goals for the community and the metacognitive goals for learning and reaching academic goals (Billig, 2011). Progress monitoring includes students collecting evidence on progress and quality and using that to improve the experience and communicate progress. Billig (2009) has shown a positive relationship between progress monitoring goals and increased academic test scores. Also, progress monitoring gives feedback to the students themselves if they are meeting both academic and community goals (Billig, 2011).
The NYLC acknowledges the importance of making sure the service-learning experience lasts long enough to promote actual community change and student learning with the standard “Duration and Intensity: Service-learning has sufficient duration and intensity to address community needs and meet specified outcomes” (NYLC, 2008, p. 4). Service-learning experiences should be structured in a way to allow enough time and structure for students to learn from the experience, and be intensive enough to allow for actual community change.

Finally, the standard, "Diversity: Service-learning promotes understanding of diversity and mutual respect among all participants" (NYLC, 2008, p. 2), while not directly relevant to this project, it acknowledges the many perspectives involved in the community surrounding a service-learning experience. This parallels Ardoin's (2006) assertion that it is important to recognize the four dimensions of understanding place in a community in order to have the most authentic, holistic, place-based educational experience. These four dimensions of understanding place are: (a) the biophysical - the context and setting of place; (b) the psychological - how place is experienced by the individual; (c) the sociocultural – the cultural community context of a place; and (d) the political economic – how people influence the physical. She argues that when these four dimensions of place are addressed in place-based education, students are exposed to a more honest, interdisciplinary, holistic understanding of their community and have a more authentic learning experience.

Applying and acknowledging these standards in a service-learning experience, from both the classroom perspective and the partner perspective, should create a high quality service-learning experience that meets the affective needs of students, the service needs of community organizations, and perhaps even the academic needs of institutions, (Figure 1, Figure 2) (Billig, 2011).
Science and service-learning. The NYLC’s service-learning standards apply to all academic subjects. Since this project approaches service-learning in the context of science education, it is important to consider what research has been conducted in the context of service-learning in science curricula. Service-learning in science education is most practical in either the subject of health and medicine or in environmental sciences because there are community needs where these subjects can be applied (Shapiro, 2009; Smith & Sobel, 2010). It seems that more of the literature on science service-learning is in the context of natural and environmental science education.

There appears to be little empirical research concerning natural science service-learning; most of the literature on the subject is written for practitioner journals and describe the anecdotal successes of a project. While these may not be the most compelling sources of information, and much is based on observation rather than rigorous research methods, there are emergent themes. Firstly, several articles mention how science service-learning fulfills a genuine community need (Cramer, 2008; Reynolds & Ahern-Dodson, 2010). Acting on a need connects students to their community (Cramer, 2008; Owens & Foos, 2007; Whitlow & Hoofnagle, 2010) and in one case, seeing students participating in a service-learning project inspired community members to participate as well (Schon et al., 2014). Practitioner articles also describe the affective benefits that natural science service-learning projects seem to have on participant students, especially in that they develop environmentally-minded students (Cramer, 2008; Dresner & Fischer, 2013). These articles also imply that since the work students perform is tangible, it makes the topic relevant, and student interest in the subject and school itself is increased when engaged in science service-learning projects (Cramer, 2008; Reynolds and Ahern-Dodson, 2010; Shapiro, 2009; Simmons, 2000). These articles also infer that the increased affect students have toward
their science education improves their academics. These emergent themes reflect findings in the general service-learning literature previously explored.

Several articles note the challenges for teachers and schools to effectively incorporate science with service-learning. Facilitating effective service-learning requires much more work from the instructor (Reynolds & Ahern-Dodson, 2010; Shapiro 2009; Whitlow & Hoofnagle, 2010). Reynolds and Ahren-Dodson (2010) claim that another big challenge of incorporating service-learning into a science curriculum is that it can be hard to connect the learning within the classroom to service-learning in the field. Finally, Whitlow and Hoofnagle (2010) mention that a huge challenge is that students are novices at the service-learning work and they might be put into a position that requires them to perform complex work with very minimal training.

Many practitioner articles describing natural science-based service learning experiences simply describe the students participating in the collection, analysis, and dissemination of environmental data (Owens & Foos, 2007; Reynolds & Ahern-Dodson, 2010). However, the majority of natural science service-learning efforts described in the literature describe students engaged in ecological restoration work (Cramer, 2008; Dresner & Fischer, 2013; Schon et al., 2014; Whitlow & Hoofnagle, 2010).

**Ecological Restoration**

*Environmental and community needs.* With trends of increased population, increased consumption, and reduced industrial efficiency, humanity consumes resources at exponentially heightening rates. From this, there has been increased development, habitat fragmentation, and climate change (Noss & Cooperrider, 1994). As a result, Earth’s biodiversity is currently threatened with mass extinction (Clewell & Aronson, 2013). A loss of biodiversity and change in climate simplify and destabilize ecosystems (Clewell & Aronson, 2013). Noss and Cooperrider
(1994) call to prioritize biodiversity conservation and to switch from focusing on habitat management that maximizes short-term gains in natural resource use, to one of long term ecologically oriented sustainability. The young field of ecological restoration has a focus on holistic ecological processes and can be a major tool in preserving ecological biodiversity (Jordan, Peters, & Allen, 1988). Anthropomorphic stresses on natural systems have created ecosystems that are no longer entirely self-sustainable and require ongoing management and restoration to prevent them from becoming further impaired (Clewell & Aronson, 2013). At this point in Earth’s history, ecological restoration should be integral to land management for both production and conservation (Hobbs, 1996).

While the research regarding and understanding of ecological processes and the field of restoration ecology is ever increasing, the amount of restoration success remains surprisingly static (Bruce, Newingham, Harris, & Krumpe, 2014). Geist and Galatowitsch (1999) identify that a lack of ongoing participation and commitment within communities are the principal factor preventing restoration success. While it has global implications, restoration is, by its nature, a local endeavor and members of the community are strong stakeholders in the restoration process (Andrews, Stevens, & Wise, 2002; Clewell & Aronson, 2013; Ewing & Gold, 2011). Geist and Galatowitsch (1999) recommend increasing community interest through integrating the community in assessment and decision-making within restoration practice. However, a study found that most governmental organizations do not perceive using volunteers to save time or money in restoration projects as the organizations perceive there to be a lack of trained and knowledgeable volunteers available to do effective work (Bruce et al., 2014). Bruce et al. (2014) recommend overcoming these perceived organizational barriers through training more volunteers in ecological restoration. The issues that Geist and Galatowitsch (1999) and Bruce et al. (2014)
bring up ultimately can be solved through increasing community education efforts in restoration. This parallels Noss and Cooperrider’s (1994) assertion that a lack of education is the prevalent barrier to biodiversity conservation.

Increasing the environmental literacy of community members can be a way to prepare them to positively contribute to restoration efforts by taking action and making well-informed decisions (The North American Association for Environmental Education [NAAEE], 2010). Environmentally literate people are those that can “analyze global, social, cultural, political, economic and environmental relationships, and weigh various sides of environmental issues to make responsible decisions as individuals, as members of their communities, and as citizens of the world.” (NAAEE, 2010, p. 2). The NAAEE calls for an environmentally literate citizenry and they developed a set of guidelines based on research for teaching environmental literacy in primary and secondary classrooms. Their guidelines integrate four strands: (a) questioning, analysis, and interpretation skills; (b) knowledge of environmental processes and systems; (c) skills for understanding and addressing environmental issues; and (d) personal and civic responsibility (NAAEE, 2010). These guidelines are rooted in understanding local systems and firsthand experiences are key for an environmentally literate populace (McCann, 2011). In this sense, restoration-based education can be a significant tool for increasing environmental literacy.

**Restoration science and practice.** In order to facilitate restoration-based science education, one must be familiar with the skills and scientific knowledge a restoration practitioner uses when engaged in ecological restoration. Successful restoration requires a thorough and intimate knowledge of ecological principles and the nature of the system in which one is working. Since the practice is applied ecology, it is often referred to as an “acid test” of our ecological understanding; in other words, there is a relationship between ecological knowledge
and restoration success (Bradshaw, 1987). A restoration ecologist, therefore needs a thorough understanding of restoration ecology, the science on which the practice of ecological restoration is based (Society for Ecological Restoration International Science & Policy Working Group, 2004). Ehrenfeld (2000) notes that the field of restoration arises from four strands, each of which contributes to themes, ecological understandings, and practices in the field as shown in Figure 5. The arrows within each box refer to what the goal of each of the strands aims to protect.

Figure 5. The strands of science that have contributed to restoration ecology, each adding complexity to the field. Used with permission from Ehrenfeld (2000, p. 3). © 2000 Society for Ecological Restoration.

Conservation biology is located in the upper left rectangle. This is a field that focuses on preserving biodiversity and individual species, and, as an extension, conserving the supporting community. Below it, geography and landscape ecology have contributed to the field. These practices focus on conserving whole landscapes often at the watershed level. In the upper right,
wetland management driven by legislation that was written to protect wetlands and the ecosystem functions and the ecosystem services they provide to humans. Ecosystem functions are often used as monitoring benchmarks in the field of restoration ecology. It is particularly important to focus restoration on wetland restoration in the face of climate change as they can enhance ecosystem resilience within and beyond their borders (Seavy et al., 2009). In the bottom right, the final lineage that contributes to the practice of restoration ecology is the practice of trying to reclaim places that were significantly disturbed from natural resource extraction (Ehrenfeld, 2000).

When a site or ecosystem is ecologically impaired, a restoration practitioner cannot directly address every issue in the ecosystem as such problems involve processes influenced by a long chain of cause and effect (Clewell & Aronson, 2013). Clewell and Aronson (2013) outline the attributes of a restored ecosystem and their relationships and interactions with one another (Figure 6). The first four attributes shown in Figure 6 (species composition, community structure, abiotic environment, and landscape context) can all be directly altered by a restoration practitioner, while the other seven attributes are indirectly influenced by the first four. As such, the ecosystem attributes that can be directly influenced by a practitioner can be boiled down to three basic components of restoration practice: (a) changing the physical aspects of a habitat (soil texture, hydrology patterns, disturbance regime, landscape features, etc.); (b) changing chemical aspects (nutrients, toxicity, etc.); (c) changing the biotic aspects (introducing missing species and removing undesirable species) (Bradshaw, 1996).
Ehrenfeld (2000) assembled several ecosystem functions identified in other research that restoration ecologists use to measure ecosystem health and restoration progress (Table 1). This list is problematic because it is incredibly heterogeneous with different levels of ecological processes driving different processes (Ehrenfeld, 2000). Some processes are influenced by specific species (mutualisms, succession) while others function at the community level (energy flow, nutrient cycling). Therefore, it is important for restoration practitioners to have an understanding of processes at different scales or “ecological hierarchies” (Aronson & Le Floc’h, 1996). For example, despite the fact that restoration focuses living systems on a macro scale, genetics can play a significant role in the success of a restoration project. It is important to
consider the genotypes of organisms one is introducing into a restoration project (Lesica &
Allendorf, 1999). Aronson and Le Floc’h (1996) propose the following ecological hierarchies to
be considered in the restoration ecology in order of scope: gene, individual, population,
community, ecosystem, landscape, matrix, biogeographical region, and biosphere. These
coincide with Ehrenfeld’s (2000) four strands that have contributed to restoration ecology
(Figure 5) from a focus on individual species at the conservation level, to entire landscapes at the
watershed level. With these multiple scales to consider, a restoration practitioner requires an
understanding of life, chemical, and earth sciences.
Table 1

*Ecosystem Functions*

<table>
<thead>
<tr>
<th>Category</th>
<th>Process</th>
</tr>
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<tbody>
<tr>
<td>Material flow</td>
<td>Energy flow</td>
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<tr>
<td></td>
<td>Nutrient cycling</td>
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<tr>
<td></td>
<td>Nutrient retention/loss</td>
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<td></td>
<td>Carbon storage</td>
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<td></td>
<td>Productivity</td>
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<td></td>
<td>Water flow</td>
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<tr>
<td></td>
<td>Water turnover rates, flow rates (aquatic)</td>
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<tr>
<td></td>
<td>Transfers to/from other ecosystems</td>
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<tr>
<td>Physical elements</td>
<td>Disturbance regimes (fire, disease, storms)</td>
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<tr>
<td></td>
<td>Water quality</td>
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<tr>
<td></td>
<td>Landscape structure</td>
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<tr>
<td></td>
<td>Soil formation</td>
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<tr>
<td>Biological structure</td>
<td>Trophic structure</td>
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<tr>
<td></td>
<td>Predation/herbivory rates</td>
</tr>
<tr>
<td></td>
<td>Succession</td>
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<tr>
<td></td>
<td>Resilience/resistance</td>
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<tr>
<td></td>
<td>Diversity</td>
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<tr>
<td></td>
<td>Mutualisms</td>
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<tr>
<td></td>
<td>Passive vs. active dispersal</td>
</tr>
</tbody>
</table>


While an understanding of ecological concepts is necessary for a restoration practitioner, one should also be familiar and have practice with a number of scientific practices. Hobbs (1996) identifies the key processes necessary to successfully integrate restoration into land management:

1. Identify processes leading to degradation or decline.
2. Develop methods to reverse or ameliorate the degradation or decline.
3. Determine realistic goals for reestablishing species and functional ecosystems, recognizing both the ecological limitations on restoration and the socioeconomic and cultural barriers to its implementation.

4. Develop easily observable measures of success.

5. Develop practical techniques for implementing these restoration goals at a scale commensurate with the problem.

6. Document and communicate these techniques for broader inclusion in land-use planning and management strategies.

7. Monitor key system variables, assess progress of restoration relative to agreed-upon goals, and adjust procedures if necessary. (p. 95-96)

Just as in Hobb’s seventh key practice, Clewell and Aronson (2013) also note the importance of monitoring in restoration in assessing restoration success. They suggest inventorying a restoration site pre-restoration and choosing a reference site to use as a model for restoration success. Bradshaw (1996) adds that a respectable restoration practitioner should actively experiment during restoration in order to identify which restoration successes were a result of natural self-repairing properties of a system versus the result of restoration practice. He also notes that experimentation and subsequent communication of findings are also important to add to this young field of science.

**Restoration-based education.** Given the environmental and community need for restoration work and the knowledge and skills it requires; several organizations are currently working to provide communities opportunities to participate in restoration work through restoration-based education.
There are several articles that describe restoration based education experiences for classrooms. While these demonstrate students engaging in unique restoration activities, there are many similarities among them. Figure 7 offers a comparison of descriptions of different organizations found in the literature.

Figure 7 shows how eight restoration-based education organizations engaged their students in various restoration practices as reported in academic articles. It also shows how many of the articles use various measures to convey success in the organizations’ efforts. The most common restoration activities described are native species planting and introduction and invasive species removal, changing only the biotic elements of a habitat. Influencing biota is only one of the three components of restoration practice (the other two being altering the physical elements
and altering the chemical elements) (Bradshaw, 1996). Three articles describe changing the physical aspects (ground stabilization) and zero describe influencing the chemical aspects of a habitat (Bradshaw, 1996). The most common measures of success were affective measures (students are more conservation minded, more interested in school, etc.) and engagement of and with the community. The least common reported measures of success were the environmental successes of the projects and any kind of academic benefit (met standards, improved standardized test scores, etc.) of the restoration-based learning experience.

It is well established that restoration-based education and/or RSL can have positive affective benefits on students. It is the most commonly used measure of success for restoration based education experience, as noted in Figure 7. Also, the fact that few organizations use environmental measures to measure program success (Figure 7) reflects the fact that there has been little research done to explore whether these types of restoration projects are environmentally and ecologically successful (McCann, 2011). One of the projects that noted environmental success was an RSL program with undergraduates at Indiana University and Purdue University where students put thousands of hours into wetland and riparian restoration activities while engaged in discussions and reflections relating back to earth and environmental science courses (Tedesco & Salazar, 2006). While the primary goal of this project was to instill a sense of environmental stewardship in students, the program received recognition for the improvement of water quality in central Indiana by both the governor of Indiana and the city of Indianapolis. Gold et al. (2006) also reported environmental successes. They describe a capstone course for an undergraduate certificate in which students collaborate with community partners in restoration projects. They attribute the high return rate of community clients as an indicator of restoration success. Finally, a study looking at schoolyard ecological restoration projects in
primary schools found that the restoration sites did not have any ecological integrity, however they did harbor more biodiversity than pre-restoration (Anthonisen, 2005). These examples suggest that while not widely reported, restoration-based education can be successful in its ecological restoration objectives.

Organizations that offer RSL opportunities for students are aware of the environmental and academic benefits of their work but many also note that there are challenges to successful implementation. Supports such as funding, resources, and educator time are all limitations to these kinds of projects (Gold et al., 2006). However, even when teachers are given such support, including professional development programs and access to information networks, secondary school teachers were unable to incorporate innovative pedagogical techniques like restoration-based learning into their classrooms because of structural roadblocks like scheduling, school consolidation, and standards-based curriculum reform (Hall & Bauer-Armstrong, 2011). Stone and Barlow describe the formation of a RSL organization after a fourth grade teacher incorporated restoring the habitat of a local endangered species into her curriculum (2009). They acknowledge that this project, and the subsequent genesis of this restoration based education organization, would not have been possible had the school not already committed to incorporating environmental project-based learning into its curriculum. Having explicit institutional support from the school allowed this teacher the flexibility to incorporate an inventive pedagogy into her education practice.

Hall and Bauer-Armstrong (2011) call for both schools and school systems to embrace environmental-based education and enhancing Science, Technology, Engineering, and Math (STEM) content connections within current environmental education. Despite the ecological, community, and academic benefits of incorporating ecological restoration-based education
experiences into classrooms, the pressure of educators to meet specific standards is a barrier preventing schools from embracing them. This barrier may be overcome if restoration-based education experiences can be shown to meet the standards adopted by a school. A thorough understanding and investigation of standards is necessary in order to find where the standards and ecological restoration practice might align.

**Next Generation Science Standards**

The Next Generation Science Standards [NGSS] (NGSS Lead States, 2013) are a recently published set of science standards that many states and school districts were adopting at the time of this project.

**Development and rationale.** In order to understand the core foundations of NGSS, it is important to consider its development within the history of science standards in the US. The following section provides a brief history of standards-based reform and the research efforts that led to NGSS in order to provide context for its development.

Standards-based reform began in the United States in the 1980s. In 1983, the National Commission for Excellence in Education published a report entitled, *A Nation at Risk*, that claimed that other nations were exceeding America technologically and the American economy was at risk due to poor science education within the public school system (NRC, 2007). This was a political catalyst that led to governors pushing for standards legislation in their own states and federal funding supporting the development of a national set of science standards to guide curriculum development in specific content areas (Brown, 2009). The American Association for the Advancement in Science (AAAS) formed a team of scientists and educators to develop the core ideas of science and engineering that all American students should know by the time they graduate high school called Project 2016 and published their findings in *Science for All*.
Americans in 1989 (Wren, 2014). This book encourages less memorization in science education and attempts to make science more approachable for students; it was instrumental in defining science literacy (Wren, 2014). The AAAS published *Benchmarks for Science Literacy* (1993) to help shape future national standards. Simultaneously, the National Research Council (NRC) was working on a parallel project that produced the National Science Education Standards (NSES) in 1996. The intention was to create clear learning goals for students (Bybee, 2013b). While these sets of national standards were met with opposition, Bybee (2013b) believes that there are several benefits to such a system. He advocates for them because they influence every aspect of the education system: they clarify what the key learning goals in science are, they allow for an equal learning opportunity for all students, and they do not need to vary based on the region in which they are implemented. After fifteen years of using the NSES, there was little improvement in science education, United States students continued to score lower than international peers in science, and there became significant achievement gaps between ethnic/racial and economic populations (NRC, 2007). Therefore, the NRC compiled the most current research on how children learn science and how it should be taught. Their synthesis, *Taking Science to School*, published in 2007, was the collection of research that eventually led to a new framework that guided the new set of standards, the NGSS.

*Taking Science to School* and its practitioner-focused companion, *Ready, Set, Science!* were both a change from previous approaches to science education that were more content focused, to one of integrating science practices and deeper understanding into science learning (Michaels, Schouse, & Schweingruber, 2008). Within these works, the NRC recommended several specific ways that science education should be approached. For example, they recognized that children are much more capable at engaging in the abstract thought and reasoning that is
required in scientific thinking than was previously believed. Standards and curriculum should be based on core ideas in science that can span disciplines and can be explored with increasing complexity as students mature (NRC, 2007). Science education should present science as “a process of building theories and models using evidence, checking them for internal consistency and coherence, and testing them empirically” (NRC, 2007, p. 4) and should expose students to a wide range of science methodology. Much of this research continued to be supported by AAAS and Project 2061 (Wren, 2014).

In 2011, the NRC published *A Framework for K-12 Science Education* (referred to in the rest of this paper as the *Framework*). This document provided a guide for future standards and curriculum development. The NRC developed the *Framework* with the intention to not only educate students in science and engineering but also give students the base knowledge they need to pursue a career in science and/or engineering (NRC, 2011). Several principles guided the *Framework* based on the research and recommendations presented in *Taking Science to School* and *Ready, Set, Science!* Guiding principles of the *Framework* included: (a) an understanding that children are sophisticated thinkers; (b) a focus on a limited set of core ideas and practices that allow for a deeper investigation of concepts and skills; (c) an understanding that knowledge happens over time and repetition; (d) the idea that science and engineering require knowledge and practice in science and engineering skills; (e) the importance of connecting learning to students’ experiences and interests; and (f) the promotion of equity among socioeconomic status, gender, race/ethnicity, ability, and language ability (NRC, 2011). Based on these guiding principles, the *Framework* was presented as three dimensions, which should be integrated together in science education. These dimensions are the scientific and engineering practices (SEPs), crosscutting concepts (CCCs), and disciplinary core ideas (DCIs).
The NRC developed Next Generation Science Standards (NGSS), released in 2013, which incorporated the three dimensions listed in the *Framework* into performance expectations separated by grade. Aligning with the guiding principles of the framework, the NRC noted that the NGSS have seven conceptual changes from the previous set of standards:

1. K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.
2. The Next Generation Science Standards are student performance expectations – not curriculum.
3. The science concepts in the NGSS build coherently from K–12.
4. The NGSS focus on deeper understanding of content as well as application of content.
5. Science and engineering are integrated in the NGSS, from K–12.
6. The NGSS are designed to prepare students for college, career, and citizenship.
7. The NGSS and Common Core State Standards (English language arts and mathematics) are aligned. (NGSS Lead States, 2013a, p. 1-5)

Bybee (2013) notes that NGSS had several innovations. Firstly, the standards themselves are no longer statements of content but rather performance expectations. This changed how these standards might be assessed. Secondly, they integrate the three dimensions within each performance expectation and expect instructors to recognize all three. In addition, engineering and the nature of science were integrated. Finally, they have an intentional progression from kindergarten through twelfth grade (Bybee, 2013). Science standards were developed because of a need for a more consistently rigorous benchmark for all students to reach. The NGSS were developed because of this need but also reflect the research for best practices in science learning and education.
**Next Generation Science Standards dimensions.** The NGSS are listed as a series of performance expectations aligned by grade that each incorporate an element of all three dimensions of the *Framework*. The foundation boxes in the performance expectations list which dimensions were incorporated into the performance expectations. While the standards themselves are complex, the National Science Teachers Association (2013) recommended using both the performance expectations and the foundation boxes to develop curriculum. The NRC is clear that the standards themselves are only performance expectations and are not meant to be curriculum (NGSS Lead States, 2013a). A curricula or lessons that aligns with NGSS do not need to directly address performance expectations, but they do need to address elements from each of the three dimensions of the *Framework* (Houseal, 2015). This is known as three-dimensional learning. Appendix B outlines how to approach a curriculum or lesson that aligns to NGSS and incorporates three-dimensional learning (Houseal, 2015). Understanding the three dimensions of NGSS and the framework are vital to grasping NGSS.

**Science and engineering practices.** Previous standards separated disciplinary content from the actual practice of science. This gave students the perception that science is simply a discrete body of information that is isolated from scientific practices (NGSS Lead States, 2013d). Not integrating the practices that develop scientific knowledge downplays its applications especially in regards to engineering (NRC, 2011). The science and engineering practices were developed with the intention to help people understand that scientific practice is not a single set of practices, nor does science happen by using one particular method, and it emphasizes practices that previous standards did not, such as engaging in evaluation and scientific critique (NRC, 2011).
The Framework identified three spheres of activity in which the practices can be categorized (investigating, evaluating, and developing explanations and solutions). Each sphere is equally important and scientists move between them in no particular order. The Framework also identified the difference between science and engineering. Engineering focuses on defining and solving a practical problem, while science may not have a practical or immediate application. Overall the Science and Engineering Practices (SEPs) outlined in the Framework and the NGSS were developed with several guiding principles: (a) students should engage in every SEP in every grade, (b) SEPs grow in complexity in every grade; (c) the SEPs are not discrete and intentionally flow into one another; and (d) they require students to engage in scientific discourse. The SEPs were not intended to be taught in isolation but in conjunction with Disciplinary Core Ideas and Crosscutting Concepts.

The eight SEPs identified by the Framework and used in the development in the NGSS are as follows:

1. Asking questions (for science) and defining problems (for engineering)
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 (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (NGSS Lead States, 2013d, p. 1)
**Disciplinary core ideas.** The Framework outlined specific Disciplinary Core Ideas (DCIs), science and engineering content, for students to learn (NRC, 2011). The intent was to pare down scientific knowledge to a few big ideas in order to allow teachers and students more time to address the topics in depth and incorporate scientific and engineering practices in education (NRC, 2011). The DCIs include three scientific disciplines: Life Science, Earth and Space Science, and Physical Science, and a fourth - Engineering, Technology, and Applications of Science. Social, behavioral, and economic sciences and statistics and computer sciences were intentionally left out (NRC, 2011). Within each discipline, there are sub-ideas that increase in complexity of understanding with each grade band, and many of these sub-ideas overlap in content and ideas (NGSS Lead States, 2013c). The DCIs and their progressions across grades are presented in Appendix C of this document.

**Crosscutting concepts.** The Crosscutting Concepts (CCCs) are unifying themes or big ideas that are found throughout all disciplines in science. Applying the CCCs to DCIs allows students to understand scientific content with more depth and gain a holistic view of science in the world (NRC, 2011). While these concepts have been identified by previous standards and addressed in science curriculum, it is important to formally, and explicitly address them in instruction. The NGSS has done this by incorporating them within performance expectations in the standards (NGSS Lead States, 2013e). The seven CCCs are:

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
NGSS in practice. The NGSS have been received fairly well within the research literature. Most articles addressing the new standards acknowledge the need for new standards and approve of the way the standards better represent science and engineering practice (Bybee, 2012; Bybee, 2013a, 2013b; Coffey & Alberts, 2013; Dentzau, 2013; National Science Teachers Association, 2013). For example, the National Science Teachers Association (2013) recommends that states and districts adopt NGSS, as they believe that the focus on key concepts and application will improve scientific literacy in the US.

A common concern with the adoption of the new standards is the curricular and institutional changes necessary. Bybee (2012; 2013b) sees the creation of NGSS as the easy step while the current challenge is to develop programs, curriculum, and training teachers in how to teach to the new standards. The biggest need now in the adoption of NGSS is the development of curriculum and administration support for them (Bybee, 2013a; NRC, 2011; National Science Teachers Association, 2013).

How NGSS should be assessed is another concern in the literature. Coffey and Alberts (2013) support the new standards but are worried that their emphasis on the practices will make the new standards a challenge to assess. The Framework even recognized that in order to facilitate the proper instruction of science, assessments need to change (NRC, 2011). While a change in standards assessment will require significant institutional changes, standardized tests used to assess older standards threaten quality teaching, remove deep thinking in education, and measure only presence of thought rather than quality of thought (Kohn, 2001). Coffee and
Alberts (2013) call for NGSS assessment to develop with the aid of scientists and should focus more on engagement rather than memory of discreet facts.

A criticism of older science standards is that they limit teachers’ ability to apply innovative ways of teaching – a necessity for teaching authentic science (Banks, Elser, & Saltz, 2007). The NGSS, by their very nature, and listed explicitly in the Framework, support a variety of science teaching methods (NRC, 2011). Appendix D of NGSS recommends specific strategies for teaching the standards so they are accessible for all students, especially populations that have historically not done as well in science (NGSS Lead States, 2013b). One recommendation is to ground science experiences in the real world, or create authentic experiences (NGSS Lead States, 2013b). Another recommendation is to connect school science to home, making science place-based (NGSS Lead States, 2013b). NGSS Lead States (2013b) note that place-based instruction is especially important if students can see how scientific knowledge can help make positive community change. They also emphasize the importance of connecting science to the psychological and sociocultural sense of place. While the NGSS Lead States (2013b) suggest that place-based and authentic teaching strategies are especially effective for their specified populations, these strategies are likely just as effective for all student populations.

NGSS does claim that addressing place in science education may not improve test scores, but it has many affective benefits for students (NGSS Lead States, 2013b). Aside from disadvantaged subgroups, several articles describe the importance of incorporating place-based learning with standards (Endreny, 2010; Jennings, Swidler, & Koliba, 2005; National Science Teachers Association, 2013; Rittenburg et al., 2015; Schon et al., 2014). Dentzau (2013) applauds NGSS for addressing the importance of place in science education but he worries that the curriculum that arises from NGSS will only focus on two of his three definitions of place:
location and locale. His third definition, a sense of place, or the subjective and emotional attachment to place, may not be present in the inevitable accountability measures. While the writers of NGSS encourage science education with the standards to be more place-based, there is little literature published on how this can be accomplished. Service-learning may be an avenue for this as it fits in the realm of place-based learning, authentic instruction, and experiential education as discussed previously in this chapter (Figure 4).

**Service-learning and restoration practice in the context of NGSS dimensions.** This project’s framework sought to investigate where restoration, service-learning, and NGSS align. Since restoration ecology is based on solving scientific problems in the environment and incorporates science knowledge and practice, restoration seems a natural fit within the NGSS dimensions. Elements of service-learning also align with NGSS in that service-learning implicates an application of knowledge. NGSS encompasses a sizable body of science content and practice that spans beyond that of restoration and service-learning, therefore in order to align the two, it is necessary to identify which elements of the NGSS dimensions correspond directly with restoration and service-learning. Table 2 demonstrates how elements of the NGSS dimensions align with restoration practice, as described in the literature, and best practices for service-learning. In this table, the work from Hobbs (1996), Aronson and Le Floc’h (1996), Bradshaw (1996), Ehrenfeld (2000), and Clewell and Aronson (2013) describe the knowledge and practice of restoration work while the NYLC’s (2008) service-learning standards are used to describe best practice for quality service learning.
Table 2
*How Elements of NGSS Dimensions Align to the Literature on Restoration and Service-Learning Theory and Practice*

<table>
<thead>
<tr>
<th>Relevant NGSS Dimensions*</th>
<th>The Aligning Restoration Ecology Theory and Practice</th>
<th>Service-Learning Standards**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and Engineering Practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking questions and defining problems</td>
<td>“1. Identify processes leading to degradation or decline” (Hobbs, 1996, p. 95)</td>
<td>Reflection</td>
</tr>
</tbody>
</table>
| Planning and carrying out investigations | “2. Develop methods to reverse or ameliorate the degradation or decline
3. Determine realistic goals
4. Develop easily measurable measures of success
5. Develop practical techniques for implementing these restoration goals” (Hobbs, 1996, p. 95-96) | Youth Voice |
| Analyzing and interpreting data | “7. Monitor key system variables” (Hobbs, 1996, p. 96) | Reflection, Progress Monitoring |
| Constructing explanations and designing solutions | “1. Identify processes leading to degradation or decline
2. Develop methods to reverse or ameliorate the degradation or decline
3. Determine realistic goals …
4. Develop easily measurable measures of success …
5. Develop practical techniques for implementing these restoration goals” (Hobbs, p. 1996, 95-96) | Reflection, Progress Monitoring |
| Obtaining, evaluating, and communicating information | “1. Identify processes leading to degradation or decline” (Hobbs, 1996 p. 95);
Communication of findings is vital to improving the field (Bradshaw, 1996) | Progress Monitoring |

(continued)
<table>
<thead>
<tr>
<th>Relevant NGSS Dimensions*</th>
<th>The Aligning Restoration Ecology Theory and Practice</th>
<th>Service-Learning Standards**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disciplinary Core Ideas</td>
<td></td>
<td></td>
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<tr>
<td>ESS2.C: The roles of water in Earth’s surface processes</td>
<td>Abiotic environment and landscape context are attributes of a restored ecosystem (Clewell &amp; Aronson, 2013); Physical elements such as disturbance regimes and water quality are processes involved in ecosystem functions (Ehrenfeld, 2000)</td>
<td></td>
</tr>
<tr>
<td>ESS2.E: Biogeology</td>
<td>Abiotic environment and landscape context are attributes of a restored ecosystem (Clewell &amp; Aronson, 2013)</td>
<td></td>
</tr>
<tr>
<td>ESS3.A: Natural resources</td>
<td>The science of reclamation/rehabilitation of disturbed lands contributes to restoration ecology (Ehrenfeld, 2000)</td>
<td></td>
</tr>
<tr>
<td>ESS3.C Human impacts on Earth systems</td>
<td>Conservation biology and the science of wetland management and the ecosystem services they provide people contributes to restoration ecology (Ehrenfeld, 2000)</td>
<td>Meaningful service, Reflection</td>
</tr>
<tr>
<td>LS2.A Interdependent relationships in ecosystems</td>
<td>Community structure, ecological complexity, and self-sustainability are all attributes of a restored ecosystem (Clewell &amp; Aronson, 2013)</td>
<td></td>
</tr>
<tr>
<td>LS2.B Cycles of matter and energy transfer in ecosystems</td>
<td>Species composition, community structure, landscape context, and self-organization are attributes of a restored ecosystem (Clewell &amp; Aronson, 2013); Material flow is a type of process in ecosystem functions (Ehrenfeld, 2000)</td>
<td></td>
</tr>
<tr>
<td>LS2.C Ecosystem dynamics, functioning and resilience</td>
<td>Conservation biology and the science of wetland management and the ecosystem services they provide people contributes to restoration ecology (Ehrenfeld, 2000); Resilience and self-sustainability are attributes of a restored ecosystem (Clewell &amp; Aronson, 2013)</td>
<td></td>
</tr>
<tr>
<td>Relevant NGSS Dimensions*</td>
<td>The Aligning Restoration Ecology Theory and Practice</td>
<td>Service-Learning Standards**</td>
</tr>
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<td>--------------------------</td>
<td>----------------------------------------------------</td>
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</tr>
<tr>
<td>LS4.C: Adaptation</td>
<td>Species composition is a changeable attribute of a restored ecosystem (Clewell &amp; Aronson, 2013); Landscape ecology should be approached through a number of hierarchies including genes, individuals, and populations. (Aronson &amp; Le Floc’h, 1996)</td>
<td></td>
</tr>
<tr>
<td>LS4.D: Biodiversity and humans</td>
<td>Conservation biology and the science of wetland management and the ecosystem services they provide people contributes to restoration ecology (Ehrenfeld, 2000); Restoration ecology is vital in land management for conservation and production (Hobbs, 1996)</td>
<td>Meaningful service, Reflection</td>
</tr>
</tbody>
</table>

**Crosscutting Concepts**

- **Cause and effect**
  - Ecosystem processes involve chains of cause and effect (Clewell & Aronson, 2013)
  - Link to Curriculum

- **Systems and system models**
  - Restoration ecology is applied ecology (Bradshaw, 1996)
  - Link to Curriculum

- **Structure and Function**
  - Ecological functions such as trophic levels, succession, and mutualisms are involved in ecosystem processes (Ehrenfeld), 2000;
  - Abiotic environment and community structure are changeable attributes in ecosystems (Clewell & Aronson, 2013)
  - Link to Curriculum

- **Stability and change**
  - Restoration ecology involves understanding historic continuity, feedback loops, resilience, and sustainability within natural systems (Clewell & Aronson, 2013)
  - Link to Curriculum

*Note:*
*Taken from NGSS Lead States, (2013c).
**Taken from NYLC (2008).
Table 2 shows that the three dimensions and ecological restoration align in several areas. Firstly, many of the SEPs match Hobb’s (1996) seven key processes that land managers should use when incorporating restoration into their practice. Secondly, several DCIs of NGSS parallel the scientific understanding a restoration ecologist must know. Ecological restoration is applied ecology (Bradshaw, 1987) and many of the life sciences DCIs are ecological concepts. DCIs beyond ecology and ecosystem science also align with restoration ecology since restoration can be approached at a number of different hierarchies – from genes to the entire biosphere (Aronson & Le Floc’h, 1996). Since restoration ecology involves abiotic systems and processes alongside biotic, knowledge of earth science DCIs is also relevant in restoration practice. Overall, DCIs that describe human influence and dependence on natural systems especially apply to ecological restoration since restoration is a response to human-caused ecological degradation (Clewell & Aronson, 2013). Finally, restoration ecology naturally contains several of the CCCs into its practice and theory. This table suggests that restoration service learning can incorporate all three dimensions of NGSS in a life and/or earth sciences curriculum.

NGSS, by design, call to intentionally integrate science practice with disciplinary understanding in science education. Given that restoration is an applied science and that service-learning involves an application of content, several elements of restoration practice and quality service-learning practice theoretically align with the dimensions of NGSS. While an RSL unit might meet the needs of the institution (NGSS), it may not necessarily meet the needs of the restoration organizations (quality restoration) or the students (quality service-learning practice) (Figure 2). The following section compares the needs and practice of quality restoration practice and quality service-learning with those of NGSS.
Thematic Alignment of Service-Learning, Restoration, and NGSS

The framework for this project (Figure 2) was based on Furco’s (2003) description of the three stakeholders invested in a service-learning experience (Figure 1). Each have their own objectives, but when a service-learning experience is well planned, it can be mutually beneficial for all parties.

Based on the literature of best practices and needs of service-learning, restoration ecology, and NGSS explored earlier in this chapter Figure 8 expands on the project framework (Figure 2) and indicates the areas where the needs and practice of service-learning, restoration practice, and NGSS each align with one another. Appendix D shows this figure in more detail.

Figure 8. Based on the academic literature, this figure expands upon Figure 2 and shows where service-learning, restoration ecology, and NGSS align in what they share and/or value.
Service-learning, ecological restoration, and NGSS each have various goals and unique stakeholder involvement. Service-learning can be an authentic (Herczog, 2000), place-based pedagogical technique (Smith & Sobel, 2010) if facilitated well, and can provide students with many affective benefits such as increased engagement and enjoyment toward their learning (Eyler & Giles, 1999) and closer ties to their community (Kennel, 2000). Ecological restoration is important for the health of natural systems (Noss & Cooperrider, 1994), valued by community groups (Clewell & Aronson, 2013), and requires community support (Geist & Galatowitsch, 1999). It is a complex field of applied ecology (Bradshaw, 1996) that incorporates science content knowledge and practice in earth and life sciences (Aronson & Le Floc’h, 1996; Bradshaw, 1996; Clewell & Aronson, 2013; Ehrenfeld, 2000; Hobbs, 1996). NGSS are a new set of science standards that are based on the most recent research on science education (NGSS Lead States, 2013a). The NGSS focus on a depth of knowledge over breadth and emphasizes science practice alongside content (NRC, 2011). Despite their unique stakeholders and goals, Figure 8 demonstrates that quality service-learning, restoration ecology theory and practice, and NGSS can align. While this project aimed to find the places where NGSS can align with RSL practice, or where NGSS aligns with restoration and service-learning, Figure 8 demonstrates merely a theoretical alignment of these three elements.

Several third-party organizations in the United States offer high school classrooms the opportunity to participate in RSL experiences. Some of these recognize the importance of aligning their curricula to standards and are trying to explicitly incorporate NGSS into their experiences (Schon et al. 2014). An investigation into how RSL organizations perceive their curricular offerings align/could align to NGSS and what limits they have to aligning RSL to NGSS shed light on the practice of incorporating NGSS with RSL.
Chapter 3: Methodology

Rationale for Qualitative Research

While the literature review synthesized theory, the research collected in this study intended to analyze practice. It addressed the part of the research question that investigated what is current practice in restoration organizations for providing service-learning and incorporating the NGSS into curriculum, and what the current barriers are. The nature of this research project was extremely contextualized; it investigated a specific type of educational method. It also did not assume that restoration research learning is the only way that educators do and/or should approach teaching to science standards. Because of this narrow focus and a need for rich data that will not identify relationships that can broadly be applied to science education practice, a qualitative research design was pursued (Braun & Clarke, 2013).

Qualitative Research Methodology

A thematic analysis was conducted on data collected from three organizations that were providing RSL experiences for middle and/or high school classrooms. Three types of data were collected from each organization: (a) an interview; (b) curriculum documents and/or materials used; and (c) outreach literature that the organizations used to describe their program. Collecting three sources of data ensured confidence of accurate data collection through triangulation (Braun & Clarke, 2013). Since the research question sought to identify common themes in the data and was not trying to develop theory, a thematic analysis approach to analyzing the data was used (Braun & Clarke, 2006).

Subject selection and description. Internet searches for habitat restoration nonprofit organizations were conducted to identify potential candidate programs for this research. Organizations that met the following criteria were included in this project: (a) the organization...
existed in the United States; (b) offered habitat restoration experiences to multiple high school and/or middle school classrooms; and (c) had developed science curricula surrounding the restoration experience that is offered before, after, and/or during service learning events.

Potential organizations that met the above criteria were identified through Internet searches that included key words and phrases such as “restoration” and “service-learning.” Seven potential organizations were contacted for the project, and after initial conversations, three organizations were picked to investigate based on their interest, relevancy to the project, and availability.

Organization A offered academic year-long RSL experiences to middle and high school classrooms within the greater urban area of a large west-coast city. Organization B was similar in scope and size to organization A and offered RSL experiences to elementary through high school classrooms in a west-coast agricultural region. Organization C was a small conservation district in the Rocky Mountains that had just completed a three-year river restoration project during which they engaged local students in RSL experiences. Organization A claimed to have already aligned their curriculum with NGSS, organization B was in the process of reworking their curricula to be more aligned with NGSS, and organization C did not try to align their curriculum with NGSS.

**Data collection.** Interviews were conducted with a representative from each of the three selected organizations who had a direct role in designing and/or teaching curricula. Potential contacts at each organization and their contact info were identified through a search of the organizations’ websites. An initial email was sent that introduced the project and asked if the potential contact was available and willing to participate. If there was a positive response, potential participants were provided with information about the context, purpose and importance...
of the study over the phone or via email. Potential participants were informed in detail about their role in accepting the invitation to be a part of this study. This included an overview of the informed consent form (Appendix E). This conversation provided information on the potential participants’ fit and interest in this study.

Once confirmed to participate, interviewees established a time, date and location to conduct one interview. Immediately after, the interviewees received an email confirmation along with an attached overview of the study, interview questions (Appendix F), and informed consent form (Appendix E). During the interview, participants were asked to answer five semi-structured and open-ended questions that provided descriptive data based on the research question (Appendix F). Clarifying or follow-up questions were asked depending on responses. When preparing interviews for analysis, transcripts did not include paralinguistic features since the analysis of the interviews focused on the information provided and not how it was said. In order to collect curricular data, participating organizations were also asked to send in a sample of curricular materials used in their instructions (PowerPoints, lesson plans, worksheets, etc.).

For self-reporting data, information was collected online regarding what each organization presents in their programs, including newsletters, website descriptions, and press releases. After interviews were conducted and materials reviewed, interviewees were sent a summary of the information gleaned from the interviews and collected materials via email. Participants confirmed that the summary was an accurate representation of their organization and the participant’s ideas. This served as a member check (Braun & Clarke, 2013). Participating organizations and interviewees were given pseudonyms and codes and are referred to by their pseudonym in the research findings.
**Data analysis.** A thematic analysis was performed on the collected data in the way described by Braun and Clarke (2006). The transcribed interviews, curricular materials, and outreach documents were individually coded and then organized into themes. A colleague also coded an excerpt of the data in order to provide and inter-rater reliability check. The inter-rater reliability was 79%. The emergent themes were organized as sub-themes under three overarching themes, each representing three major topics of this project. They were identified as (a) service-learning, (b) restoration, and (c) NGSS. Once defined, reviewed, and named, a thematic map was developed to show the three overarching themes and their subthemes. Chapter 4 describes the analytical results of the emergent themes and subthemes with examples from the data.
Chapter 4: Results and Conclusions

The interviews and collected data provided interesting insights on using RSL to teach to NGSS. This chapter first reviews the major themes and subthemes that emerged from a thematic analysis of the data. Conclusions and recommendations for RSL organizations interested in aligning their curricular offerings to NGSS are provided. These were based on the literature and the results of the thematic analysis. This chapter concludes with suggestions for future research.

Thematic Analysis

Figure 9 describes the major themes and subthemes that emerged from the data about what the current practice of RSL looked like from the perspective of the restoration organizations.

![Diagram showing major emergent themes and subthemes from an analysis of the collected data.]

*Figure 9.* This chart shows the major emergent themes and subthemes from an analysis of the collected data.
The three major themes RSL organizations were practicing in the field and their challenges and needs coincided with the three main topics of the project framework. They were (a) service-learning; (b) ecological restoration; and (c) NGSS (Figure 2). Nothing to the contrary to these themes emerged in the collected data. These themes and their subthemes are discussed in subsequent sections.

**RSL organizations valued the affective benefits of service-learning.** Organizations could engage their community in restoration through means other than service-learning. All three of the RSL Organizations valued RSL for the specific affective benefits that the service-learning experiences brought to their students. Much of their observations reflected the service-learning literature.

**Organizations saw RSL as experiential, authentic, and place-based.** Just as in the service-learning framework presented in this paper (Figure 4), the RSL organizations recognized the experiential, authentic, and place-based nature of their service-learning experiences. All three organizations made similar comments to Organization A, when they noted that their RSL experience had students, “learn more about the world around them and really doing hands on learning, taking science outside of the classroom, and restoring our watersheds at the same time.” The three organizations also seemed to value that their service-learning experiences incorporated these innovative pedagogical techniques. In a document describing their educational design, Organization B described an educational goal of the experience to be “inquiry-based learning.” An annual report from Organization A had a section of participant quotes about why the experience was important to them and every quote was from a student describing how they were more interested in science, feel stronger connections to their community, or discusses how they had positive attitudes toward the work they did. While restoration and service-learning are both
naturally authentic, the literature review also concluded that authenticity is important to the NGSS and is a place where restoration, service-learning and NGSS naturally align (Figure 8).

**Organizations believed RSL empowers students.** RSL organizations highly valued how an RSL experience may empower their participant students. Organization A noted that their main learning goals included “awareness and empowerment” while Organization B said that after the students’ experience they anticipated that, “students and teachers will understand they can make a big difference in their community.” In these cases, the empowerment that the organizations wanted to foster was a feeling that their student participants were not powerless to make positive change in their community. They anticipated that after this positive experience, students would want to continue to engage in restoration work in their community. RSL organizations believed that through empowering their students, they built community buy-in and support for restoration needed for restoration success. Organization A noted that “You're not going to get a lot of students excited about the environment and more overwhelmed by environmental issues if they've never actually gotten out there and done something about it.” They believed that by physically being in the field and taking action, students would not only become more interested in the issues that led to ecosystem disturbance, but would feel that something could be done about it. In this sense, students were not only understanding the negative human effects on natural systems (a shared value of restoration, service-learning, and NGSS [Figure 8]) but they also understood that those effects could be reversed and humans could have positive influences on natural systems. RSL organizations believed that students would feel empowered to be that positive influence.
How do these contaminates enter the water system?

Contaminants range from naturally occurring minerals to man-made chemicals and by-products

- Chemical spills
- Insecticides and herbicides
- Non-native parasites brought in during shipping from other countries
- Marine vehicles (freighters, boats and ships)

*Figure 10.* This is an example slide from Organization C’s pre-field experience slideshow that gave context as to why their restoration work is important.

*Organizations structured their programs so that direct instruction informs service and deeper learning emerges from service.* In all three of the organizations investigated, their service-learning was structured in similar ways. First, the organizations gave a slideshow presentation that gave context to the service work (Figure 10). Second, they instructed the students on how to perform the restoration task (such as planting trees or removing invasive species) and students completed the task. Finally, there was a reflection activity at the end of each day. Organization B described a typical day with students:

> We go in and have a pre-restoration lesson to basically get students thinking about watersheds, how we are all upstream from somewhere, and to give them a little bit of
information about the site they'll be going to so that they can get excited about that. At the very end of it, [we] give them the basics on what shoes to wear and stuff like that. That lesson is about forty-five minutes to an hour. Then they come out to a restoration for a full school day, which ends up being from about 9:30 am to about 1:30-2:30 pm. During the restoration day, we have an opening circle first, where we review some of the connections that they might see to the things we talked about in the classroom. Then for quite a long time, [we] give them safety info and site info and all of that. [Students] do mostly planting at our restoration sites. That's when we individually go up to small groups and chat with them. At the end of the day we circle back up and have a closing circle and review why we did the work we did, if students felt proud of themselves, [and] things like that.

In this way the service and learning were organized so that direct instruction provided context for service, and understanding of disciplinary ideas emerged from engaging in the service. While there might have been clear learning goals with the introductory presentation, there did not seem to be articulated learning goals for the emergent learning from the service. It also seemed that within emergent learning, a change in affect was more important than a change in content knowledge or skills. As Organization A noted:

[We hope that] students can leave the year with an understanding of a watershed, understanding that they are currently in one, and all their actions and the actions of their community is affecting that chain. … I am not expecting them to have 15 native plant species memorized by the time they are done with [our program], but that they know the difference, and that not all green is good, and there are native species and invasive species.
In the collected data, measurable academic outcomes of RSL either were not mentioned or were downplayed next to affective benefits. Only Organization A briefly mentioned a positive pre/post test percentage difference for classrooms participating in their experience in a recent annual report (Figure 11).

![Evaluation](image)

*Figure 11.* This is an excerpt from Organization A's 2014 annual report for their RSL program describing the improvement of 16 of their participant schools in mean test scores on their pre/post test before and after participating in the program. Parts were edited out in order to provide program anonymity.

The test Organization A used for their reporting (Figure 11) was brief and measured understanding of a limited number of disciplinary concepts:

1. What is a watershed?
2. True or false? Your school building is located in a watershed.
3. Which watershed do you live in?

4. What are four (4) ways that planting native trees and shrubs along streams positively impacts stream health?

5. What is an invasive species?

6. Please name four (4) different invasive plant species in your neighborhood.

7. Please name four plant species that are native to the Pacific Northwest.

It appeared that these organizations believed having authentic place-based experiences was most important within their curricula and important to emphasize when describing their organization to the public. The affective benefits of service work are important, but there need to be clear learning goals for an organization to be facilitating quality service-learning (NYLC, 2008) and they need to align with standards in order to have institutional support (Eyler & Giles, 1999; Herczog 2000; Smith and Sobel 2010; Steinke & Buresh, 2002). Organizations discussed the affective benefits as if they are naturally emergent from a student participating in the service work. Restoration work requires an understanding of content knowledge and a familiarity with scientific practices, (Bradshaw, 1987). In addition, the application of knowledge with experience is valued in NGSS and quality service-learning practice (Figure 8). If students were truly participating in restoration service work, there should also be equally emergent measurable academic benefits. Either organizations were not measuring or advertising this well, or students were not engaged in restoration practice as deeply as they should be for learning.

**RSL organizations valued restoration success.** The three organizations investigated in this project were each concerned with making sure that their restoration efforts succeed. While students engaged in restoration efforts during RSL experiences, the experiences seemed structured in a way to make sure the restoration efforts would be successful above all else.
Organizations' biggest focus was restoration success. All of the organizations interviewed seemed to focus on quality restoration practices and in some cases this seemed to overshadow best educational practices in their RSL. Firstly, most of the people working with students did not have formal education backgrounds and tended to have more expertise in restoration. Organization B noted in their interview:

A lot of our funding and opportunities in general in the past ten or so years have been on the restoration side and so our staffing reflects that. And thus, our programmatic choices have reflected that where we're really focused is on our restoration and to do the restoration really well.

The people working with students at these organizations tended to focus more on restoration success rather than making sure that students were meeting specific educational outcomes and/or standards. Students seemed to have no say in what is done in the restoration practices. Organization C noted of their experience: “decisions were made by engineers and all of that. … The plan is already established, the kids get to help participate.” This sentiment was also reflected in a report Organization C presented to their stakeholders about the students’ service-learning projects. The report described only the successes of the restoration project and included no mention of the associated outreach and education. This indicated that successful conservation is a higher priority than their outreach efforts.

If students are merely being told what to do, they may not make the connections as to why it is important and the service-learning simply becomes service, without learning. The literature described the importance of students having a role in decision-making in service-learning (NYLC, 2008) and getting the community involved in restoration work (Geist & Galatowitsch, 1999) and NGSS’s SEPs include practices that involve defining problems,
planning and carrying out investigations, and designing. Despite this, the organizations approached designing their RSL experiences from a restoration success perspective.

**Organizations engaged students in the direct alteration of plant communities and monitoring.** The service work in which the students were engaged within these three organizations was primarily the labor of direct alteration of plant communities and subsequent monitoring. All three organizations described engaging students in planting plants and collecting environmental data on adjacent waterways.

Such practices are necessary and important for successful restoration. A restoration practitioner not only considers the biotic aspects of a restoration site but also physical and the chemical (Bradshaw, 1996). Organizations A and C did engage their students in land stabilization. Perhaps the reason why RSL organizations tended to focus on influencing the biotic aspect of a restoration site is that it is tangible work that novice restoration workers can actually complete. Altering the physical aspect of a community may require significant machinery and altering the chemistry of a system requires a strong understanding of soil science and chemical inputs, outputs and their interactions.

**Organizations offered and suggested classroom extensions for teachers.** The organizations did offer several extension experiences for classrooms beyond the field. For example, in spite of the fact that all three organizations engaged students in the monitoring of restoration sites, they did not actively work with students to analyze and make sense of the data. They did suggest that teachers engage their students in that at their own prerogative. They also each offered a menu of options for extending the field experience in the classrooms. These included the curriculum guide of extensions Organization A offers (Figure 12), or an option for a staff member to come in and teach a lesson on the topic of the classroom teacher’s choosing as
with Organizations B and C. The three organizations also mentioned some opportunities for
teachers to engage in professional development around their restoration work and network with
each other to help build their classroom curricula around the restoration experience.

<table>
<thead>
<tr>
<th>Adaptations/Extensions</th>
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<tbody>
<tr>
<td>1. Prior to or following the field work, have students research a specific invasive plant to learn more about its life cycle and its negative role in ecosystems. Findings could be shared with the rest of the class through class presentations. One possible Invasive Species Project is explained on the following pages.</td>
</tr>
<tr>
<td>2. Prior to or following the field work, have students watch The Silent Invasion documentary film from OPB: <a href="http://www.opb.org/programs/invasives">http://www.opb.org/programs/invasives</a>. Student worksheets to record movie notes are included in the pages which follow the Invasive Species Project.</td>
</tr>
<tr>
<td>3. Ask students to save samples of the invasive plants. These can be preserved by pressing and drying to use when educating others about the project.</td>
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**Figure 12.** This is an example of extensions provided by Organization A in their Teacher's Guide distributed to all participating teachers.

An RSL organization’s focus on quality restoration over educational experiences makes
sense as RSL might have been seen as an outreach component of a greater restoration plan, and
their leadership may have valued restoration success over quality of educational practices.
Organizations were likely limited by funding and time they have with students. There are also several challenges to teaching in the field, as Organization A noted:

[In the field] we are a little bit more service-heavy than … the learning portion just
because it’s so dependent on what the teacher is teaching or what the weather’s like that
day. You’re not going to do a half an hour lesson when it’s hailing or something. … We
are limited by those variable factors, how much we can be doing in the field.

Perhaps as a response to this, options for extending the restoration experience into the
classroom might provide an opportunity for more learning that might not be possible in the field.

Although, having content-heavy curriculum in the classroom and practice-heavy curriculum in
the field may separate the learning from the service, a problem noted in the literature (Reynolds & Ahren-Dodson, 2010).

**Organizations saw NGSS as challenging to comprehend but necessary to address.** Ultimately, the organizations realized that it is important for them to address standards in their educational experiences and be explicit about it. While the NGSS do align with the RSL experiences fundamentally, their complexity has been a challenge for the RSL organizations to comprehend. At the time of the interview, Organization A noted that they had already addressed NGSS in their curriculum, Organization B was in the process of aligning their curricular offerings to NGSS, and Organization C had not yet begun to address it.

**Organizations believed that NGSS can align with RSL.** The interviews and supplementary educational materials suggested that the work in which the organizations engaged their students could align to the three dimensions of NGSS, whether the organizations explicitly were trying to or not. The DCIs were the most clearly aligned in the collected data. The pre-field presentations collected from each organization covered topics of several of the Earth Sciences and the Life Sciences DCIs, especially those that are related to human’s relationship with and impacts on natural systems (Appendix C). For example, Organization C’s presentation they give to students before visiting a polluted river describes the human activities that caused the pollution, why the pollution affects the community, and what technologies are being developed to help reduce or prevent pollution (Figure 10). These are concepts covered in the DCI: ESS3.C: Human Impacts on Earth Systems (Appendix C). This presentation also covered themes aligning with the CCCs, cause and effect and stability and change, although not explicitly.

While these organizations seem to engage students in SEPs, it was not as strong as the other two dimensions of NGSS. Organization B stated that they were developing their
curriculum to engage students explicitly in asking questions and defining problems, planning and carrying out investigations, and constructing explanations and designing solutions. The SEPs were not evident in the educational materials presented to this project and so their engagement was based on the word of the representatives in the interview. Given the fact that students were not engaged in planning or decision-making in the restoration projects, the SEPs that students practiced were not as strong as they could be. Organization B even noted that they were actively working on trying to “figure out how to reintroduce inquiry back into our program in a stronger way.”

While organizations might have potential to align their curricula to NGSS given the content they cover and the practices they engage students in, they did not seem to truly be engaged in three-dimensional learning. DCIs seemed to be well-addressed. However, since CCCs within the lessons are not clearly identified, and since students did not seem to be very engaged in SEPs, the presented lessons did not fully align with NGSS (Houseal, 2015). Given the nature of the RSL experiences, there is potential for these lessons to be adjusted to align to NGSS. The organizations seemed to recognize this: “I don't think we have ever experienced a lesson that we do in the field that wouldn't align with the standards” (Organization A).

Organizations recognized that teachers/school's learning goals ultimately inform learning. There was consensus in the interviews that the organizations felt it was important for them to align their experiences with standards. As Organization C notes: “there's only so much time the teachers have to teach. So to be respectful of what those students have to learn, we should be obligated or automatically trying to meet those standards.” The organizations understood the needs of the overall institution: to meet specific academic benchmarks. They also all recognized it was ultimately the teacher’s needs that guided how the students would
experience the RSL experience. The organizations therefore catered to the varying needs of the teachers depending on what standard the teacher wanted to meet in their curricula. This differed between organizations. For example Organization C would completely change their experience based on the explicit needs of each individual teacher while Organization A offered their teachers a curriculum guide that proposed several different options to extend the experience beyond the days in the field.

It might be challenging to balance several different RSL projects with several different classrooms. This is especially true if each participant teacher was trying to meet a different standard or if what the teacher was trying to accomplish did not line up with the restoration needs of the organization. Organization B seems to recognize this as they noted that they were trying to simplify their overall offerings to teachers.

Organizations found NGSS complicated and time was limited to comprehend them. Despite the fact that NGSS and RSL can align, comprehending the new NGSS was a challenge for the RSL organizations. Organization B described them as, “convoluted and confusing.” However, Organizations A and B, both of which are actively engaged in connecting their experience to NGSS, noted that they have received help from outside organizations that offer aid for educators to understand NGSS. This included attending seminars and one-on-one help. While these have been helpful, representatives from Organizations A and B claimed that, despite several training sessions, they continued to need outside help in figuring out how to align NGSS to their curricula and that they did not feel like they had a strong mastery of them.

A surprising challenge of aligning NGSS to RSL was that the teachers themselves were also having trouble comprehending NGSS. Organization B noted that an “overall challenge is engaging our teachers with yet another set of standards because they are all so overwhelmed
because common core is still being rolled out and is still new.” Organization B felt the need to offer teacher trainings on NGSS to their participant teachers and also use the trainings as an opportunity to describe how their program aligns with an NGSS curriculum.

Time seemed to be a limiting factor for comprehending NGSS for RSL organizations. The education representative from Organization A noted about NGSS, “I don't know a whole ton about all of it and I think that's just mostly from not having a ton of time to devote to sitting down and really getting into the nitty gritty of it all.” In this sense, the complexity of NGSS and the lack of time organizations and teachers have to comprehend them was a massive hurdle for aligning RSL to NGSS.

Conclusions and Recommendations

The literature suggested that the core needs and practices of RSL and NGSS could theoretically align and the collected data indicated that they could align at some level in practice. Organizations that offer RSL recognized the importance of aligning their experiences to standards and so it is necessary for them to understand how best to integrate NGSS into their RSL experiences. The following sections are a synthesis of both the limits to integrating NGSS into RSL experiences, recommendations for RSL organizations integrating NGSS, and suggestions for further research.

Limitations to aligning NGSS with RSL. Perhaps the greatest limit to fully incorporating NGSS into RSL is the fact that students are novice restoration ecologists (Whitlow & Hoofnagle, 2010). An important part of NGSS is a focus on students engaging in the practice of science. This coincides with the research on quality service-learning which indicates that it is important for students to be active in their learning and making decisions (NYLC, 2008). The collected data indicated that the students who participated in RSL experiences did not have
decision-making responsibilities in the restoration work and were usually told what work to do. This limits students’ engagement in SEPs. If organizations want to complete quality restoration work, it is risky and time-consuming to have students be in charge of making decisions. As organizations tended to employ more people with restoration backgrounds rather than education backgrounds to interact with students, accomplishing quality restoration work seemed to be more important than pursuing quality education practice. However, organizations should not be faulted to want to have control over the restoration work, they take on the financial burden of restoration costs.

NGSS' complexity is another limitation for its integration into RSL experiences. This project’s data suggested that the three organizations reviewed were spending much of their limited resources and time trying to understand NGSS. Despite these efforts, representatives from the organizations still felt that they did not have a strong grasp of NGSS. If organizations offer RSL experiences that they claim to align with NGSS, their staff and educators, and the participant teachers, need to understand NGSS. NGSS, like any other new set of standards have a steep learning curve. This limitation may dissolve over time as the novelty of NGSS wears off, assessment for NGSS is established, and curricular guides for teaching to NGSS are developed.

A final limitation to aligning RSL to NGSS for organizations is the individual needs of educators. All three of the organizations studied in this project offered ways for the experience to differ depending on the classroom teacher’s curricular or thematic requirements. Individualized experiences require more planning time. Individualized experiences also require a thorough understanding of NGSS so that the organization can make sure each individual experience meets standards. In addition, RSL may lose its authenticity if teachers and organizations favor restoration work that is less urgent or unnecessary in their community but matches their
curriculum better. Ideally, a service-learning project should be meeting a genuine community need while also meeting the curricular expectations of the institution. This limitation may also fade away as the education community becomes more familiar with NGSS and curriculum that supports NGSS becomes more available.

**Recommendations.** Despite the several challenges that RSL organizations experience, it seems that RSL and NGSS could still align and many of the aforementioned limitations could be overcome. Based on the theory presented in the literature and the thematic analysis of RSL organizations in this project, the following section provides six suggestions for RSL organizations that would like to best align their experiential offerings to NGSS.

1. **RSL organizations should be explicit about their learning outcomes to both teachers and students.** The studied RSL organizations, both in their self-reporting documents and in their interviews, celebrated the affective benefits of students participating in RSL, especially valuing how it empowered students. Research suggests that affective benefits such as increased interest in school and science, deeper thinking, and self-efficacy are naturally emergent from service-learning since it is a place-based authentic experience (Braund & Rice, 2006; Smith & Sobel, 2010; Steinke & Buresh, 2002). The studied organizations were not as explicit when describing the knowledge and skills with which students walked away from their experience as they were with the students’ change in affect. Students who are aware of what their expected learning outcomes are can self-reflect on their progress of meeting both their educational and service goals (NYLC, 2008). Organizations should be clear about what their academic learning outcomes are. When learning goals are clear, teachers know what to expect, and can clearly fit the experience into their curriculum, rather than having the experience be altered to meet the needs of individual teachers.
2. **RSL organizations should develop curricula that clearly align with the three dimensions of NGSS.** In order to have the support from the institution (Figure 2), it is vital that the explicit learning outcomes clearly align with NGSS. Also, since teachers are struggling with comprehending NGSS, an educator might be more attracted to participating in an RSL experience if the organization has done the work for them in terms of aligning the experience with NGSS.

The RSL experience does not need to match up with the performance expectations of NGSS, those are the standards, not curricula. To align with NGSS, an RSL experience should be three-dimensional, integrating elements from each of the three NGSS dimensions (Houseal, 2015). It is therefore important for organizations to understand and be clear about which of NGSS’ DCI’s, CCC’s, and SEP’s are integrated within their RSL experiences (Houseal, 2015). Organizations should also understand how each of the dimensions progress through grade bands and adjust their content to appropriately meet the expectations of the grade to which they teach.

If an organization knows what restoration work needs to be completed, it will help them understand which NGSS elements align to the specific experience. If organizations understand how their experience fits with NGSS and are clear about it, they can better meet the needs of both educators and the restoration work, rather than one being favored over the other. Table 2 references which elements of NGSS best align with restoration practice. While both Life Science and Earth Science DCIs match restoration practice, RSL organizations should focus on Life Science DCIs since restoration organizations seem to engage their students primarily in the alteration of the biotic community (Figure 9). The Earth Science DCIs that focus on the relationship between living and nonliving aspects of an ecosystem might also apply.
3. **RSL staff should have strong training and/or experience in education, especially standards.** Since the studied organizations were heavily invested in the success of their restoration work, there seemed to be a tendency for them to employ staff that has more expertise in restoration work than in education. While it is important for students to interact with specialists in the field to have an authentic experience, having a restoration specialist-heavy staff could be problematic. The staff may not be familiar with effective teaching techniques and classroom management strategies and they are less likely to have an understanding of relevant educational theory and standards. A staff that either has prior expertise/experience in education or training staff in educational practices and especially NGSS should improve both the quality of instruction and an understanding of teaching to the standards.

4. **Students should have a strong decision-making power in restoration practice.** Both the literature on service-learning and NGSS’ SEPs strongly recommended students have a strong voice throughout their educational experiences. According to the interviews of the three RSL organizations, their students were usually told what restoration work to perform and were given an explanation and some time to reflect on why it was important. Telling students what to do removes much of the opportunity for deeper learning in a service-learning experience and is a missed opportunity for engaging in SEPs. If students had more decision-making power, they would need to acquire a deep understanding of the scientific concepts surrounding restoration, and thus apply that knowledge to scientific practice – an experience of science that is at the core of NGSS.

The logistics of allowing students to have a stronger say in the planning, implementing, and evaluation of a restoration effort may complicate a RSL experience for the organizations. A RSL experience should be organized in a way that gives students decision-making power in the
restoration processes, allowing them to engage in NGSS' SEPs, but is scaffolded in a way that sets them and the restoration efforts up for success. Reflection can be an important tool in mitigating this (NYLC, 2008). If students reflect on their work, what they know, and what they do not know, they can recognize when their service surpasses their own ability and identify the areas where they need outside help and expertise.

5. **Organizations and their participating teachers should engage in professional development together.** It is important for teachers to understand not only what the RSL organizations teach their students, what standards they meet, and how the RSL experience might be incorporated into their own curriculum. Reynolds and Ahren-Dodson (2010) note that with service-learning experiences it is challenging for educators to connect classroom instruction to service in the field. It is equally important for RSL organizations to understand the pedagogical approaches teachers use to teach in their classrooms so they can make the transition outside more seamless. Engaging both parties in professional development with the facilitation of an outside NGSS expert could benefit the learning experience. Getting teachers and RSL educators together could clarify expectations and understandings, and strategies can be established. In their interviews, Organizations A and B mentioned engaging with a local organization to help them comprehend and align their curricula better to the NGSS. Including the participant classroom teachers in their interactions with these organizations could help students, teachers, and organizations with the transitions between the field and the classroom.

6. **Organizations should consider developing programs that engage the same students over several years.** Quality practice of NGSS, restoration, and service-learning practice all take time (Figure 8). The NGSS were developed on the concept that scientific knowledge acquisition should build on itself over time (NRC, 2011), restoration projects can also take several years to
be successful (Clewell & Aronson, 2013), and service-learning should take as much time as it needs to meet specified outcomes (NYLC, 2008). Given this, it can be argued that a RSL experience that aligns to NGSS should ideally last over several years. In this way, students could be a part of planning, carrying out, and monitoring a specific project and with each year, their knowledge content and skills would build on itself. The logistics of organizing this would be extremely complicated, but if done well, can best meet the needs of the institution/NGSS, the organizations/restoration, and the students/service-learning.

**Project Limitations.** The recommendations of this project were based off a thorough review of the literature on RSL and NGSS, but also a very small qualitative study on what was being done in the field. This project collected data from three different RSL organizations for a thematic analysis. Braun and Clarke (2013) recommend collecting data from at least six different parties for a small thematic analysis. Therefore, it is challenging to make strong generalizations about the practices and views of RSL organizations. Nevertheless, this project does suggest some interesting insights that are worth investigating further.

**Future research.** RSL can be a powerful tool to connect students to their communities, teach quality science, and improve natural areas while meeting mandated standards. This project is a preliminary study that can inform further research.

First, it would be intriguing to test the recommendations of this study. Such a project would include designing a RSL curriculum following as many of the recommendations as feasible and teaching it to a classroom of students at a specific restoration site. A research project would be conducted that explored problems encountered with the design and the implementation of these recommendations, the success of incorporating NGSS into the experience, the success of
the restoration efforts, and student affect toward the experience. Such a project could help refine these recommendations and perhaps shed light on additional opportunities for improvement.

This project looked at RSL from the perspective of the organizations leading the RSL experiences. It would be equally important to study the perspectives of the teachers and education institutions, and the students. This might include exploring how teachers integrate RSL experiences into their curricula, especially in the context of NGSS, and investigating which limitations teachers encounter to fully participate in a RSL experience. From the student perspective, a study that compared students who did and did not participate in a RSL experience while learning the same NGSS-based content could disclose how RSL affects student learning in the context of NGSS.

A gap identified in the literature on restoration-based learning efforts was investigating the environmental successes at a site after engaging students in restoration work. One of the biggest limitations uncovered by this study in terms of RSL and NGSS alignment was the perception that higher student autonomy might result in lower restoration success. A survey on current RSL organizations and their restoration successes would provide light on how to best scaffold experiences for students so that they are given a voice in restoration efforts while still accomplishing successful restoration work.

Finally, this project determined that NGSS and RSL could align. The NGSS are nascent and it will be important to see how the relationship between NGSS and RSL changes as NGSS assessment becomes standardized and curricula becomes developed.
References


learning in biology (pp. 25-30). Washington DC: American Association for Higher Education.


Appendix A: K-12 Service-Learning Standards for Quality Practice

Meaningful Service: Service-learning actively engages participants in meaningful and personally relevant service activities.
Indicators:

1. Service-learning experiences are appropriate to participant ages and developmental abilities.
2. Service-learning addresses issues that are personally relevant to the participants.
3. Service-learning provides participants with interesting and engaging service activities.
4. Service-learning encourages participants to understand their service experiences in the context of the underlying societal issues being addressed.
5. Service-learning leads to attainable and visible outcomes that are valued by those being served.

Link to Curriculum: Service-learning is intentionally used as an instructional strategy to meet learning goals and/or content standards.
Indicators:

1. Service-learning has clearly articulated learning goals.
2. Service-learning is aligned with the academic and/or programmatic curriculum.
3. Service-learning helps participants learn how to transfer knowledge and skills from one setting to another.
4. Service-learning that takes place in schools is formally

Reflection: Service-learning incorporates multiple challenging reflection activities that are ongoing and that prompt deep thinking and analysis about oneself and one’s relationship to society.
Indicators:

1. Service-learning reflection includes a variety of verbal, written, artistic, and nonverbal activities to demonstrate understanding and changes in participants’ knowledge, skills, and/or attitudes.
2. Service-learning reflection occurs before, during, and after the service experience.
3. Service-learning reflection prompts participants to think deeply about complex community problems and alternative solutions.
4. Service-learning reflection encourages participants to examine their preconceptions and assumptions in order to explore and understand their roles and responsibilities as citizens.
5. Service-learning reflection encourages participants to examine a variety of social and civic issues related to their service-learning experience so that participants understand connections to public policy and civic life.

Diversity: Service-learning promotes understanding of diversity and mutual respect among all participants.
Indicators:

1. Service-learning helps participants identify and analyze different points of view to gain understanding of multiple perspectives.

Link to Curriculum: Service-learning is intentionally used as an instructional strategy to meet learning goals and/or content standards.
Indicators:

1. Service-learning has clearly articulated learning goals.
2. Service-learning is aligned with the academic and/or programmatic curriculum.
3. Service-learning helps participants learn how to transfer knowledge and skills from one setting to another.
4. Service-learning that takes place in schools is formally
2. Service-learning helps participants develop interpersonal skills in conflict resolution and group decision-making.
3. Service-learning helps participants actively seek to understand and value the diverse backgrounds and perspectives of those offering and receiving service.
4. Service-learning encourages participants to recognize and overcome stereotypes.

**Youth Voice:** Service-learning provides youth with a strong voice in planning, implementing, and evaluating service-learning experiences with guidance from adults.

**Indicators:**

1. Service-learning engages youth in generating ideas during the planning, implementation, and evaluation processes.
2. Service-learning involves youth in the decision-making process throughout the service-learning experiences.
3. Service-learning involves youth and adults in creating an environment that supports trust and open expression of ideas.
4. Service-learning promotes acquisition of knowledge and skills to enhance youth leadership and decision-making.
5. Service-learning involves youth in evaluating the quality and effectiveness of the service-learning experience.

**Partnerships:** Service-learning partnerships are collaborative, mutually beneficial, and address community needs.

**Indicators:**

1. Service-learning involves a variety of partners, including youth, educators, families, community members, community-based organizations, and/or businesses.
2. Service-learning partnerships are characterized by frequent and regular communication to keep all partners well-informed about activities and progress.
3. Service-learning partners collaborate to establish a shared vision and set common goals to address community needs.
4. Service-learning partners collaboratively develop and implement action plans to meet specified goals.
5. Service-learning partners share knowledge and understanding of school and community assets and needs, and view each other as valued resources.

**Progress Monitoring:** Service-learning engages participants in an ongoing process to assess the quality of implementation and progress toward meeting specified goals, and uses results for improvement and sustainability.

**Indicators:**

1. Service-learning participants collect evidence of progress toward meeting specific service goals and learning outcomes from multiple sources throughout the service-learning experience.
2. Service-learning participants collect evidence of the quality of service-learning implementation from multiple sources throughout the service-learning experience.
3. Service-learning participants use evidence to improve service-learning experiences.
4. Service-learning participants communicate evidence of progress toward goals and outcomes with the broader community, including policy-makers and education leaders, to deepen service-learning understanding and ensure that high quality practices are sustained.

**Duration and Intensity:** Service-learning has sufficient duration and intensity to address community needs and meet specified outcomes.

Indicators:

1. Service-learning experiences include the processes of investigating community needs, preparing for service, action, reflection, demonstration of learning and impacts, and celebration.
2. Service-learning is conducted during concentrated blocks of time across a period of several weeks or months.
3. Service-learning experiences provide enough time to address identified community needs and achieve learning outcomes.

NYLC (2008)
Appendix B: A Model of the Three Dimensions of Service Learn

![Diagram of the Three Dimensions of Science Learning](image)

Reproduced with permission from Houseal (2015)
### Appendix C: NGSS DCI Progression

#### Earth Space Science Progression

<table>
<thead>
<tr>
<th>DCI</th>
<th>K-2</th>
<th>3-5</th>
<th>6-8</th>
<th>9-12</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ISSU A</strong></td>
<td>The universe and its stars</td>
<td>Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.</td>
<td>The solar system is part of the Milky Way, which is one of many billions of galaxies.</td>
<td>Light zones from stars are used to determine their characteristics, processes, and lifetimes. Solar activity creates the elements through nuclear fusion. The development of technologies has provided the astrophysical data that provide the empirical evidence for the Big Bang theory.</td>
</tr>
<tr>
<td><strong>ISSU B</strong></td>
<td>Earth and the solar system</td>
<td>The Earth’s orbit and rotation, and the orbits of the Moon around the Earth cause observable patterns.</td>
<td>The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.</td>
<td>Know how and why common features of the motions of orbiting objects, observations from space hardware and space probes provide evidence for explanations of solar system formation. Changes in Earth’s history and cause changes in climate change such as for ages.</td>
</tr>
<tr>
<td><strong>ISSU C</strong></td>
<td>The history of planet Earth</td>
<td>Some events on Earth occur very quickly; others can occur very slowly.</td>
<td>Rock strata and the fossil record can be used to order events that have occurred in a landscape.</td>
<td>The rock record includes evidence of processes such as plate tectonics from the solar system that can provide evidence of Earth’s early history and the relative ages of major geological formations.</td>
</tr>
<tr>
<td><strong>ISSU A</strong></td>
<td>Earth materials and systems</td>
<td>Earth’s physical features occur in patterns, as do earthquakes and volcanoes. Maps are used to locate features and describe patterns in these events.</td>
<td>Earth’s physical features occur in patterns, as do earthquakes and volcanoes. Maps are used to locate features and describe patterns in these events.</td>
<td>Rock strata and the fossil record can be used to order events that have occurred in a landscape.</td>
</tr>
<tr>
<td><strong>ISSU B</strong></td>
<td>Planet Earth’s atmosphere</td>
<td>Maps show where things are located. One can map the shapes and kinds of land and water in any area.</td>
<td>Maps show where things are located. One can map the shapes and kinds of land and water in any area.</td>
<td>Maps are used to display evidence of past movements.</td>
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</table>

<table>
<thead>
<tr>
<th>DCI</th>
<th>K-2</th>
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<th>9-12</th>
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</thead>
<tbody>
<tr>
<td><strong>ISSU C</strong></td>
<td>The roles of water in Earth’s surface processes</td>
<td>Water is found in many types of places and is different forms on Earth.</td>
<td>Water cycles among land, ocean, and atmosphere, and is populated by wind and gravity. Density variations of sea water drive interannual ocean currents. Water movement causes weathering and erosion, changing landscape features.</td>
<td>The planet’s dynamics are greatly influenced by water’s unique chemical and physical properties.</td>
</tr>
<tr>
<td><strong>ISSU D</strong></td>
<td>Weather and climate</td>
<td>Weather is the combination of wind, snow, rain, and temperature in particular regions and times. People record weather patterns over time.</td>
<td>Climate describes patterns of typical weather conditions over different scales and durations. Historical weather patterns can be analyzed.</td>
<td>The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes in biodiversity caused by changes to temperature and precipitation factors.</td>
</tr>
<tr>
<td><strong>ISSU A</strong></td>
<td>Natural resources</td>
<td>Living things need water, air, and minerals from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.</td>
<td>Humans depend on Earth’s land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.</td>
<td>Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.</td>
</tr>
<tr>
<td><strong>ISSU B</strong></td>
<td>Natural hazards</td>
<td>In regions, some kinds of natural hazards occur more often than others. People can use strategies to reduce their impacts.</td>
<td>Natural hazards such as earthquakes, volcanic eruptions, and hurricanes have shaped the course of human history at local, regional, and global scales.</td>
<td>Natural hazards such as earthquakes, volcanic eruptions, and hurricanes have shaped the course of human history at local, regional, and global scales.</td>
</tr>
<tr>
<td><strong>ISSU C</strong></td>
<td>Human impacts on Earth systems</td>
<td>Things people do can affect the environment and the health of their communities.</td>
<td>Human activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth’s resources and environments.</td>
<td>Sustainability of human societies and the biodiversity that supports them require responsible management of natural resources, including the development of technologies.</td>
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<tr>
<td>ESS#D</td>
<td>Global climate change</td>
<td>N/A</td>
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Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics. Global climate models used to predict changes necessary to be improved, although observations about the global climate system are ongoing and continually needed.

### Life Science Progression

<table>
<thead>
<tr>
<th></th>
<th>K-2</th>
<th>5-5</th>
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<th>9-12</th>
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</thead>
<tbody>
<tr>
<td><strong>LS1.A</strong> Structure and function</td>
<td>All organisms have external parts that they use to perform daily functions.</td>
<td>Organisms have both internal and external macroscopic structures that allow for growth, survival, behavior, and reproduction.</td>
<td>All living things are made up of cells. Cells divide and grow and they are specialized for particular body functions.</td>
<td>Systems of operational cells within organisms carry out functions of life. At the cellular level, an organism is made up of numerous cells. Feedback mechanisms maintain an organism's internal conditions within certain limits and regulate behaviors.</td>
</tr>
<tr>
<td><strong>LS1.B</strong> Growth and development of organisms</td>
<td>Reproduction is essential to every kind of organism. Organisms have unique and diverse life cycles.</td>
<td>All living things are made up of cells. Cells divide and grow and are specialized for particular body functions.</td>
<td>Growth and division of cells and tissues occur by mitosis and meiosis for specific cell types.</td>
<td></td>
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<tr>
<td><strong>LS1.C</strong> Organization for matter and energy flow in organisms</td>
<td>Animals obtain food they need from plants or other animals. Plants need water and light.</td>
<td>Plants use energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.</td>
<td>This hydrocarbon backbone of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism. As elements are rearranged to form different products, energy is transferred.</td>
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<tr>
<td><strong>LS1.D</strong> Information Processing</td>
<td>Different sense receptors are specialized for particular kinds of information. Animals use their senses to gather information and to guide their behavior.</td>
<td>Each sense receptor responds to different inputs, transmitting them as signals that travel along nerves in the brain. The signals are then processed in the brain, resulting in immediate behavior or memories.</td>
<td>N/A</td>
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### L53A Inheritance of traits
Different organisms vary in how they look and function because they have different inherited information. The environment also affects the traits that an organism develops.

- **Genes or proteins**: In genetic reproduction, each parent contributes half of the genes acquired by the offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.

- **DNA replication**: DNA directs instructions for forming proteins' characteristics. Each cell has the same genetic content, but genes expressed by cells can differ.

### L53B Variation of traits
- **Natural selection**: The variation and distribution of traits is influenced by genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication or from recombination involving sections of DNA.

- **Behaviors of the same organism**: The variable branching patterns produced by multiple lines of descent can be inferred by comparing DNA sequences, amino acid sequences, and morphological and embryological evidence of different organisms.

### L53C Adaptation
Populations of organisms exist in a variety of habitats. Change in these habitats affects the organisms living there.

- **Adaptation**: Adaptation is increased by formation of new species and reduction by extinction. Humans depend on biodiversity but also have adverse impacts on it. Preserving biodiversity is essential to supporting life on Earth.

## Physical Science Progression

### Increasing Sophistication of Student Thinking

<table>
<thead>
<tr>
<th>PS1.2</th>
<th>3-5</th>
<th>6-8</th>
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<tbody>
<tr>
<td><strong>PS1.2</strong></td>
<td><strong>Decay of matter</strong> (includes PS1.3 Nuclear processes)</td>
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<tr>
<td><strong>PS1.3</strong></td>
<td><strong>Chemical reactions</strong></td>
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<tr>
<td><strong>PS1.4</strong></td>
<td><strong>Force and motion</strong></td>
<td></td>
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<tr>
<td><strong>PS1.5</strong></td>
<td><strong>Types of interactions</strong></td>
<td></td>
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<tr>
<td><strong>PS1.6</strong></td>
<td><strong>Adhesive and cohesive forces</strong></td>
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<td><strong>PS1.7</strong></td>
<td><strong>Energy in physical systems</strong></td>
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<td><strong>PS1.8</strong></td>
<td><strong>Energy and matter</strong></td>
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<td><strong>PS1.9</strong></td>
<td><strong>Energy and matter</strong></td>
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<td><strong>PS1.10</strong></td>
<td><strong>Energy and matter</strong></td>
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- **PS1.3 Chemical reactions**: Chemical reactions in which substances combine to form new substances. Chemical reactions occur when substances are mixed and new substances form. The reaction mixture may change color, give off heat, or change state. Reactions that mix or react with one another are called chemical reactions. Chemical reactions have different properties, such as reactants, products, reactant, and product. Chemical reactions are a change in the form of the reactants.

- **PS1.4 Force and motion**: Pushes and pulls can change the speed or direction of an object. The effect of a substantial force on an object is a change in the motion of an object. Forces on the object are caused by the interaction of objects. The gravitational force of Earth acting on the Moon is a force that moves the Moon around Earth. Force is a change in the direction of an object. Force is a change in the direction of an object.

- **PS1.5 Types of interactions**: Force is a change in the direction of an object. Force is a change in the direction of an object. Force is a change in the direction of an object. Force is a change in the direction of an object. Force is a change in the direction of an object. Force is a change in the direction of an object.

- **PS1.6 Adhesive and cohesive forces**: Adhesive and cohesive forces are the forces that hold objects together. Adhesive and cohesive forces are the forces that hold objects together. Adhesive and cohesive forces are the forces that hold objects together. Adhesive and cohesive forces are the forces that hold objects together. Adhesive and cohesive forces are the forces that hold objects together. Adhesive and cohesive forces are the forces that hold objects together.

- **PS1.7 Energy in physical systems**: Energy in physical systems is the ability to do work. Energy in physical systems is the ability to do work. Energy in physical systems is the ability to do work. Energy in physical systems is the ability to do work. Energy in physical systems is the ability to do work. Energy in physical systems is the ability to do work.

- **PS1.8 Energy and matter**: Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy.

- **PS1.9 Energy and matter**: Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy.

- **PS1.10 Energy and matter**: Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy. Energy and matter are connected by energy.
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<tbody>
<tr>
<td>Relationship between energy and forces.</td>
<td>Energy in chemical processes and everyday life.</td>
<td>Wave properties</td>
<td>Electromagnetic radiation.</td>
</tr>
</tbody>
</table>

**P3.C**

Bigger forces and pulls cause bigger changes in an object's motion or state.

**P3.D**

- **Sunlight warms Earth's surface:** Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as light or food.
- **Energy is captured by plants and used in a reaction to produce sugar molecules, which can be converted into molecules to release energy.**

**P3.A**

- **Sound can make matter vibrate and vibrating matter can make sound.**
- **Waves are regular patterns of motion, which can be made by vibrating the surface. Waves of the same type can differ in amplitude and wavelength. Waves can create objects move.**
- **A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model is used to explain many phenomena, including sound and light. Waves can transfer energy.**

**P3.B**

- **Objects can be seen only when light is available to illuminate them.**
- **Objects can be seen when light reflected from their surface enters our eyes.**
- **The contrast of a wave is used to model how light interacts with objects.**
- **Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation and describe some common applications of electromagnetic radiation.**

**P3.C**

- **People can devices to send and receive information.**
- **Patterns can encode, send, receive, and decode information.**
- **Waves can be used to transmit digital information. Digital information is comprised of a pattern of 1s and 0s.**
- **Large amounts of information can be sent and shared around as a result of being digitized.**

---

NGSS Lead States (2013c, p. 2-8)
Appendix D: Detailed Theoretic Alignment of Service-Learning, Ecological Restoration, and NGSS

This figure, based off Sigmon (1996), expands upon Figure 8 and identifies the areas where service-learning, ecological restoration, and NGSS align in what they each value or share.
Appendix E: Participant Informed Consent Form

DESCRIPTION OF THE RESEARCH

I, Charles Vogelheim, am a graduate student at the University of Wyoming completing a Master’s in Science, Natural Science Education and Environment & Natural Resources. By conducting this research study, I hope to gain insight on how organizations facilitating habitat restoration service learning experiences for middle and high school classrooms can adjust their curriculum to better align with Next Generation Science Standards. My graduate work is being conducted under the supervision of Dr. Jason Katzmann. I would like to invite you to participate in this research study. You have been selected due to your organization’s qualifications related to my topic and your experience with your organization.

WHAT YOU WILL BE ASKED TO DO

If you decide to participate, you will be asked to schedule and participate in an interview that will not exceed 90 minutes either in person, via phone, or video conference with the researcher. Before the interview you will receive an overview of the research and the seven open-ended interview questions that will be asked orally. You have the choice to or not to allow the researcher to video or audio record the interview (see Privacy and Confidentiality). The interview questions will be structured around obtaining descriptive data pertinent to the following research question.

- How can third-party organizations facilitation habitat restoration service-learning experiences for middle and high school classrooms better connect their curriculum to next Generation Science Standards in places where they naturally align?

RISKS AND POSSIBLE BENEFITS

There will be minimal risks involved in this research study. Due to the focus and methodology of this research, there is minimal risk involved in participating. The minimal risk of this research includes the possibility that some interviewees may be uncomfortable with the topic of the research or the act of being interviewed. The risks involved in this study do not exceed the risks involved in ordinary life. If you feel uncomfortable in any way, you may ask at any time to withdraw from the research study. If opting out of the study, please send to the researcher in writing, via email or mail, a letter requesting to terminate your participation from the study. Upon receiving this letter, the researcher will immediately follow the protocols outlined in the protection of privacy and confidentiality section. There is no cost for participating in this research study. The researcher has not received funding for this study, as it is not being sponsored by any governmental and/or private organizations.

For participating in this research study, you will be provided with an electronic version of the final research paper that will highlight ways in which similar programs are educating students during habitat restoration experiences as well as advice for programs such as yours to better connect their curriculum to standards. In addition, the researcher will provide an executive summary document of the findings to all participants.

PROTECTION OF PRIVACY AND CONFIDENTIALITY

Everyone interviewed will be given a code name that will be used in the research findings.
I will provide you with summary of your interview in order for you to strike anything that is incorrect and/or that you do not want in the final copy. You have the right to review your interview material before it is published. At any time, you may request your interview material to be withheld from the study. Only I will be transcribing visual and/or audio recordings if you approve of these data collection methods on the bottom of this form.

You have the right to or not to allow me to video or audio record the interview. If you choose to allow the interview to be recorded, both you and I have joint ownership of the recording once the recorder is turned off. Only I, and my adviser, Dr. Jason Katzmann, have access to the recordings. The recordings will be stored on a password protected computer that I only know the password to. The recordings will be destroyed after three years from the date of my Master’s defense (September 2018).

If you opt-out-of the study at any time and terminate your participation, all data including the informed consent form, digital recordings, transcripts and any printed materials associated to you will be destroyed or deleted.

CHOOSING TO BE IN THE STUDY

Your participation in this research study is voluntary. Your decision to or not to participate in this study will not affect any of your personal or professional relationships. If you decided to participate, you are free to withdraw your consent and terminate your participation at any time without any repercussions.

CONTACT INFORMATION

If you have any questions about the study or this form at this time or anytime during or after the interview, please feel free to contact me at 949.400.5996 or cvogelhe@uwyo.edu, or my University of Wyoming adviser, Dr. Jason Katzmann, at 307.268.2583 or JKatzma1@uwyo.edu. If you have questions regarding your rights as a research subject, please contact the IRB Administrator at 307.766.5320. You will be offered a copy of this form to keep for your own records.

CONSENT

Your signature indicates that you have read and understand the information provided above, and that you willingly agree to participate. In addition, you agree that you will not waive any legal claims. Interviews will not be conducted until the researcher has received a copy of this form in person, email, or by mail to the researchers office at: Charles Vogelheim c/o SMTC 1000 E. University Avenue Dept. 3992, Laramie, WY 82071

☐ Please check this box if you agree to allow the name of the organization you represent to be used in my written report and executive summary.

Consent to Participate:

Printed name of participant: __________________________________________________________

Participant signature and date: _________________________________________________________

Consent to have your interview audio or visually recorded:

Participant signature and date: _________________________________________________________
Appendix F: Interview Questions:

1. Please describe the mission and/or vision of your organization.
   a. Do you identify the experiences that students do with you as “service-learning”?
      i. How balance between service and learning play out?
         1. Do you focus on one over the other?
      ii. How are service and learning connected? Does one inform the other?
      iii. What are your main learning goals for students? Academic? Affective? Ex: community connections, science concepts, teambuilding, ecological literacy

2. What does a typical interaction with a class of students with your organization look like?
   a. What restoration activities do students engage in with your organization?
   b. How many times do students go out in the field?
   c. What supplementary experiences or materials do you offer your classrooms?
      i. Do you offer in-classroom instruction before/after restoration experiences?
      ii. Do you work with teachers in any way to help to incorporate your education experiences within their curriculum?
      iii. Do you provide any kind of professional development for teachers?
   d. Who in your organization is usually having direct educational interactions with the students?
      i. What training in education are they given/required to have?
      ii. Are they involved in developing the curriculum?

3. What big ideas of science do you hope students to walk away with?
   a. What science concepts do you think align the most with the work you do?
   b. What science concepts do you perceive students are actually walking away with?

4. Are there any science skills that students get to practice during their experience with you?
   a. Asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence, obtaining, evaluating, and communicating information

5. How did you develop your curriculum?
   a. Did you design your educational experiences specifically tailored to connect with any formal set(s) of science standards?
      i. If yes:
         1. Which set of standards? Next Generation Science Standards?
         a. What is your experience and understanding with NGSS?
         2. How are they incorporated into your curriculum?
         3. Have you experienced any challenges in incorporating standards into your curriculum?
      ii. If no:
         1. Was that an intentional decision?
         2. Would you like your curriculum to connect more to formal science standards?
   b. Where did/do you seek aid in developing your curriculum?
      i. Do you feel like you need more help in curriculum development?
   c. What limitations have you experienced in incorporating standards into your curriculum?
Appendix G: IRB Exempt Approval

UNIVERSITY
OF WYOMING

Vice President for Research & Economic Development
1000 E. University Avenue, Department 3355 • Room 305/308, Old Main • Laramie, WY 82071
(307) 766-5355 • (307) 766-5320 • fax (307) 766-2608 • www.uwyo.edu/research

May 7, 2015

Charles Vogelheim
Graduate Student
Science and Math Teaching Center
University of Wyoming
Faculty Advisor: Dr. Jason Katzmann

Protocol # 20150507CV90790

Re: IRB Proposal “Science, Standards, and Service: How Habitat Restoration Service Learning Experiences can be used to support students in meeting Next Generation Science Standards in Middle and High Schools.”

Dear Mr. Vogelheim:

The proposal referenced above qualifies for exempt review and is approved as one that would not involve more than minimal risk to participants. Our exempt review and approval will be reported to the IRB at their next convened meeting May 21, 2015.

Any significant change(s) in the research/project protocol(s) from what was approved should be submitted to the IRB (Protocol Update Form) for review and approval prior to initiating any change. Per recent policy and compliance requirements, any investigator with an active research protocol may be contacted by the recently convened Data Safety Monitoring Board (DSMB) for periodic review. The DSMB’s charge (sections 7.3 and 7.4 of the IRB Policy and Procedures Manual) is to review active human subject(s) projects to assure that the procedures, data management, and protection of human participants follow approved protocols. Further information and the forms referenced above may be accessed at the “Human Subjects” link on the Office of Research and Economic Development website: http://www.uwyo.edu/research/human-subjects/index.html.

You may proceed with the project/research and we wish you luck in the endeavor. Please feel free to call me if you have any questions.

Sincerely,

Colette Kuhfuss
Colette Kuhfuss
IRB Coordinator
On behalf of the Chairman,
Institutional Review Board