Students' Understanding of Sustainability and Climate Change Across Linked Service-Learning Courses

Kimberly Coleman,[1,2,a] James Murdoch,[2] Shelly Rayback,[2] Amy Seidl,[2] and Kimberly Wallin[2,3]

ABSTRACT

College and university faculty are increasingly being called upon to teach about sustainability. Many of these faculty members are incorporating content related to climate change because climate change is arguably the biggest threat to global sustainability. However, the concept of sustainability is complex, interdisciplinary, and potentially difficult to teach. Further, students may feel paralyzed in the face of climate change. Thus, delivering a course that effectively covers the concept of sustainability while also empowering students to take action against climate change is difficult. The goal of this article is to describe a joint effort between four college courses in different disciplines that used service-learning projects focused on climate change as a tool to teach sustainability concepts. Although the four courses were rooted in different disciplines, they intentionally shared common components and assignments, including community service projects, shared readings and reflections, and a symposium that brought all students together. Eighty preproject and 77 postproject reflections were qualitatively analyzed for themes related to learning outcomes. The results demonstrate that students in these classes gained a more sophisticated understanding of climate change and how it affects their respective disciplines, as well as a newfound sense of personal responsibility and agency for addressing climate change. Service-learning is an increasingly popular pedagogy on college campuses. This article highlights how the pedagogy can be used as a tool for integrating climate change into courses from multiple disciplines to teach about sustainability and empower students. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/16-168.1]

Key words: interdisciplinary, pedagogy, student empowerment, learning communities

INTRODUCTION

Institutions of higher education are increasingly being called upon to teach their students about concepts and implications related to sustainability (Sipos et al., 2008). For example, the United Nations declared 2005–2015 the Decade of Education for Sustainable Development and issued a recommendation that institutions of higher education incorporate sustainability concepts into their teaching and research (Wals, 2014). That recommendation was echoed by scholars, such as Stephens et al. (2008), Sibbel (2009), and others. Perhaps in response, college and university faculty members are increasing taking on the challenge of teaching about sustainability (Kaza et al., 2016). Many faculty members are seeking interdisciplinary approaches to teaching about the topic. Indeed, research suggests that interdisciplinary teaching approaches lead students to more comprehensive and nuanced understanding of the academic content (Newell, 2010). Models for sustainability education include creating sustainability majors and minors, infusing sustainability into courses from many disciplines, creating cross-disciplinary programs, incorporating sustainability language into campus mission statements, and establishing sustainability general education requirements (Rowe, 2002).

Given that climate change is arguably the biggest threat to global sustainability (McCright et al., 2013), discussing climate change in courses focused on sustainability is a natural fit. Indeed, climate change is an important concept often integrated into sustainability course work (Nolet, 2016). Climate change may provide concrete examples of sustainability issues, making the concept of sustainability more digestible for students. For example, teaching students about the social, environmental, and economic costs of climate change may help illustrate sustainability in concrete terms. Further, teaching students about climate change may increase their knowledge and understanding about the complexity of the challenge (McCright et al., 2013).

However, because of that very complexity, teaching climate change is challenging (Kirk et al., 2014). To help students make sense of such complexity, some faculty members have turned to project-based pedagogies that allow students to apply academic concepts in real-world context (e.g., see Sipos et al., 2008). Active teaching approaches have been shown to increase both student learning (Hake, 1998) and student understanding about the connection between personal action and climate change (Cordero et al., 2008). For example, the Interdisciplinary Teaching of Geoscience for a Sustainable Future (InTeGrate) program promotes active teaching approaches, such as place-based learning (Gosselin et al., 2016) and service learning (InTeGrate, 2015) to teach about concepts, such as climate change.

Service learning is a form of education in which students work with community partners to identify and address community needs in an academic setting, together with structured reflections designed to achieve desired learning outcomes (Jacoby, 2015). The concept of service learning is frequently conflated with related yet distinct activities, such as volunteerism, internships, and civic engagement. Service

Received 2 May 2016; revised 10 October 2016 and 20 January 2017; accepted 10 February 2017; published online XX Month XXXX.
[1]Vermont Higher Education Council, SMC Box 298, One Winooski Place, Colchester, Vermont 05439, USA
[2]University of Vermont, Burlington, Vermont 05405, USA
[3]U.S. Department of Agriculture, Forest Service, Northern Research Station, 707 Spear Street, South Burlington, Vermont 05403, USA
[a]Author to whom correspondence should be addressed. Electronic mail: kim@vermonthec.org.

TABLE I: Demographic information for students ($n = 119$) enrolled in four undergraduate, service-learning courses taught at the University of Vermont in 2014.

Course	Student Year	Major	Total
Sustainability science	Second- and third-year undergraduates	Predominately environmental studies	60
Forest ecosystem health	Third- and fourth-year undergraduates and graduate students	Forestry	25
Dendrochonology	Third- and fourth-year undergraduates and graduate students	Geography	9
Terrestrial wildlife	Third- and fourth-year undergraduates and graduate students	Wildlife biology	25
Total			119

learning is set apart from these other related activities because it is a pedagogical approach. Unlike volunteering and community service, it necessarily involves structured opportunities for students to engage in reflection (Jacoby, 2015). Service learning offers many benefits for students and the community, such as deepening student personal and interpersonal development, fostering a commitment to service, improving academic learning, providing useful services for local communities, and enhancing university–community relationships (Driscoll, 1996; Jacoby, 1996; Gelmon et al., 1998). Previous studies have also demonstrated that service learning can be an effective tool in helping students achieve discipline-specific outcomes (Shuman et al., 2005; Prokopy, 2009; Bielefeldt, 2013; Coleman and Danks, 2015) and that it has promise for teaching students about issues related to climate change (Tedesco and Salazar, 2006).

Learning communities are yet another pedagogical approach to teaching about complex topics, such as climate change. Smith et al. (2004, pg. 67) defined *learning communities* as practices that, "intentionally link or cluster two or more courses, often around an interdisciplinary theme or problem, and enroll a common cohort of students." Learning communities can be structured in several ways, ranging from two or more courses that all enroll a common group of students, to residential communities in which students both live in the same dorm and enroll in the same course work as a cohort (Gabelnick et al., 1990). Regardless of the specific model, learning communities involve a cohort approach, wherein a group of students undertakes common experiences and engages in learning together as a community. Because learning communities have the potential to link course work across multiple disciplines, they are well suited to addressing complex themes and topics, such as climate change.

Scholarly research on sustainability in higher education has tended to focus on sustainability practices on college campuses, rather than on pedagogy (Wals, 2014). Therefore, although practices such as service learning and learning communities may hold potential for teaching about climate change, and by extension, the concept of sustainability, questions remain about how to execute such experiences. This article seeks to inform this important aspect of sustainability education by sharing an interdisciplinary approach employed by a team of four faculty members who employed service-learning projects focused on climate change as a way to teach about sustainability concepts.

PURPOSE AND LEARNING GOALS

An opportunity exists to illuminate the concept of sustainability for students by teaching them about the social, economic, and environmental issues related to climate change. Because of the complex nature of both climate change and the concept of sustainability, we believe such teaching approaches should be interdisciplinary in nature. Service learning represents an opportunity to apply academic course content and deepen students' understanding of these complex topics. However, we recognize that an interdisciplinary, service-learning experience focused on climate change and sustainability presents an undertaking for faculty, requiring substantial time, energy, and resources. Additionally, there are many ways that faculty members could structure a course or courses. The goal of this article is to describe one innovative approach a team of four faculty members implemented to teach students across their courses about climate change and sustainability via service-learning experiences.

Four faculty members, each teaching in a different discipline, participated in a faculty development program aimed at integrating sustainability education across diverse disciplines using service learning. As part of the program, called Campuses for Environmental Stewardship, the faculty team received a grant from the Northern New England Campus Compact and the U.S. Environmental Protection Agency, as well as training in service learning and sustainability education. The four faculty members created or updated service-learning projects to integrate the topic of climate change into preexisting undergraduate courses. The four courses drew from different demographics of students (see Table I). However, all four courses shared five common goals:

1. Deliver four courses embedded with, and connected by, the topic of climate change in the 2013–2014 academic year.
2. Coordinate and embed a service-learning project, focused on some aspect of climate change, in each of the four courses.
3. Increase students' understanding of the term *environmental stewardship* and how it relates to them.
4. Create opportunities for faculty development and sharing of the teaching model with other faculty and administration.
5. Evaluate and disseminate information and observations of the project.

The four instructors addressed these goals together by developing and implementing service-learning projects that focused on the intersection of their respective disciplines and climate change, as well as by creating shared-learning experiences that stretched across their courses.

TABLE II: Common and unique elements of four courses at the University of Vermont.

Course	Content	Service Learning	Common Readings	Common Reflections	Common Final Event
Sustainability science	Techniques to measure progress in sustainability	Students prepared reports on changes in emissions over time	Groffman et al. (2012), Wilmers et al. (2012), Gawande (2013), Klinenberg (2013)	Common reflection prompts at the beginning of the semester and again at the end of the semester	Event at which students from all four courses came together to present posters of their service-learning projects
Forest ecosystem health	Biophysical and ecological factors of forest health and functioning	Students conducted surveys for nonnative organisms			
Dendrochronology	Concepts and techniques to understand the influence of a changing climate	Students collected and analyzed data for use as ecological baseline data for a preserved site			
Terrestrial wildlife	Principles of wildlife ecology	Students collected and synthesized data into tools for planning activities			

MATERIALS AND IMPLEMENTATION

The four courses discussed in this article included undergraduate-level classes taught at the University of Vermont in sustainability science, forest ecosystem health, dendrochronology, and wildlife biology. Although the courses each focused on different academic content, they also incorporated several common components that served to link them together (see Table II).

Course Descriptions

Students in Sustainability Science learned the importance of measuring progress in sustainability using a range of metrics, including life-cycle analysis, human-development indices, and ecological footprints. Students in Sustainability Science were predominantly second- and third-year students (total enrollment = 60) and Environmental Studies majors, although Environmental Science, Political Science, Geography, and Environmental Engineering majors were also represented. During the course of the semester, students worked with a local municipality to generate a greenhouse gas inventory, which was subsequently compared with inventories conducted 3 and 6 y earlier for that city.

Forest Ecosystem Health focused on biophysical and ecological factors of forest health, including management, sustainability, and ecosystem functioning. Most students in the course were upper-level (third and fourth year), undergraduate forestry students and graduate students (total enrollment = 25). The course has included a service-learning component since it was first taught in 2008.

Dendrochronology is the study of tree rings and is used to understand the influence of the changing environment on tree growth and function over time. The students in this course were third- and fourth-year undergraduates in the Department of Geography and two graduate students, who were in the Field Naturalist program and Geology (total enrollment = 9). In this course, students learn and implement dendrochronological concepts and techniques to understand and investigate the influence of changing climate and other environmental variables on the growth and health of northern New England forests over time.

Terrestrial Wildlife focused on principles of wildlife ecology and how to apply those principles to questions of species management and conservation. The course builds on other courses students take in Basic Ecology and uses a quantitative approach by challenging students to build models of the concepts covered and to use those models to make predictions about species and ecosystems. Most students in the course were upper level (third and fourth year) students of Wildlife Biology (total enrollment = 25).

Service-Learning Projects

Students in Sustainability Science were assigned a sector (e.g., municipal airport, street lighting, city buildings, city car fleet, etc.) to collect greenhouse gas data. Working in teams of two to five students, the teams met with municipal authorities, collected data from those authorities, entered data into spreadsheets, and analyzed changes in emissions over time. Student teams reported to the local municipality during a formal presentation and collectively wrote and edited a document on findings. The municipality was then able to use the updated Greenhouse Gas Inventory to identify sectors that needed efficiency measures as well as those that were stable or decreasing in emissions.

The service-learning component of Forest Ecosystem Health involved conducting surveys for organisms not native to the ecosystem on private campgrounds and in street trees in nearby cities and town forests for public education efforts with the U.S. Department of Agricultural Animal and Plant Health Inspection Service. The results provided the state of Vermont and cities with tools for planning prevention, monitoring, and remediation activities with the detection of organisms not native to the local, forested ecosystem.

In Dendrochronology, students used dendrochronological techniques to sample a shagbark hickory (*Carya ovata*) stand and to identify the dominant climate and environmental drivers of the forest stand's past and current growth. The students also explored archival materials from local libraries and historical societies to understand the unique land use history of this unusual forest stand. The data collected, analyzed, and presented by the students provided the community partner, a local nonprofit, with additional

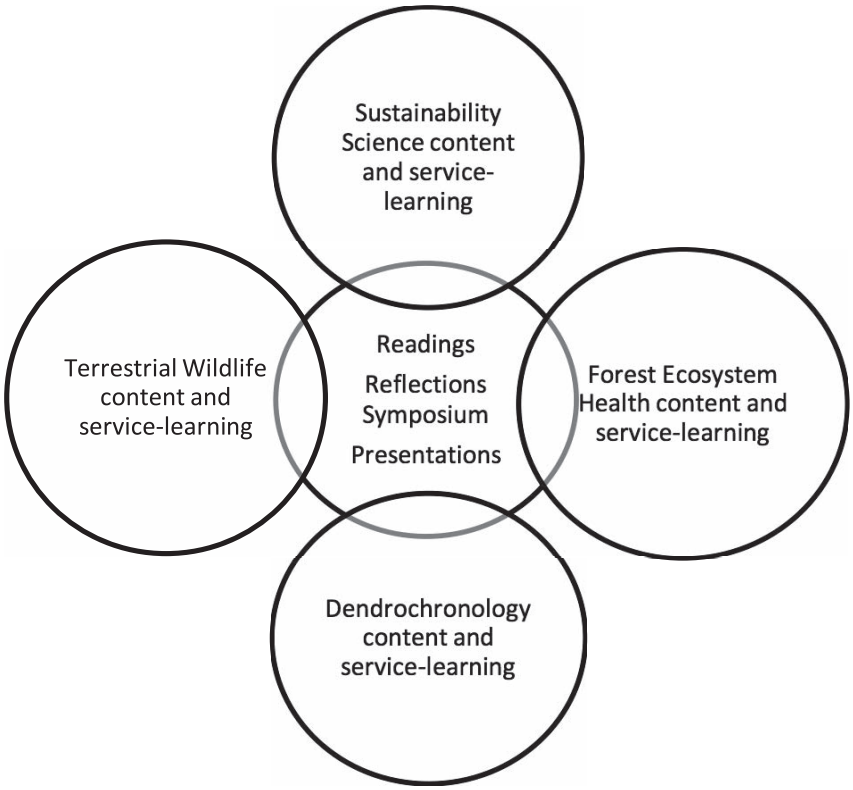

FIGURE 1: Model of common and unique elements of four undergraduate service-learning courses taught at the University of Vermont in 2014. Each course engaged in a unique service-learning project and also participated in shared readings, reflections, a symposium, and presentations.

information for use in educational and promotional material about the preserved site and ecological baseline data.

The service-learning component of Terrestrial Wildlife involved collaborating with a nonprofit organization that manages 18 urban, semiurban, and rural parks. Students collected data on three species—bear (*Ursus americanus*), bobcat (*Lynx rufus*), and fisher (*Martes pennanti*)—and used models to explore how climate change will affect the distribution of these species in some of the parks. The results provided the organization with tools for planning conservation activities as the landscape changes under scenarios of climate change.

Common Readings

Each of the instructors selected an article focused on climate change for students across the four courses to read, reflect on, and discuss. The faculty selected articles within their disciplines, but by having all four courses read all articles, students gained interdisciplinary perspectives on climate change. These common readings were Gawande (2013), Groffman et al. (2012), Klinenberg (2013), and Wilmers et al. (2012). Two of the readings (Gawande, 2013; Klinenberg, 2013) were articles published in *The New Yorker*, whereas the other two readings (Groffman et al., 2012; Wilmers et al., 2012) were peer-reviewed research articles.

Common Reflection Assignments

The students in all four courses completed common reflection assignments, designed to help them both integrate their knowledge of climate change with the discipline-specific course content as well as explore their personal roles in taking action against climate change. As part of these reflections, students were asked to reflect on their understanding of the term *environmental stewardship* at the beginning of the semester (first week) and again at the end of the semester (last week). Specifically, students were asked to reflect on the question, "What does 'environmental stewardship' mean to you?"

Common Final Event

The faculty organized a symposium at the end of the semester in which students from all four courses came together. Teams of students in each class created posters of their service-learning projects. This was designed to give students a chance to actively discuss climate change and their classroom and service experiences with peers and provided an opportunity to draw attention to the interdisciplinary nature of climate change.

Summary of Materials and Implementation

Thus, regardless of the course they enrolled in, all students participated in a climate change–focused, service-learning project; read four common climate change articles; completed the same reflection assignments; and participated in a group symposium (see Fig. 1). This model does not meet the definition for a true learning community because the courses did not enroll a common cohort. Rather, with the exception of two students, the courses each had unique rosters. Nonetheless, we suggest that the coordination between faculty and interaction between students across the four courses constituted a modified learning community.

Common readings, events, and reflection activities created an opportunity for students to learn from all four faculty and to teach others in a way that is similar to how learning communities function.

EVALUATION

The evaluation team was composed of the four faculty members who taught the courses plus the first author (K.C.), who was brought on to the team to lead a qualitative analysis of course materials and outcomes. For the remainder of the article, we use the term *we* and *the team* to refer to all authors and *the faculty* to refer to all authors with the exception of the first author. The goal of the analysis was to take a grounded theory approach (Glaser and Strauss, 2009) to understanding what, if any, changes occurred in students' understanding of the concept *environmental stewardship* from the beginning of the courses until the end.

Data Sources and Collection

Given that the faculty assigned common reflection activities at the start and end of each course, K.C. was able to qualitatively code the reflections and use them as pretest and posttest data. The decision to have K.C. conduct a qualitative analysis of the reflection assignments was made retroactively (i.e., the reflection assignment was not designed as part of a research study). Nevertheless, qualitative analyzing of the reflection assignments was an appropriate method for evaluating outcomes because reflection provides a rich data source for evaluating course outcomes (Ash et al., 2005) and because qualitative research is well suited for studying people and social processes, such as learning (Maxwell et al., 2006). Although small studies like this one are limited in their ability to develop broader implications, they remain important because they pave the way for meta-analyses of multiple-case studies (Ford and Beaumier, 2011).

Data Analysis

To analyze the reflections, K.C. scanned the 80 preproject and 77 postproject reflections and qualitatively coded them using NVivo 11 software (QSR International, Doncaster, VIC, Australia). The analysis included all reflections completed by students across the four courses (not just a subset). However, it does not represent all the students in the classes ($n = 119$) because not all students completed the assignments. Because the students were asked to complete the reflection activities during class time, some students were not present to complete the assignments. The coding process involved an iterative approach to data analysis in which K.C. looked for recurrent themes and sought to identify patterns and linkages among t4hem (Glesne and Peshkin, 1992). In the first round of coding, K.C. sought to identify all emerging themes and then shared those themes with the faculty. Sharing the codes with faculty served as a member-check and ensured accurate coding. Member-checking serves to increase both validity and reliability in qualitative analyses (Glesne and Peshkin, 1992). The faculty then supplied additional themes they expected to see, given their experiences during the semester. K.C. then recoded the data to look for evidence to support the second round of themes. Coding was done in that order so that emergent themes would not be overlooked in favor of themes that fit the expectations of the faculty (Glesne and Peshkin, 1992).

TABLE III: Preproject and postproject reflection themes that emerged from reflections ($n = 157$) on environmental stewardship, sustainability, and climate change among four undergraduate service-learning courses taught at the University of Vermont in 2014.

Preproject Themes	Postproject Themes
• Undefined use of terms *environment* and *nature* • Exclusion of human aspects • Focused on the nonhuman of nature • Lack of personal responsibility • Lack of agency	• Climate change focused • Discipline-specific perspective • Inclusion of human aspects • Acquisition of knowledge and skills • Personal responsibility • Empowerment

K.C. was then able to conduct pretest and posttest comparison to look for changes that occurred from the start of the courses until the end. *Pretest* and *posttest* refer to studies designed to measure change caused by an intervention (Dimitrov and Rumrill, 2003). Throughout this article, we refer to those as *preproject reflections* and *postproject reflections*. By comparing the preproject reflections to the postproject reflections, we were able to explore how students' understanding of environmental stewardship changed during the semester. In addition to coding the reflections for recurrent themes and patterns, we classified each reflection as either *pre* or *post* with the attribute function in NVivo 11. This allowed K.C. to then run a matrix-coding query, which compared the major themes of the preproject reflections to those in the postproject reflections. This highlighted differences in themes from the beginning of the semester to end. Finally, self-reflection by the faculty helped to interpret and refine results (Ortlipp, 2008). In particular, this self-reflection informed our thinking about specific course elements that may have contributed to the changes we observed between the preproject and postproject reflections.

RESULTS

Qualitative coding of the reflections revealed key differences between the preproject and postproject reflections. Because we looked for themes that were common across all four courses, we present the data as one group. Postproject themes indicated an increase in students' understanding of environmental stewardship in light of climate change and demonstrated that students became empowered to take action against climate change (Table III).

Preproject Reflection Themes

Undefined use of the terms *environment* and *nature* emerged as major themes within the preproject reflections (Table III). Students' reflections about environmental stewardship often employed the terms *environment* and *nature* without delineating what counted and what did not as being part of the environment or nature. For example, it was often unclear whether students were writing about only nonhuman aspects of the environment or were also reflecting on humans and human-made aspects of the environment, such as homes, cities, and other infrastructures. For example, one

student wrote, "Environmental stewardship means protecting the environment." Another student stated that environmental stewardship meant, "Taking care of nature." Both of these statements highlight the broad use of these terms without any real indication of what the students intended the terms to mean. This theme emerged consistently across all four of the courses.

Although most students did not provide much specificity around their use of the terms *environment* and *nature*, those that did tended to focus on the nonhuman, nonbuilt aspects of the terms. This emerged as another major theme in the preproject reflections. When students wrote about specific aspects of the environment, they named elements, such as wildlife, plants, and the land, rather than human elements. For example, one student wrote that to be an environmental steward, one must "…do what's best for the land in the future." Another student reflected, "Ensuring our landscapes and the resources they provide such as wildlife and plants are essential part of environmental stewardship." Within the preproject reflections from all four classes, there was exclusion of any discussion linking environmental stewardship and current or future human communities.

Another major theme was the use of unspecific actions to describe environmental stewardship. Just as students' reflections lacked concrete definitions of the terms *environment* and *nature*, they also did not include specific actions that constitute *stewardship*. For example, one student wrote, "[environmental stewardship] means taking care of the environment, being a steward of it." Another student wrote that it meant, "Going out of your way to save the environment." Both of these quotes demonstrate a theme that emerged across preproject reflections from all four classes: many students did not articulate any concrete actions that would fall under the term *environmental stewardship*.

The last major theme that emerged consistently from the preproject reflections of all four courses was a lack of agency on the part of the students regarding their role as environmental stewards, particularly given climate change. Perhaps related to the missing concrete actions, students did not identify personal steps they could take to be environmental stewards. Further, a number of students expressed feelings of uncertainty about their role and capability in being an environmental steward. One student wrote, "Environmental stewardship means that you are working toward making something more environmentally friendly in that it won't change the climate. I am not really sure how to do this." This quote exemplifies students' feelings that they were unsure of what it would mean for them to personally act as environmental stewards.

Postproject Reflection Themes

Postproject reflections revealed greater specificity regarding students' understanding of the term *environmental stewardship* (Table III). Across all four courses, students made specific mention of climate change and the impacts of climate change in their postproject reflections. For example, one student wrote:

> *"… the meaning of environmental stewardship is to address that the climate is changing and use the information we've gathered about how it might change to safeguard the future biodiversity of the planet."*

Similarly, students wrote about elements of the environment that were specific to the disciplines of their respective courses during the postproject reflections. Students in the forest ecosystem health class wrote about forest health concepts; students in the wildlife class wrote about wildlife concepts, and so on. For example, one student reflected that, "Environmental stewardship has become an increasingly important concept as climate change and urbanization continue to change the landscape for wildlife populations." These quotes demonstrate the increased specificity that was common among the postproject reflections.

Additionally, discussions of humans and the human environment emerged as a major theme of the postproject reflections. For example, one student wrote:

> *"I have always been a big proponent of individual freedoms, but I now realize that we must constrain some individual freedoms (more so than in the past) for the greater good of all. By putting the community first, we will be able to move society into a place much more beneficial than if a selfish mode of thinking were to persist. This means not just the human community, but taking into consideration all of the animals and plants that are necessary to support human life in our local community."*

This statement illustrates the student's understanding that climate change will affect humans and human communities, in addition to the nonhuman environment. A number of students also reflected on urban development and its linkages to climate change and the concept of environmental stewardship. One student commented, "…seeing the implications that urban development had on wildlife populations opened my eyes."

In addition to showing greater specificity regarding students' understanding of the term *environmental stewardship*, the postproject reflections also revealed increased agency regarding personal action to combat climate change. This manifested in three ways in the postproject reflections: discussion of newly acquired knowledge and skills, realization of personal responsibility, and demonstration of empowerment to make a difference. Across all four courses, students delineated the knowledge and skills they acquired through their experiences that will be critical for them to act as environmental stewards. For example, one student wrote:

> *"Since my time in this course I have gained more confidence in my understanding of wildlife populations and have acquired the skills to predict shifts in population demographics. I now know how to find the occupancy probability of a species, another step in finding ways to prevent species loss. I am excited to take the knowledge I've gained and apply it to real world problems as well as teaching others these beneficial skills."*

Another student echoed that sentiment in their writing:

> *"I now better understand the importance of, and ability to, get involved with local government to address climate change.… I better understand that government is not something that I simply vote on then step back from—it is something that I have a responsibility to be engaged in."*

Postproject reflections from all four classes also demonstrated that students came to understand their personal roles in influencing climate change. One student reflected, "This class has helped me to understand that how I act as a consumer… affects the future of populations of wildlife globally."

Finally, students from all four of the courses discussed a new sense of empowerment in their postproject reflections. Many students reported that they now understood that even small changes in their daily activities were important steps to take against climate change. This sentiment is exemplified by the following student reflection:

> *"I have been inspired to make changes in my life. I am starting a worm compost system at my shared house. I have been using my vehicle much less and biking/taking the bus more. These are only small steps in the right direction. As an individual, I need to make changes within my own life. I also need to demand big changes from my leaders."*

These statements highlight a common theme across all four courses: students reported that they acquired new knowledge and skills, realized they have a personal responsibility to act to combat climate change, and felt empowered to do so. Taken together, quotes under this theme demonstrate an increase in student agency to address climate change.

DISCUSSION

A comparison of the preproject and postproject reflections showed that changes in the themes fell into two major categories. The first major category was a more sophisticated understanding of climate change. Under this category, students demonstrated knowledge about the impact of climate change on their specific disciplines and also articulated an understanding and connection between climate change and human communities. This was a particularly important finding because, as Pruneau et al. (2003 p. 430) stated, "…it is normal for climate change to appear to be only a catastrophic event in the far future. It then becomes difficult to incite people to modify daily behaviour [sic]." In this case, the preproject reflections completed by students in the four courses we studied were almost completely devoid of discussion about humans but did include discussion about the nonhuman environment. However, in their postproject reflections, students acknowledged that climate change will affect humans. It is interesting to note that this trend held among upper-class students, who entered their service-learning experiences with background in their respective disciplines. We posit that they displayed less-sophisticated ideas in the preproject reflections because, although they had completed many natural resource courses, they may not have enrolled in course work that explicitly addressed climate change and stewardship. We did not conduct a true experimental design, so we cannot fully attribute this change to the service-learning component of the course. Future research efforts could replicate the design described in this article and additionally include nonservice-learning courses as control groups. This would allow researchers to further explore the ability of service-learning to improve students' understanding about complex topics, such as climate change and sustainability.

The second major category is a newfound sense of personal responsibility and agency for addressing climate change. Within this category, students reported in their postproject reflections that they acquired new knowledge and skills, realized they have a personal responsibility to act to combat climate change, and felt empowered to do so. This finding is in line with previous research by Prokopy et al. (2014), which found that students were more motivated to take action in their community after completing natural resource–focused, service-learning courses. The potential for service-learning to act as a catalyst for action is particularly important because there are significant psychological barriers that limit individual action against climate change, including lack of knowledge and feelings of uncertainty and disempowerment (Lorenzoni et al., 2007; Gifford, 2011). Furthermore, several previous studies have demonstrated challenges associated with successfully getting students to apply ecological knowledge in their own lives (McBean and Hengeveld, 2000; Devine-Wright et al., 2004).

Again, because we did not conduct a true experimental design, we cannot fully attribute the increase in personal responsibility and agency to service learning. However, self-reflection on the part of faculty point toward the service-learning projects as at least contributing to the increases we observed. One faculty member (K.W.) reflected that students entered her class with general and advanced knowledge of how forested ecosystems are structured and function. Students also entered the class with an understanding of the impacts of climate change on forested ecosystems, but became overwhelmed as they were introduced to the course content on the complexity of these impacts. In K.W.'s estimation, the service-learning component was vital to empowering the students. The projects, which involved conducting surveys of private campgrounds, street trees, and town forests, gave the students the opportunity to test their knowledge. Compiling, analyzing, and synthesizing the data for the cities (i.e., the community partners), as well as participating in outreach events, helped students to realize their ability to act as advocates.

A second faculty member (J.M.) similarly reflected that students entered his class with a general background in ecology and conservation biology, which they had gained from other prerequisite courses. They had a clear understanding that climate change will have impacts on the natural world and that they will be required to address these impacts at some point in their careers. However, students seemed to be uncertain and a bit overwhelmed at times about how to address the impacts to species, populations, and ecosystems. J.M. observed that the service-learning component provided students with an opportunity to directly engage with an actual organization grappling with how to manage a landscape as the climate changes through the collection of data, creation of models, and the application of those models to scenarios of climate change. The result was quantitative information to help the organization better plan for climate change. From J.M.'s perspective, the project had a clear "empowering" effect on students as they learned ways to make sense of data with respect to a complex issue (climate change) and apply their results to an organization that will actually use them. Their interactions with the partner seemed to instill a sense of responsibility and

ownership over the quality of the project and its outcomes. Students also seemed to realize that they had developed an important knowledge and skill set that could be applied to other questions of climate change at multiple spatial and temporal scales.

A.S. also reflected that the students responded positively to "doing something" in response to their study of climate change and society's transition to sustainability. A.S. noted that students had read and studied the science and policy implications of climate change in previous courses but had not been asked to apply their knowledge. A.S. also observed that students appreciated talking with municipal employees about energy consumption and the types of energy used, e.g., fuel oils, electricity, heating and cooling, and transportation, and these interactions highlighted the complexity of measuring energy usage and how efficiency technologies work. By the end of the service-learning engagement, students better understood how measuring greenhouse gas emissions was an elemental step to decreasing municipal consumption of nonrenewable energy, one that could then lead to advocating for alternative technologies that emitted fewer greenhouse gases. From A.S.'s perspective, engaging with the local community allowed students to gain a sense of agency regarding climate change, an issue that can be overwhelming and intangible.

Finally, S.R. reflected that her students entered the service-learning course with a strong earth systems science perspective that facilitated their holistic understanding of the connections between multiple components and processes on Earth, including climate change. However, S.R. noted that students were less sure how they could contribute to an expanding, yet still uncertain, understanding of climate change effects on forest health and productivity. S.R. observed that the service-learning experience provided the structure through which students could apply their newly acquired skills and knowledge base to help the partner organization understand more clearly how a protected forest stand has responded and might respond in the future to climate change. The final presentation to the community partner also provided a forum for communication of the results, and the debriefing afterward allowed for greater sharing with the partner of the students' thoughts and ideas that were informed by the course content, their field and laboratory experiences, and the data analysis. Again, S.R. felt the experience empowered the students through the contribution of their own research and scholarship to a growing collective knowledge, as well as to an organization that would use the information to guide future decisions and management of the site. S.R. reflected that students appeared to gain confidence that their individual and combined knowledge and skill sets could be brought to bear on a global, yet local, problem.

These self-reflections by faculty highlight several commonalities across the four courses. In each course, students possessed preexisting, discipline-specific knowledge. From the perspective of the faculty, the service-learning experience allowed students to develop a deeper understanding of the impact of climate change on their discipline by giving them the opportunity to conduct real-world, applied work. This reflection is supported by a wealth of research, perhaps best exemplified by the Kolb (1984) work, which demonstrated the positive effect of experiential learning.

The faculty also reflected that completing their service-learning projects had an empowering effect on students. This aligns with previous research by Pruneau et al. (2003), which pointed to accomplishing environmental actions as an antecedent to feelings of empowerment related to the capacity to make a difference. Contributing in concrete ways to actual organizations (via service-learning projects) may help students to feel they are capable of making a difference, even in the face of complex and overwhelming scenarios such as climate change. We note, however, that not all service-learning projects provide students with the same level of autonomy in designing and delivering project outputs. Howe et al. (2014) described three "phases," or levels, of service-learning experiences. Students in phase-one experiences are given less autonomy than students in phases two and three. It is possible that the differences in autonomy may translate into differences in feelings of project ownership, a sense of accomplishment, and ultimately, feelings of empowerment to take future action. Future research could explore whether the level or phase of the service-learning experience matters for achieving student empowerment. This would provide a more precise understanding of the types of experiences that successfully empower students.

Although the model described in this article did not meet the definition for a true learning community, the experience still revealed insight into strategies for linking courses around a common theme. The faculty reflected that six practices proved particularly important for successfully linking service learning courses:

1. *Starting From a Common Knowledge Base*. All four faculty members enrolled in an intensive, week-long training in service learning at University of Vermont and participated together in a service-learning minicourse with Maine Campus Compact (Lewiston, ME). Additionally, each faculty member had experience teaching service-learning courses. Thus, each team member was building from a common base of knowledge regarding the benefits and challenges of experiential learning. The faculty members were able to draw on those experiences to discuss development of the linked courses.
2. *Common Commitment*. The faculty discussed and drafted a collective mission statement for all four courses, which clarified their common approaches to the themes of sustainability and climate change. All team members included this statement in their syllabi to solidify this common commitment and make it clear to students in all four courses.
3. *Collective Planning*. The faculty met throughout the semester before teaching the linked courses to identify common readings, reflection questions, and invited speakers. These conversations resulted in common readings, assignments, and reflection questions that were relevant to each of the course goals and objectives and spanned the diverse backgrounds of our students.
4. *Regular Check-ins*. The faculty scheduled group check-ins with each other regularly throughout the semester to compare and discuss the progress of the courses. During meetings, faculty provided updates, shared activities or assignments that were working

well, and discussed challenges. This allowed each faculty to learn from the successes of others and also created an opportunity for the collective trouble-shooting of challenges.

5. *Common Event*. All four classes participated in a joint poster presentation during which students presented on their service-learning projects. This event served as the capstone to the course and functioned as a rigorous outlet for students to share their experiences and results. It also allowed faculty and students from all four classes to celebrate their achievements collectively.
6. *Collective Reflection*. After the end of the semester, the faculty met off campus for "PI retreat." This retreat was a day for faculty to reflect on their experiences and discuss them in an open space. This provided the faculty with a dedicated time for reflection and distillation of lessons learned. It also allowed the faculty to discuss ways to share the results of the experience with others.

From the perspective of the faculty involved with the four courses discussed in this article, these six practices contributed to the success of linking multiple service-learning courses. These six practices are in line with recommendations for creating successful learning communities (Smith et al., 2014), particularly regarding coordination and communication across linked courses. As such, these six practices should be considered by others interested in linking courses, even if the linkage does not result in a true learning community.

LIMITATIONS

This research did not take into account differences among courses, including discipline, level of skills and knowledge of students at the start of the course, academic year of students, or the effect of diverse faculty. Thus, we are unable to comment on whether differences in the courses translated into differences in outcomes. It is possible, for example, that variance in frequency and quality of reflection activities may translate into differences in students' understanding of their own personal responsibility regarding climate change. Similarly, amount of time spent interacting with community partners may affect their sense of empowerment and agency. Future research should identify specific aspects of service-learning courses that may contribute to sustainability learning and compare courses to look for differences in outcomes.

The findings reported in this article relied on self-report data from students. In the context of pretest and posttest analysis, self-report data is subject to response-shift bias (Howard and Daily, 1979). *Response-shift bias* refers to the tendency for study participants to realize, often as the results of the intervention being studied, that their pretest response was inaccurate (Howard and Daily, 1979). Thus, it is more reliable to measure behaviors rather than have students self-report their understanding. In this case, we were unable to measure behaviors to validate the self-report data.

This work qualitatively examined four courses at one university and is, therefore, not necessarily generalizable to all sustainability-focused, service-learning courses. It does, however, serve as a case study that highlights the potential of service learning to be used as a tool to teach about sustainability. Future quantitative analyses could build on our results and address more specifically questions not fully explored in this article. Specifically, researchers focused on understanding the sustainability learning outcomes of service-learning should consider designing studies that investigate outcomes from courses across multiple universities to uncover commonalities that emerge despite changes in context.

CONCLUSIONS

The contribution of this article is threefold. First, it provides a model for how faculty teaching outside the geosciences can use service learning as a tool to incorporate geoscience concepts, in this case, climate change, into their courses as a way to teach students about sustainability. Because sustainability is a complex and sometimes vague idea, service-learning projects that focus on the intersection of climate change and a given discipline can serve as a concrete way for students to learn about and engage with sustainability issues in their field. Faculty may consider the approach described in this article and adapt it to their own courses. Second, this article contributes to a growing body of literature on discipline-specific outcomes of service learning by illustrating students' learning about the topic of sustainability, as opposed to research on service learning that has focused on outcomes like empathy and critical thinking. Within this research, students increased their understanding and sense of agency around climate change. This mirrors research in other fields that have detailed the ability of service learning to contribute to discipline-specific skill development. Third, the results suggest that service learning can serve as a tool for faculty to empower students. Thus, the potential of service learning to produce sustainability learning outcomes may be of particular interest to faculty members who seek to not only teach their students about complex issues related to sustainability and climate change but also encourage students to take action.

Acknowledgments

We thank the Northern New England Campus Compact (NNECC) and U.S. Environmental Protection Agency for funding and the University of Vermont for providing administrative and logistical support for the project. Although the information in this document has been funded in part by the U.S. Environmental Protection Agency under an assistance agreement to Bates College, it may not necessarily reflect the views of the agency, and no official endorsement should be inferred. We also thank Dr. Carrie Williams Howe for her feedback on drafts of this manuscript.

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